Journal of Physics: Conference Series

PAPER • **OPEN ACCESS**

The effect of multiple representation approach on students' creative thinking skills: A case of 'Rate of Reaction' topic

To cite this article: A Wiyarsi *et al* 2018 *J. Phys.: Conf. Ser.* **1097** 012054

IOP Conf. Series: Journal of Physics: Conf. Series **1097** (2018) 012054 doi:10.1088/1742-6596/1097/1/012054

The effect of multiple representation approach on students' creative thinking skills: A case of 'Rate of Reaction' topic

A Wiyarsi*, H Sutrisno and E Rohaeti

Chemistry Education Department, Faculty of Mathematics and Natural Science, Universitas Negeri Yogyakarta, Indonesia
*Email: antuni_w@uny.ac.id

Abstract. The aim of the study was to analyze students' creative thinking skills in implementing multiple representation approach on 'rate of reaction' topic. The one-shot case study research design was conducted with 30-eleventh grade students drawn from a public senior high school in Yogyakarta, Indonesia. The learning process involved in implementing concept attainment models with multiple representation approach (CAM-MRA). There were five lesson sequences including presentation of example and non-example, formulation of example, formulation and analysis of hypothesis, closure and application. In each session, macroscopic, microscopic, symbolic and mathematics representation were employed to illustrate 'rate of reaction' concepts. The data were collected by creative thinking based on multiple representation test (CT-MRT) with 24 items. The results showed that the CAM-MRA facilitated the students' creative thinking skills of 'rate of reaction'. However, the students still had difficulty to show the microscopic representation. This study suggests that multiple representations in chemistry should be emphasized in chemistry learning at senior high school.

1. Introduction

The development of the 21st century is affecting several educational aspects such as learning process and learning assessment. Chemistry learning also is emphasized to develop 21st century skills learning. The Partnership for 21st Century Skills describes these skills that students needed to address global challenges and be successful in work and life. There are needed learning and innovation skills such as creative thinking, critical thinking, problem solving also effective communication and collaboration. Creative thinking, one of the 21^{st} century skills, has been becoming a priority in Indonesian National Curriculum 2013 (K-13). Creative thinking helps students to move "sideways" to try different perceptions, concepts and point entries [1]. Using creative thinking in chemistry learning enables students to have divergent thinking habits in problem solving. The results of previous research indicated that students' creative thinking skills could be improved by applying constructivist learning [1,2]. For example, students' creative thinking skills can be evolved via problem-based learning [1] resulting in an increasing in positive attitudes (emotionally and cognitive) towards science/chemistry [3].

Constructivist learning approach uses concept attainment to strengthen the students' impulse in understanding the concept by exploring, organizing and developing language to express the concepts obtained [4]. The stages in the concept attainment models encourage students to develop higher order thinking skills because students need to use the reasoning to conclude the truth of a concept. The previous result showed that the implementations of concept attainment models can improve concept comprehension, critical thinking skills, develop of concluding ability and metacognitive skills [5-9]. Hence, concept attainment model may enhance students' creative thinking skills.

One of the chemistry concepts characteristics is bring up the abstract phenomena [10]. The abstractness of chemistry concepts might be caused by the three levels of phenomenon usually occurs in chemistry, or it is usually better known as multiple representations. The abstractness of chemistry phenomena can be explained through different level, i.e. macroscopic, microscopic, symbolic, and mathematics [10-15]. Implementation of concept attainment models can be alternative to overcome the abstractness of chemistry concepts, so students get their understanding easier. According to [16] suggest that students' ability to connect and represent macro, sub-micro and symbolic phenomena is key to understanding chemistry concepts that are abstract.

Macroscopic representations depict phenomena based on experience life or experiment [17]. Macroscopic representation is anything that can be seen, touched, and felt [11]. This phenomenon had mostly studied in chemistry learning. Microscopic representation is defined as a chemical representation in the form of visualization of atoms, ions, molecules in a chemical reaction [18]. The use of diagrams the microscopic level provides a more complete picture of the reaction, rather than a net summary of a chemical equation, leading to deeper conceptual understanding [13]. Chemistry learning that is less attention to this aspect will cause students to tend simply memorize microscopic representations in the form of word descriptions. This learning results in the inability of students to imagine how the processes and structures of a substance are reacting. Symbolic representation defines by [19] as a chemical representation consisting of symbols as a means of describing atomic symbols, properties, phases, and chemical reaction equations. Mathematical representation is defined as a representation containing chemical calculations. Students will interpret the chemistry concepts well if they can visualize the phenomena in various representations.

