MENTAL MODELS OF STUDENTS ON STOICHIOMETRY CONCEPT IN LEARNING BY METHOD BASED ON MULTIPLE REPRESENTATION

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Abstract: This study was conducted to obtain students' mental models after learning using multiple representations. The application of learning based on multiple representations is carried out through the interconnection between the three levels of chemical phenomenon (macro, sub-micro, and symbolic). The research samples are taken from the 2011 year of Physics Education (3 class) randomly selected from 8 available classes. The number of students from whom the samples were taken is 96 students. The students' mental model is confirmed through the procurement of essay test questions encourage them to think at the three levels of chemical phenomenon. The results of this research show that the students' mental models towards chemistry reaction stoichiometry was mirrored in various questions from the interpretation down to the verbal-to-symbolic transformation and verbal-to-visual transformation (sub-micro diagram) and vice versa. Findings indicated that *macro–submicro–symbolic* teaching by used multiple representation method could be enhancing student mental models and learning effectivity of chemical reactions. It indicates that there has been a statistically significant change on the students' mental models after multiple representations learning method was implemented.
Key Words: Mental models, multiple representations, chemical phenomena.

INTRODUCTION

Several researches indicate that many factors can affect the ability of students to make connections between the three levels of chemical phenomenon in growing thinking skills (Eilam & Poyas, 2010; Prain, *et al*, 2009; Schönborn and Anderson, 2009). In addition, teaching chemistry to build mental models requires a strategy that involves the use of chemical representations as mentioned above accurately, because to build a mental model of students requires an understanding of the three levels of chemical phenomenon. Mental models are unstable and the student's ability to operate or use their mental models in order to explain the events that involve the use of a visual model is very limited, so the need for ongoing training to build it (Coll, 2008; Devetak, *et al.,* 2009; Davidowitz, *et a.l*, 2010; McBroom, 2011). Therefore, this study was conducted in order to build a student's mental model in learning by involving the three representations on the topic of chemical stoichiometry. Learning model used is learning the IF-SO framework (Waldrip, 2008 and 2010) which is modified by considering the seven basic concepts the student's ability in dealing with the phenomena of external representation (Schönborn and Anderson, 2009).

Mental Model

Stoichiometry is one of the most basic topics of learning chemistry and it is required to understand the qualitative and quantitative aspects regarding chemistry phenomena as well as to solve various chemistry problems at high schools and college level. Hence, understanding the concept of stoichiometry is critical to solve chemistry problems. For example, chemistry equation is the basic concept for solving various chemistry problems. Without understanding the chemistry reaction, it will be far more difficult to solve the problem (Chandrasegaran, *et al*., 2007; Davidowitz, *et al*., 2010; Laugier & Dumon, 2004). Understanding the concept of chemistry can be achieved if the students perform higher level of mind processing using an internal representation (mental model) established using various visualization models to describe all three macroscopic, sub-microscopic and symbolic phenomenon (Chandrasegaran, *et al*., 2007; Johnstone, 1991).

According to the experts on cognitive psychology, mental model is an internal-scale model representation of an external reality, or person's private representation of an idea or concept (Greca and Moreira, 2000). Mental model can be defined as conceptual model, mental representation, mental image, internal representation, mental process, abstract construction and personal cognitive representation (Chittleborough & Treagust, 2007; Chittleborough & Treagust, 2008). In this case, the experts of cognitive psychology often use academic studies on mental model to obtain information on thinking process, especially during problem solving. Bower and Morrow (Strickland, *et. al*., 2010) defined the mental model in the following statement: *"an individual's mental models are complex knowledge constructs representing the person's experiences regarding a particular phenomenon. The construction of mental models is not limited to tangible objects; the phenomena may be as abstract as the notions of 'right' and 'wrong"'.* Therefore, mental model construction is the core of a meaningful learning. People should construct mental model system he/she encounters in his or her mind in order to understand and comprehend how it works.

Related to the chemistry learning system, Wood (2006) and BouJaoude & Barakat (2003) stated that learning chemistry is similar to learning the logics of problem solving, the achievement of which indicate the use of various chemistry problems at molecular level by the student in a correct manner. However, most students perceive chemistry as a difficult subject (BouJaoude & Barakat, 2003; Huddle & Pillay, 1996; Wood, 2006). If the students can understand the roles of all three levels of chemistry phenomenon, they can transfer their knowledge by interconnecting the levels to one another, which means that they can obtain the conceptual knowledge required to solve a problem. According to Johnstone (1991), the three levels of phenomenon connect one another and all of them provide great contribution towards the development of students' mental model in building definition and conceptual understanding.