Some research results indicated that the students' inability to represent chemical phenomena at the microscopic level can inhibit the ability to solve chemistry problems related to both macroscopic and symbolic phenomena [20, 21]. Multiple representations approach in chemistry learning provides good opportunities for developing an understanding of chemistry concepts, solving of chemistry problems and creating conceptual relationships [8, 22-25]. Learning by multiple representations approach is able to bridge the process of students' understanding of the chemistry concept. Therefore, chemical representations must be part of the various components of chemistry learning such as teaching materials, learning media or textbooks. It will support the improvement of students' understanding.

'Rate of reaction' topic is largely abstract and needs to be supported by visualizing the abstraction in various representations to achieve conceptual understanding. The Rate of reaction topic involves in several concepts such as the concept of chemical reaction, collision theory, factors affecting rate of reaction, equation of rate of reaction and level of reaction. Some problems encountered in learning of Rate of reaction topic were identified. An inability to define the rate of reaction and misunderstanding, misapplying or misinterpreting of the relationship between the reaction rate and its affecting factors were some of problems for students' conception [26]. This problem might be caused by the less of a thorough student understanding of the various representations in Rate of reaction topic. The macroscopic representation can be observed directly from experiments on factors affecting the rate of reaction. The microscopic is studied from collision theory and its application. The symbolic and mathematical aspects can be studied by formulas, tables, and graphs in the concept of rate of reaction, rate of reaction equation, and reaction level.

Concept attainment model that conducted by multiple representations approach can be alternative in chemistry learning strategies to overcome the problem of students' conception. This study not only help the students' to see the chemical phenomena in multilevel but also promote new strategies to enhance students' creative thinking skills. Students would have an opportunity to declare their own knowledge about chemical phenomena actively through analysis of an appropriate example. Hence, this study will useful for students and teachers as contribution for chemistry learning quality improvement in Rate of reaction topic. In addition, it can be researchers' consideration to do similar researches for other topic. Therefore, this study purposes to examine the effect of multiple representation approach on the students' creative thinking skills and chemical representation ability in Rate of reaction topic. The following research questions guide the study:

1. At which level do the students' creative thinking skills in Rate of reaction topic?
2. At which level do the students' chemical representation ability in Rate of reaction topic?

2. Method

2.1. Research design

The one-shot case study design was conducted. This design is one of single-group design in experimental research design [27]. The posttest was given after did the treatment in learning process. This study only employed an experimental group and measured its own level of creative thinking skills and chemical representation ability without any comparison pretest or control group.

2.2. Samples

This study was undertaken in one of public senior high school in Yogyakarta, Indonesia. The samples were 30-eleventh grade students (10 males and 20 females) that are in one class. The ages of students were 16-17 years old. The samples were determined based on the consideration of the researcher where the class had been designed by the school as a research class.

2.3. Intervention

The 5-week (90 minutes per week) the Rate of reaction topic was taught by the teacher using the concept attainment models with multiple representation approach (CAM-MRA). The 5-concepts included theory of chemical reaction, collision theory, factors affecting rate of reaction, equation of rate of reaction and level of reaction. Then, students were completed the posttest in 6^{th} week. There were four lesson sequences in CAM-MRA including formulation of example, formulation and analysis of hypothesis, closure and application. In each session, the explaining of Rate of reaction topic presented in macroscopic, microscopic, symbolic and mathematics representation.

First step of CAM-MRA was done by presenting example and non-example of multiple representations in the Rate of reaction concept. Then, students analyzed and formulated an initial idea about multiple representations of Rate of reaction concept in collaboration with others. In the third step, by collaboration with others students made the conclusion. Finally, students completed the task independently to get deep understanding about multiple representations of Rate of reaction concept. For example, in the session of factors affecting rate of reaction, First, the students observed a piece of apple peeled in some places, such as: 1) evaporating dish porcelain, 2) beaker glass covered with aluminium foil, 3) 100 mL water in beaker glass covered with aluminium foil, 4) 100 mL vitamin C 50mg in beaker glass 5) 100 mL vitamin C 150 mg in beaker glass. The observation was conducted for about 15 minutes. Then, students drawn initial idea about kind of factor affecting reaction in symbolic and microscopic representation with collaboration in groups (3-5 students). Third step, students collected data based on example of chemical representation and then concluded. The last, students did some exercises to improve their understanding.

2.4. Data collection instrument

One of the instrument that was used in research called creative thinking based on multiple representation test (CT-MRT). The instrument was developed by researcher based on the creative thinking indicator and multiple representation level from [1, 28, 29]. There are four indicators of creative thinking skills i.e. originality, fluency, flexibility and elaboration. Three indicators are based on the measurement aspect of Torrance Tests of Creative Thinking (TTCT) [1, 29, 30]. The last indicator was considered from basic concept of creative thinking declare by Guilford [31, 32]. A group of expert, three of lecturer in chemistry education and two chemistry teachers confirmed construct and face validity of the CT-MRT with 32 items. According to the result of item- total correlation analysis it showed that 8 items test had not good validity. Reliability analysis toward 24 items test resulted the Cronbach's alpha was 0.87. This means that the reliability of CT-MRT was high, so it acceptable as a good instrument to collect the data. Table 1 presents the distribution of indicators on the CT-MRT items.

TABLE 1. The Distribution of Indicators on CT-MRT Items

Creative thinking skills indicators	Multiple representation level				Total items
	Macroscopic	Microscopic	Symbolic	Mathematics	
Originality	5a	-	1c; 5b	1d	4
Fluency	-	-	1a; 3c; 5c; 6b	-	4
Flexibility	7a; 9a	1b; 2b; 7c	4a	-	6
Elaboration	-	8c	2a; 5d; 6c; 8a	2c; 4c; 5e; 6d; 8b;	10
Total items	3	4	11	6	24

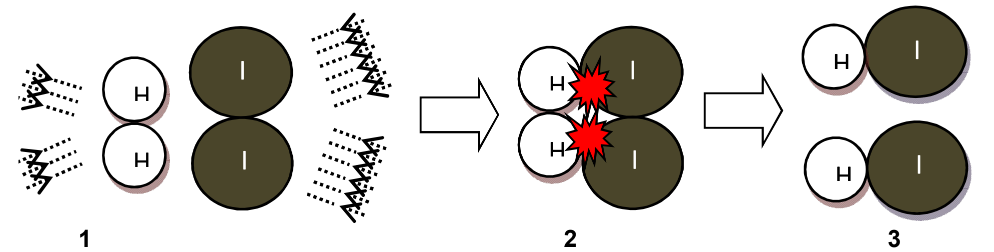
2.5. Data Analysis
Descriptive quantitative analysis was used to determine the category of students' creative thinking skills and chemical representations ability. The steps of data analyses were calculated the mean score – both in total or in each measurement indicators-, categorize the measurement results. According to [33] the ideal scoring criteria was category determination based on standard deviation value and ideal maximum/minimum scores. The students' creative thinking skills and chemical representation ability were categorized as very good (>97.6); good (84.8–97.5); quite good (59.2-84.7); less good (43.2-59.1) and very less good (<43.2).

3. Results and Discussion
3.1. The students' creative thinking skills of reaction rate concept in implementation of CAM-RA
The result showed that the categories of students' creative thinking skills of reaction rate concepts included in quite good category. The average score was 74, while the maximal ideal score was 120. There were about 17% students that had very good category in creative thinking skills. Then, there were 29.17% of students in good category; 50% of students in quite good category and 16.67% in less good category.

According to the research result can be stated that the implementation of CAM-MRA fostering students' creative thinking skills. Thinking -in general- is a process and it is natural. Creative thinking skills must be practiced continuous until the thought patterns in the minds become comfortable with principle of divergent thinking. During first step of CAM-MRA, students were faced with the facts about the appropriate and inappropriate concepts. Students develop their ability to convey thoughts about conceptual inappropriateness. The ability to produce a large number of idea is called fluency [1]. Then, students can propose various ways of representing a chemical reaction that is included in the flexibility indicator.Originality and elaboration especially will develop when students complete the task individually. This is relevant to the results of the previous studied by [1] that learning begins with the exposure of the problem affecting student to use various methods including provocations to solve the problems. So, within creative thinking skills students can become a perfect problem solver.