Several results of research indicated that learning methods which do not interconnect the three levels of chemistry phenomenon leave the students unable to create their own mental model (Coll, 2008; Devetak, *et al*., 2009; Jansoon, *et al*., 2009; McBroom, 2011). In his research, Jansoon, *et al*. (2009) in his study on "understanding the mental model of students in relation to the dilution process" reported that most students' encountered difficulties in describing symbolic representation to explain the phenomena occur at sub-microscopic level. According to Coll (2008), the students' ability to operate or use their mental model to describe the events, involving the use of visual model is very limited. Rendering is necessary to hold training on how to interpret a visual sub-micro image through learning method which involves the three levels of chemical phenomenon. Next, Devetak, *et al*. (2009) found that students who have not been trained with external representation found it difficult to interpret sub-micro structure of a molecule. McBroom (2011) stated that students who are not constantly drilled with learning method involving the multiple roles of representation would encounter difficulties in transforming all three levels of chemical phenomenon presented.

Learning Based on Multiple Representations

This model is a learning method based on a multi-representation of science that tries to connect the three levels of chemical phenomenon (macro, sub-micro and symbolic) into the learning steps. Through this model, the learning of IF-SO framework (Waldrip, 2008 and 2010) applied by considering the interaction factor (seven basic concepts) that affects the student's ability to represent the phenomena of science (Schönborn and Anderson, 2009). Seven Basic Concept, the ability of learners which have been identified by Shönborn and Andeson (2009) is the ability of the reasoning learners *(Reasoning;* R), conceptual knowledge learners *(Conceptual*; C), and select the mode of representation of the learner's skills *(representation modes;* M), then four other factor are the factor R-C is a self-conceptual knowledge of the ER; R–M factor is a feature of the ER itself; the C–M is interactive factors affecting the interpretation of the ER; and the C–R–M is the interaction of these three factors early (C, R, and M), which represents the ability of learners to engage all the factors in order to interpret the ER properly.

By considering the interaction of R–C and C–M, the required learning model conceptual stages of exploration activities is needed, while while the stage of imagination is needed in considering the interaction of R–M and C–R–M. Exploration stage with more emphasis on the conceptualization of the problems is being faced by science discussions, laboratory experiments or demonstrations, and tracking information via text books, *weblog* or *webpage*. The stage of imagination is required to perform the mental imagery of the external representation of the sub-microscopic level. Hence, it transforms into macroscopic level or symbolic or otherwise. Imagination is very helpful in improving conceptual knowledge learners and raises the creative power of the learner (Ogawa, *et al*., 2009; Thomas & Brown, 2011). Therefore, imagination representation as one of the activities include in the syntax in developing learning model. During the conceptual stage of exploration carried imaginative activities to train students in conducting mental image representation through the imagination. Train students to perform mental imagery representation through the imagination. Thus, the stage of exploration and imagination are combined into a single phase, i.e.; exploration–imagination phase.

The results of the exploration-imagination need to be internalized through presentations, assignments, and exercises. The last stage of evaluation is the stage to get feedback during the learning process. Before the exploration of imagination, teachers need to learn orientation capabilities as the basis for the exploration–imagination phase. Therefore, the learning model developed consist of four stages (phases), i.e.; orientation, exploration–imagination, internalization, and evaluation. In the exploration-imagination phase, learning sequence depends on the concept learned by learners. The abstract topics of the concrete examples (e.g.; the law of conservation of mass and comparative law anyway), can be taught these following order: exploration, and coupled with imaginative representation. However, the abstract topics (e.g.; discussion and calculation of chemical reaction) and the stage of exploration and imagination sequences can be implemented with imagination and conceptual exploration. The fourth stage of the representasion multiple methods have the following steps:

Tabel 1. Phases of Teaching in Multiple Representation

Phase I: Orientation	1. Delivering the purpose of study. 2. Motivating with various chemistry phenomena related with the students' experiences
Phase II: Exploration–Imagination	1. Introducing the concept of chemistry by providing several different abstractions regarding chemistry phenomena (such as transformation of substance phase, chemical transformation, etc.) verbally or through demonstrations and visualizations such as pictures, charts or simulation and or analogy with the involvement students in listening and Q & A (question & answer). 2. Guiding the students in establishing imaginative representation of chemical phenomena through collaboration (discussion). 3. Encouraging and facilitating students discussion panels to establish mental model to interconnect different levels of chemical phenomena by implementing chemical transformation phenomena in the students' activity sheet.
Phase III: Internalization	1. Guiding and facilitating the students in articulating / communicating their ideas through presentation of group works. 2. Encouraging other students to comment or respond to the represented group works. 3. Giving assignments to create individual activity on articulation of imagination. Individual practice is stated on the Student Activity Sheet (SAS) which contains questions and/or instructions to interconnect the three levels of chemical phonomena and/or crossword puzzle on chemistry.
Phase IV: Evaluation	1. Reviewing the student's work result 2. Assigning works on interconnection of three levels of chemical phenomena and providing feedback. 3. Conducting formative and summative evaluation.