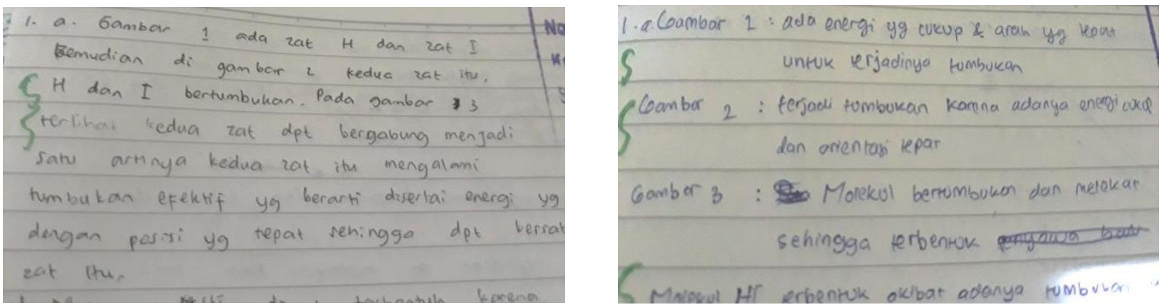
FIGURE 1. Category of Students' Creative Thinking Skills in Each Indicator

The other results indicated the students' skills when were viewed from each indicator of creative thinking was in good category for originality, and the category was quite good for the fluency, flexibility and elaboration. Figure 1 presented the distribution of Students' Creative Thinking Skills in Each Indicator. A sample question for the fluency indicator is presented in Figure 2. Students are asked to observe and explain the relationship between the three images. This problem facilitates students' thinking to write down ideas according to their perspectives but to keep the truth. The idea proposed is certainly different for students. Figures 3a and 3b provide examples of different idea but students' responses were correct. Students (a) declared the idea preceded by the existence of two different atoms which then merge to form molecules through a collision. While student (b) focuses the observation begins from the existence of enough energy, so that the atoms can collide effectively to form molecules. These results showed that students have no difficulty in describing the concept of chemical reactions.



Question:
a. Observe the pictures and explain the relationship among Fig.1, 2 & 3!

FIGURE 2. Item Example for fluency indicator



A B

FIGURE 3. Students' Responses for fluency indicator

Another example for the analysis of flexibility indicators when students were asked to explain the factors that affect the reaction rate based on the image of experimental reaction between iron in bar-shaped (nails) and powders (see Fig.5). Most of the students' answers Indicated that they had alternative conceptions. The reaction rate will settle quickly when reacting with the nail because of more touch surfaces. Other students correctly answer that the reaction with the powder will result in a faster reaction rate. Even though, the reason given was not right. Students stated that the reaction rate is faster because the smaller the form of the reactant (powder) indicates the number of particles that can collide. This result is in line with previous research that showed most of students had a lack of understanding of the effect of "surface area" on the reaction rate that students declared partial understanding with specific alternative conception [34].

The achievement of students' thinking skills in quite good and good category was relatively not much different. Besides that, no one is in the less good category. Nevertheless, students who have very good category are still few, three students only. This condition indicates that various efforts are still needed to improve students 'creative thinking skills as well as to develop students' understanding of multiple representations in various chemistry concepts.

3.2. The students' chemical representation ability of reaction rate concept in implementation of CAM-MRA

Based on the level of representation, the results of data analysis showed that the category of students' ability to macroscopic representation is good, while for symbolic and mathematical representation are quite good and less good category for microscopic representation. Figure 4 presents the percentage of student distribution with different ability categories for each level of representation.