The purpose of this study

The purpose of this study was to determine how the mental models of students after the intervention using a learning model based on multiple representations. In addition, this study also aims to determine the effectiveness of a learning model based on multiple representations in building student's mental models. Intervension from this learning model done with involving the chemical phenomenon on the macro, sub-micro and symbolic levels, so hopefully will be able to bring up a mental model of the student with the category of "good mental model" or the characteristics of the mental model of "consensus" and "target. It is based on previous findings that the study involving all three levels of chemical phenomena (macro, sub-micro, and symbolic), was able to produce students with the mental model of "good" category and can achieve mental model of "consensus" and mental models of the "target" (Chittleborough, 2004; Coll & Treagust, 2003; Park, 2006; Jaber and Boujaoude, 2012; Wang, 2007). Learning interventions in this study involves higher-order thinking, reasoning, and deep understanding, so hopefully will be able to build a mental model of students about the reaction stoichiometry concept on the "good" category. To reach the reasoning and deep understanding, then the intervention in this study was conducted involving potential student imagination. The power of imagination will be able to excite students to learn and foster student creativity (Ogawa, *et al*., 2009; Thomas & Brown, 2011). Therefore, these research questions are:

1. *how students' mental models after applied learning to use multiple representations that involves the interconnection of the three levels of chemical phenomenon?*

2. *whether the application of learning to use multiple representations can be effective in building students' mental models?*

METHODOLOGY

Population, sample and research procedure

The population in this research consists of all students in 2011 year of Basic Chemistry Studies, Department of Math and Science Education, Faculty of Teacher Training and Education, University of Lampung-Indonesia. The research samples are taken from the 2011 year of Physics Education (3 class) randomly selected from 8 available classes. The number of student from whom the samples were taken is 96 students. The design used in this stage is group pre-test and post-test design (Fraenkel and Wallen, 2003 p. 271-272)

The students' mental model is confirmed through the procurement of essay test questions encourage them to think at the three levels of chemical phenomena. The measurement of mental model is adapted from the model developed by Park (2006), Wang (2007), and Davidowitz, *et al*. (2010), in the form of written essay questions with sub-micro illustrations. The Mental model test consists of 6 questions for Stoichiometry discussion materials in the order of competence achievement criteria (indicator). The mental model test questions are selected in order to encourage mental processing among students by the following steps:

- Transforming visual representation into verbal representation, chemistry equations and mathematical calculations.
- Representing the occurrence of chemical reaction by describing the representation into external representation (macro, symbolic or sub-micro).

The intervention in this study is done by using multiple representation methods, i.e. learning methods that involve interconnection between the three levels of chemical phenomenon (macro, sub-micro and symbolic). Intervention in the early stages of learning is the orientation of the initial knowledge of students. The purpose of this orientation is to know the initial experience of the students that used as to determine the next intervention. After the orientation phase, the learning is done with the exploration–imagination. At this stage students involved in seeking information via a webpage/webblog and trained in the interpretation and transformation through the visualization of chemical phenomena. The power of the imagination of students at this stage is maximized to perform reasoning on the external representation of the sub-micro of chemical reaction, so as to generate creative thinking. Student activities on the exploration–imagination phase is done collaboratively in groups. The next activity is the internalization of the results of the group's imagination through the presentation, and then proceed to optimize the power of imagination through the implementation of individual activities. Individual activities carried out through exercises in interconnect the three levels of chemical phenomena, as stated in the student worksheet. Last intervention in learning is evaluation. Evaluation phase activities conducted through a review of student work by faculty and individual task assessment, as well as giving homework.

Data Analysis

The mental model test data analysis is performed by assigning scores to each answer given by the students (Park, 2006; Wang, 2007) according to the types of student's answer. Scoring technique is performed by assessing the students' answer to a test question with a label indicating their level of achievement. The labels are written "very good", "good", "moderate", "poor", and "very poor", which correspond respectively to 5, 4, 3, 2, and 1 at ordinal scale, as is common in mental model assessment topic. Next, the data undergoes a descriptive analysis to describe the student's mental model before and after the implementation of multiple representations method. Student responses as answers to the test questions in the form of an explanation, mathematical calculation, molecule images, and chemical reactions indicated as mental models. As said by Mumford, *et al*. (2012) that the students' mental models can be generated through the mapping task conceptually where the maps, or models, it is expressed through the image of structural model that describes the relationship between the concepts selected by the student in completing creative problem.

FINDINGS

Student mental models analyzed by acquisition of mental models as a rubric score for each test question mental models can be seen in the students' ability to interpret sub-micro drawing transformation of molecular and chemical phenomena on one level to another level.

The Questions regarding students' mental model of simple chemical reactions required the students to use their mental model in transforming chemical phenomena to verbal form and from verbal form to mathematical form (calculations), to interpret the sub-micro visual image of a simple reaction with reactant and the product available in the box. Furthermore, the students are also asked to describe the product of reaction as well as to perform transformation from verbal statement into a sub-micro (visual) diagram by drawing the reactant and product of a given reaction, and to interpret the reaction occurring in a container. Questions to measure students' mental models with stoichiometry concepts expressed in the No.1, 2, and 3 (TMM 1, TMM 2, and TMM 3) in the appendix.

An analysis of the student's answer to the TMM 1, TMM 2, and TMM 3 questions is stated in the diagrams apparent in Figures 1, 2, and 3.

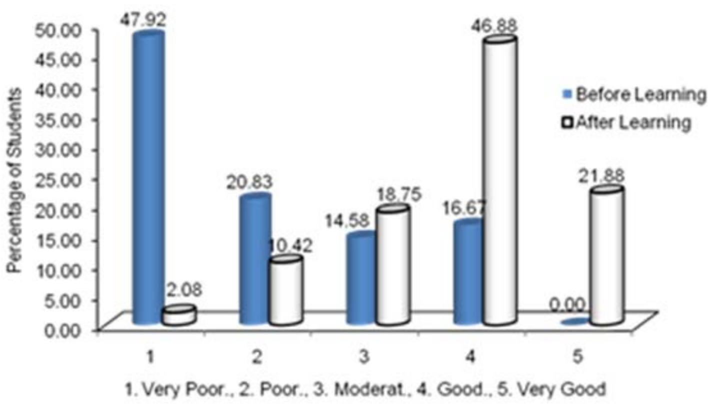


Figure1. Chart of Student's Mental Models on Stoichiometry Topic for question of TMM_1.

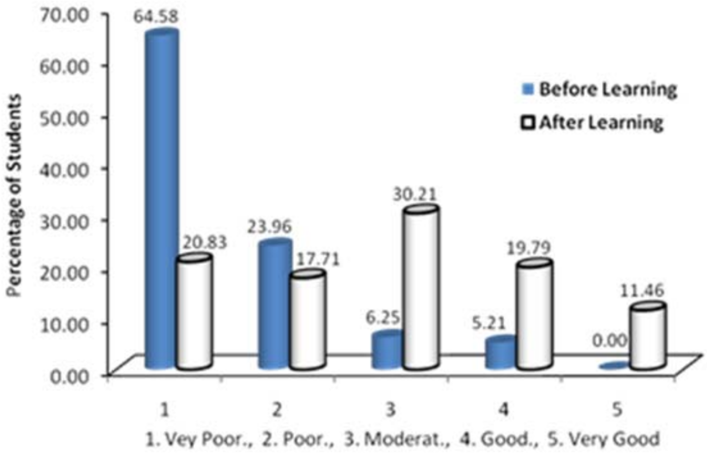


Figure2. Chart of Student's Mental Models on Stoichiometry Topic for question of TMM_2.

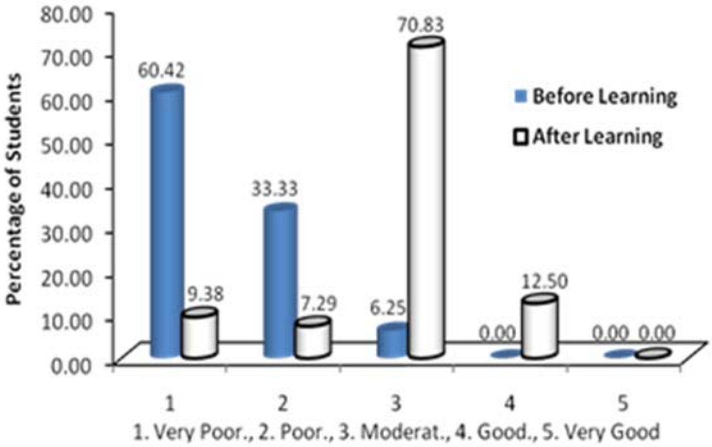


Figure3. Chart of Student's Mental Models on Stoichiometry Topic for question of TMM_3.

Based on the analysis of student mental models of the charts above, it seems like the students' mental model of chemical reaction stoichiometry with various questions from interpretation down to verbal-to-symbolic and verbal-to-visual transformations (sub-micro diagram) and vice versa indicates significant differences before and after the implementation of multiple representations method.