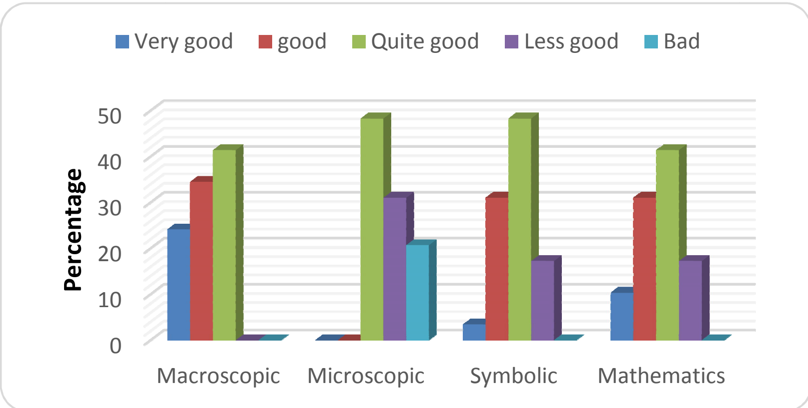


FIGURE 4. Distribution of Students' Ability for Each Representation Level

The result on the level of representation of reaction rate concepts showed that students' ability in microscopic and mathematical representation were still in quite category. Symbolic representation related to students' ability to use mathematical calculations to solve chemical problems. In the concept of reaction rate, the greatest difficult problem is founding in the calculation of the reaction level.

The microscopic representation describes the interactions that occur between the particles involved in the reaction. Students have to have a good conceptual understanding, be able to relate macroscopic (observable) phenomena to what actually happens at the molecular level. For example, students still have difficulty to describe what happens when iron is reacted with hydrochloric acid in microscopic level. Figure 5 shows the macroscopic representation seen at the practicum and Figure 6 illustrates the microscopic representation of the reaction.

A b

FIGURE 5. Reaction between HCl and Fe (a) powder; (b) bar-shape

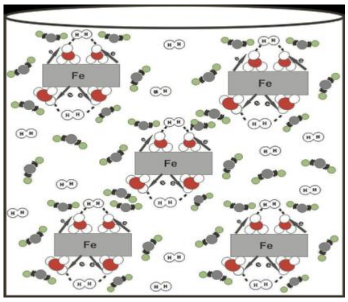


FIGURE 6. The interaction when Fe and HCl was react

Microscopic representation shows that what is seen as a bubble that is collected on a glass beaker is a reaction hydrogen gas. Iron will release 2 electrons which will then be captured by electrons from 2 hydrogen atoms forming hydrogen gas (H_2). Then, the ion of Fe^{2+} will interact with the Cl^{-1} ion by collision. However, high school students had not been able to represent the micro phenomena well. It was as shown in Fig.7 when students were asked to explain the microscopic representations in the reaction between magnesium metal and hydrochloric acid. An example of the student's answer indicated that the student has not been able to illustrate the actual mechanisms occurring at the molecular level when magnesium metal is reacted with hydrochloric acid. Students were only able to represent it symbolically.

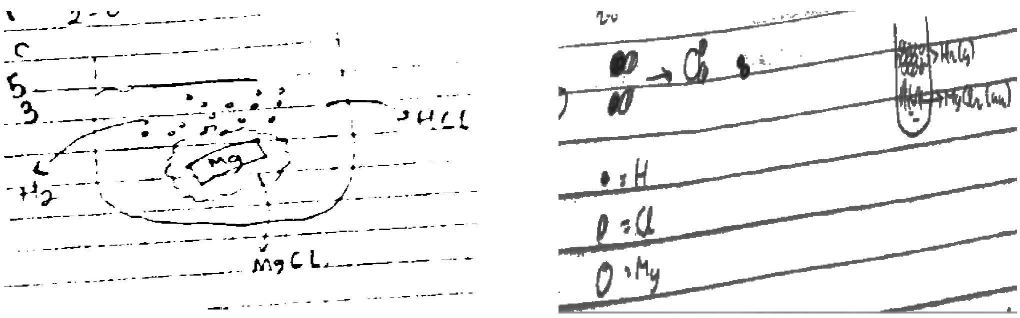


FIGURE 7. Example of Students' Response to Microscopic Representation

This situation is in line with previous research which it suggested that students were more likely to use symbolic macroscopic level transformation, but they are unable to transform from the macroscopic and symbolic levels to the microscopic level. It happens because the chemistry learning that has been happening more emphasizes the macroscopic and symbolic levels [14, 35]. The implementation of CAM-MRA becomes an applicable alternative in the effort to train and familiarize students to represent chemical phenomena in all four levels. In addition, CAM-MRA also facilitates the development of students' collaborative skills and creative thinking skills that become basic skills for students facing the 21st century global challenge.