In Figure 1 and Figure 2, students who were initially unable to write reaction equation by directly translating the sub-micro image were able to directly interpret the reaction equation from sub-micro image as well as solve a balanced reaction at the same time after adopting the learning model based on multiple representations. The percentage of students who are able to accurately reply, interpret and transform the sub-micro to macro and symbolic or vice versa for TMM_1 (Figure 1) is 21.88% (very good), 46.88% (good) and 18.75% (moderate), whereas the remaining percentage of students still have low capabilities and must continue to practice their interpretation and transformation of sub-micro to macro and symbolic figure and vice versa. For TMM_2 (Figure 2), the percentage of students with very good, good, and moderate mental models are 11.46%, 19.79% and 30.21% respectively, and the remaining students have bad mental models. In Figure 3 (TMM_ 3), students who have the ability to transform the macro phenomena (verbal) to sub-micro is low, in which case the student with excellent skills mental models (0%), good (6.25%), and moderate (78, 13%).This indicates that the student has not been fully able to do the transformation of macro phenomena to the phenomena of sub-micro (picture) as well.

Difficulties in transforming these students is the ability to interpret the term "excess substance" in a reaction, so the images transform into sub-micro level, the term does not appear in the sub-micro images created by the students. Therefore, students need guidance and training in making representations imagination in order to build good mental models. Nonetheless, these results suggest that after the implementation of learning by using multiple representation method, students have been able to cultivate mental models in the face of external representation of macro and sub-micro level, when compared to the prior implementation of learning.

Based on these results, students still have difficulty in transforming verbal to visual (sub-micro images of chemical reactions), although the study was conducted, involving all three levels of chemical phenomenon. This sub-microscopic external representation is highly required to explain the existing reaction phenomena, since an in-depth understanding of stoichiometry requires more than just an ability to follow an algorhythm or equation alone (Ben Zvi, *et al*., 1987), but also the ability to translate symbols and explain the reaction phenomena occurring at molecular scale. Such findings correspond to those reported by Davidowitz, *et al*. (2010) that 22% students are able to translate sub-micro image directly into a reaction equation, 63% are able to write a balanced reaction accurately, and 15% are incapable of translating a sub-micro image. As such, we can conclude that even though the learning emphasizes on the visual approach using diagrams at sub-micro levels, some students still find it difficult to understand the chemical reaction stoichiometry subject in dealing with the external representation at sub-micro scale (Ben-Zvi, *et al*., 1987; Sanger, 2005).

The results can also be seen from the percentage of students' ability to create images sub-micro, determination of limiting reactant, and write chemical equations directly from the image and the balanced equation. More results are contained in Table 2 to Table 5 below.

Table 2. Percentage of students who can answer questions TMM_1a, TMM_2c, and TMM_3a before and after the learning by using multiple representation method.

No.	Representation/Answer	Percentage of students					
		TMM_1a		TMM_2c		TMM_3a	
		Before	After	Before	After	Before	After
1	Writing a reaction equation based on visual image	19.79	79.17	25.00	68.75	-	-
2	Writing a balanced equation of chemical reaction.	14.58	70.83	31.27	61.46	51.04	80.21
3	Incorrectly writing reaction equation/unbalanced reaction	43.75	20.83	47.92	22.92	34.38	17.71
4	No answer	21.88	0.00	16.67	8.33	14.58	2.18

Table 3. Result of analysis on the students' answers to questions TMM_1c and TMM_2b regarding the determination of limiting reactant from visual image representation before and after the learning by using multiple representation method.

Question	Student's answer	Percentage of students	
		Before	After
TMM_1c	Limiting reactant: O_2	18.75	76.04
	Limiting reactant: H_2	43.75	12.50
	Limiting reactant: H_2 and O_2	16.67	8.33
	No answer	20.83	3.13
TMM_2b	Limiting reactant: SO_2	30.21	68.75
	Limiting reactant: O_2	32.29	15.62
	Limiting reactant: SO_2 and O_2	14.58	5.21
	No answer	22.92	10.42

Table 2 shows that the students have been able to write a balanced equation of the reaction by using the smallest number with the correct ratio, as many as 70.83% (TMM_1), 61.46% (TMM_2) and 80.21% (TMM_3) and these results better than before the application of the learning model based on multiple representation, although not maximized. Not maximal percentage of students who are able to balance the equation with the smallest ratios, because students do not realize that a balanced chemical equation always use the ratio of the smallest numbers. In this case, students are stuck with only translating images sub-micro, which is just write the equation with a direct view of the image without settling into a balanced equation. The ability to write a balanced equation on TMM_1 and TMM_2 highly dependent on the ability of the mental models of students in identifying chemical formulas of molecules involved in the reaction. Table 3 shows that after learning using multiple representation method, the ability of students to use their mental models to move from sub-micro level to the symbolic and mathematical level is better than before the study. Question on TMM_1c and TMM_2b require students to use the algorithm model in problem solving of computation of chemistry with better results. Although most students can identify reactions that occur by writing the equation, but there are still students who failed to identify the reaction products and limitinh reactants, so the answer is to be one who does not even give an answer. After learning, there are 23.96% of the students are not able to recognize that the limiting reactant is O_2 on TMM_1 question, and as much as 31.25% on TMM_2 students can not recognize that the limiting reactant is SO_2.

Table 4. Results of an analysis of student answers to questions TMM_1b.

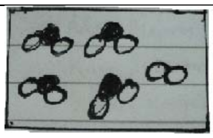
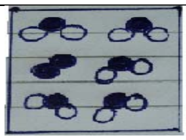
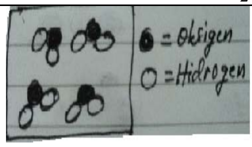
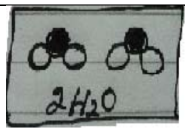
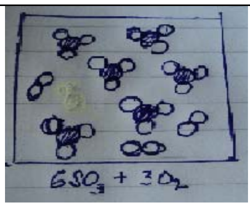
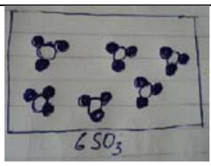
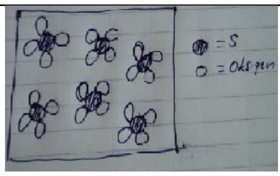
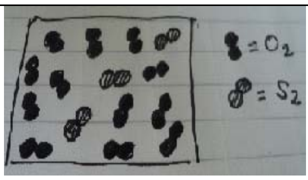
Students' Answer; Sub-micro image of Reaction Product	**Percentage of students**	
	Before	**After**
 $4H_2O + H_2$	19.79	76.04
 $5H_2O + O_2$	31.25	6.25
 $4H_2O$	20.83	7.29
 $2H_2O$	19.79	6.25
 H_2O	8.33	4.17

Table 5. Result of analysis on the students' answer to question TMM_2a.

Students' Answer: Sub-micro image of Reaction Product	**Percentage of students**	
	Before	**After**
 $6SO_3 + 3O_2$	30.21	68.75
 $6SO_3$	33.33	12.50
 $6SO_4$	14.58	6.25
 $3S_2 + 24O_2$	16.67	8.33

Analysis of the images created by students (Table 4 and Table 5) with the predictions of the reaction products showed that after the application of the learning model based on multiple representation, 76.04% (TMM_1) and

68.75% (TMM_2) students can make a picture of the product molecule appropriately. This result is higher than before the study. In Table 4 and Table 5 also shows that the students as much as 7.29% (TMM_1) and 12.50% (TMM_2) which draw molecule products, but does not show the reactants remaining in the container (box). Nevertheless, their percentage decreased as compared with before application of the learning model based on multiple representation. In addition, for TMM_1 (Table 4) as much as 6.25% of the students draw a molecule products in accordance with the reaction coefficient in the balanced equation (i.e. $2H_2O$), and 4.17% draw students with an understanding of the formation of 1 mole of water (H_2O).

DISCUSSIONS AND CONCLUSIONS

Learning chemistry based on multiple representation is performed with the purpose of increasing the students' analogical thinking capacity on stoichiometry by establishing a student's mental model. The appearance of a student's mental model is reflected by his/her ability to interpret all three levels of chemical representation phenomenon (Johnstone, 1991), as seen from the students' answers in verbal, mathematical or symbolic forms and visual image at molecular level. The result of this research shows that the students' mental model has been well formed. In this case, before the implementation by using multiple representation method, the students' mental model was generally in the category of "very poor", but after the implementation of multiple representation method, it improved to "moderate" and "good". The establishment of the students' mental model shows that there has been an improvement of the their ability to understand the macroscopic, sub-microscopic and symbolic representation, as well as the ability to interpret and transform all three levels of chemical phenomenon as reported by Chittleborough & Treagust (2007), Coll (2008), Devetak, *et al*. (2009), Davidowitzt *et al*. (2010).

This research finding shows that the learning model based on multiple representation can be used as an alternative learning model to train the students in interconnecting the three levels of chemical phenomenon representation. In learning the stoichiometry, the students are not only able to learn using algorhythm, but also understand the reaction phenomena at molecular level through imagination. Chemical learning which only focuses on the algorhythm will result in a shallow understanding (Dahsah and Coll, 2008). As such, the roles of imagination in chemistry learning become very important, since the students will be able to improve their imagination, skills and creativity. Thomas & Brown (2011) stated as follows:

> "…*imagination is the process of world building to create a new context in which the strange, the new, the different can be understood as familiar*."
>
> Results of research conducted by Ogawa, *et al*., (2009) reported that
>
> "…*the teaching with emphasis on the imagination can evoke the representation capabilities of learners, so that learners can improve their creativity. The power of imagination will evoke passion to improve the skills and conceptual knowledge of the learners*."

For example, the response to TMM_1 and TMM_2 shows the students' imagination in understanding the chemistry reaction at molecular level, not only in interpreting sub-micro image but also creating a sub-micro image out of reaction product at molecular level (Table 2 and Table 3). Reaction equation which must be written directly from the molecular diagram in TMM_1 is $5H_2 + 2O_2 \rightarrow 4H_2O + H_2$, and its balanced reaction is $2H_2 + O_2 \rightarrow 2H_2O$. In the case of TMM_2, the reaction written directly out of the visual image is $6SO_2 + 6O_2 \rightarrow 6SO_3 + 3O_2$, its balanced reaction is $2SO_2 + O_2 \rightarrow 2SO_3$. In TMM_3, the balanced chemical equation is $2K + 2HCl \rightarrow 2KCl + H_2$. The students' abilities to interpret sub-microscopic image indicate that learning through the exploration – imagination phase can grow the students' imagination, since they are constantly trained and familiarized with interpretation and transformation of chemical phenomena representation levels. With constant training, the students will be able to use their mental model to explain events through the use of visual model (Coll, 2008) and will encounter no difficulties in interpreting the sub-micro structure of a molecule (Devetak *et al*., 2009), so that the students' creativity may grow and develop (Ogawa, *et al*., 2009) as indicated by their ability to draw a sub-micro image of reaction result in questions TMM_1 and TMM_2 (Table 4 and Table 5).

Question on TMM_3 are questions that ask students to do the imagination of the macroscopic phenomena of reaction between potassium with excess HCl. In the experimental class students, students who are in the area and well once have been able to make a sub-microscopic description of the reaction between potassium with excess HCl with molecular images representing the reactants and products appropriately. Where the reactant HCl molecule not only represented 2 molecules as the reaction coefficient is written by students, but exceeded one, because the statements in question stated that it's excess HCl, so the product must also be there HCl remaining on sub-microscopic image made students (Figure4). However, students do not realize that the HCl in the solution will be in the form of H^+ and Cl^- ions, as well as KCl in the solution is also ionized into K^+ ion and Cl^- ion. Thus, students should have created images indicate the presence of H^+ ion, C^- ion, and K metal in the reactant, while the product showed a K^+ ion, $Cl^{-,}$ and H_2 gas as the reaction proceeds. However, the imagination of students with the depiction of the reacting molecules and the reaction product is better than before learning that involves three levels of chemical phenomenon.

Result of analysis of TMM_3 are consistent with those reported by Devetak, *et al* (2009) that through a more detailed analysis of the students who are just learning the stoichiometry was only 57.00% of respondents (students) understand that a strong acid (such as HCl) and salt (such as KCl) almost completely break down into ions in aqueous solution. Furthermore, BouJaoude & Barakat (2003) reported that not a few learners who are less conscientious and make mistakes in understanding the meaning of excess reactants, so that learners have difficulty in making the connection between moles with reaction coefficient.

In addition, student difficulties due to inability to perform interpretation and transformation of the sub-microscopic phenomena, especially in TMM_3. The inability of some students (<48.00%) in this study is likely due to the students not having a process-oriented thinking, so that in describing the reaction only focuses on changes in macro with only a few mechanisms of verbal information (Strickland, *et al*., 2010). Another possibility is the ability to build a mental model of the third-level interconnect of chemical representation is not a natural talent, but it is a skill and should be studied seriously, because the ability to build a mental model associated with the ability of reasoning and mental models itself is dynamic (Chittleborough & Treagust, 2007).

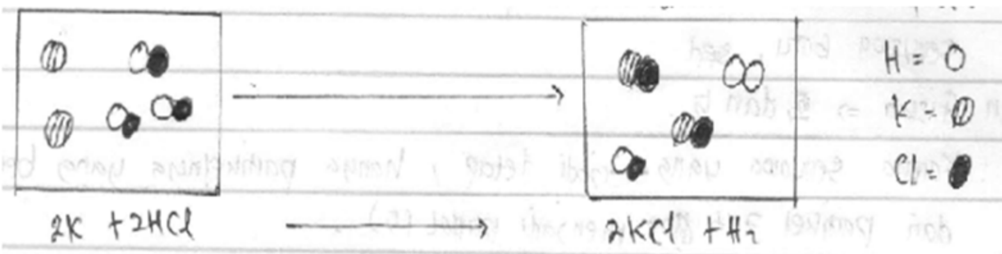


Figure4. Examples of students' answer in drawing a reaction between the metal K and excess HCl

Based on the data stated in Figure 1 to Figure 3 and the data in Table 2 to Table 5, it seems that even though the current learning method already emphasizes on the roles of multiple representation through the imagination phase, the majority of the students still encountered difficulties in interpreting the sub-microscopic representation and creating a sub-micro image of the reaction product at molecular level, since the students underwent the process of “forgetting”. This suggests that an unstable mental models (Norman, 1983) among them. In this case, McBroom (2011) stated that the participants’ difficulties in understanding the particular level which corresponds to its terminology might be connected to Norman’s idea (1983) that a person’s mental model is unstable and one can easily forget the detailed concept of a learned system.

However, based on some of the findings in this study can be said that the learning model based on multiple representation is effective in build mental models of students. These findings reinforce previous findings related to the learning based on multiple representations, for example: Yakmaci-Guzel & Adadan (2013) has utilized multiple representations in learning to develop an understanding of chemistry teacher candidates about the structure of matter; Jaber & BouJaoude (2012) has utilized the interaction between the three levels of representation of the macro – sub-micro –symbolic for increasing understanding of relational of chemical reactions; A research conducted by Abdurrahman (2010) who also uses learning based on multiple representations to improve the mastery of concepts, generic science skills, and critical thinking skills of students of physics; Eilam & Poyas (2010) has utilized external visual representations through the application of STS approaches to look at students' ability to identify the cellular system components and relations, and to construct new interrelations.

The findings in this study indicate that the chemistry lesson should involve several representatives at the first opportunity, since students in junior high school or even earlier, if possible. This study also provides information that the learning model based on multiple representation is an alternative learning model that can be used to construct mental models involving the three levels of chemical representation.

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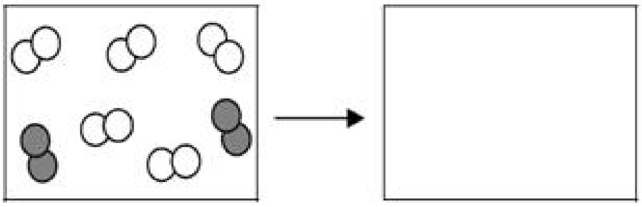
Appendix:
Questions To Test Mental Models On The Concept Of The Reaction Stoichiometry (TMM 1, TMM 2, and TMM_3)

Question TMM_1: Pay attention to the following reaction diagram:

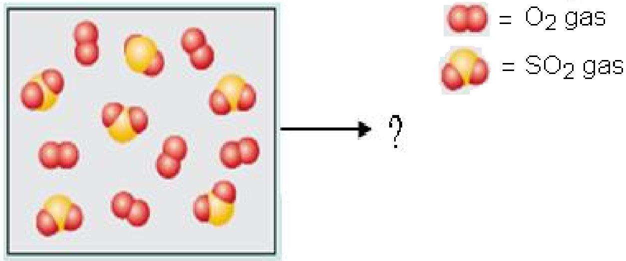


Note: ○ = H atom and ● = O atom

(Source: Davidowitz, *et al.*, 2010).

a. Write a balanced reaction equation to produce gas, as shown in the above figure!
b. Use the available space to draw molecules in the reaction flask (the empty box) after the reactant is converted into product.
c. Based on the drawing you made, determine the limiting reactant!

Question TMM_2: Pay attention to the following molecular level diagram:



(Source: Zumdahl & Zumdahl, 2007)

If the mixture of both gas reacts with one another:

a. Describe all molecules in the container which indicate that a reaction has occurred in a closed container !
b. Indicate which reactant molecule acts as a limiting reactant?
c. Write a balanced reaction equation!
d. If 96.0 grams of SO_2 reacts with 32 grams of O_2 gas, count the mass of product from such reaction and the remaining reactant! (Ar. S=32, and O=16) !

Question TMM_3: A total of 3,9 grams of potassium metals reacted with excess hydrochloric acidin a room that has a temperature of 27^{o}C and1 atm.

a. Write the balanced chemical equations of the reactions!
b. Draw your imagination results in a box about how the phenomena of chemical reactions, thus allowing other people can see each component separately !. Copy the box below and work on folio sheets provided!.
c. Describe your images and why this phenomena occurs?