4. Conclusion

The implementation of CAM-MRA is facilitating students’ creative thinking skills of reaction rate better. Students construct their own knowledge by observing some of the chemistry phenomenon representations. Thus, the students’ understanding about Rate of Reaction topic will be more thoroughly with the better retention. However, in the perspective of multiple representations indicated that students had difficulty to show the microscopic representation because students just know about symbolic and mathematic. The implication of this research result is multiple representation approach must be conducted in chemistry learning of senior high school. Learning process can be started by observation in laboratory for macroscopic aspect. It can be developed for the other aspects.

References

[1] Awang H and Ramly I 2008 *Int. J. Human. Soc. Sci.* **3** 334-229
[2] Saowakon A S and Sumalee C 2012 *Eur. J. Soc. Sci.* **30** 410-421
[3] Hugerat M and Kortam N 2014 *Eurasia J. Math. Sci. Technol. Educ.* **10** 447-454
[4] Eggen P and Kauchak D 2012 *Strategic and Models for Teachers: Teaching Content and Thinking Skills* (New Jersey: Pearson Education)
[5] Reid B 2011 *Sci. Teach.* **78** 51-55
[6] Pugh K, Linnenbrink G L, Koskey K, Stewart V and Manzey C 2010 *J. Sci. Educ.* **94** 1–28
[7] Roehrig G and Garrow S 2007 *Int. J. Sci. Educ.* **29** 1789-1811
[8] Kumar S and Mathur M 2013 *Universal. J. Educ. Res.* **1** 165-169
[9] Ostad G and Solaymanpour J 2014 *Int. J. Innov. Res. Sci. Eng. Technol.* **3** 9774-9781
[10] Santos V C and Arios A 2016 *J. Turkish. Sci. Educ.* **13** 3-18
[11] Johnstone A 2009 *Int. J. Sci. Educ.* **31** 2271-2273
[12] Cheng M and Gilbert J K 2009 *Toward a better utilization of diagrams in research into the use of representative levels in chemical education* vol 4, eds. Gilbert J K and Treagust D (Netherlands: Springer) p 55-57
[13] Davidowitz B, Chittleborough G D and Eileen M 2010 *Chem. Educ. Res. Pract.* **11** 154–164
[14] Gilbert J K and Treagust D F 2009 *Multiple Representations in Chemical Education* vol 4, eds. Gilbert J K and Treagust D (Netherlands: Springer) p 4-6
[15] Hafsah T, Hashim R, Zurida I, Jusoff K and Yin K Y 2014 *SJASS* **21** 3-21
[16] Treagust D F, Chittleborough and Mamiala 2003 *Int. J. Sci. Educ.* **25** 1353-1368
[17] Li W S and Arshad M Y 2014 *J. Turkish. Sci. Educ.* **11** 35-52
[18] Bucat B and Mocerino M 2009 *Learning at the sub-micro level: structural representations* vol 4, eds. Gilbert J K and Treagust D (Netherlands: Springer) p 11-29
[19] Talanquer V 2011 *Int. J. Sci. Educ.* **33** 179-195
[20] Kozma R 2005 *Learn. Instr.* **13** 205-226
[21] Chandrasegaran A L, Treagust D F and Mocerino M 2007 *Sch. Sci. Rev.* **88** 325-335
[22] Waldrip B, Prain V and Carolan J 2010 *Res. Sci. Educ.* **40** 65-80
[23] Won M, Treagust D F and Yoon H 2014 *Proc. of the ACSME* (Curtin University) vol 20 (Bentley, Australia: Public Knowledge Project) p 69
[24] Abdurrahman, Liliasari, Rusli A and Waldrip B 2011 *Cakrawala Pendidik.* **XXX** 30-45
[25] O’Keefe P, Letourneau S M, Homer B D, Schwartz R N and Plass J L 2014 *Comput. Hum. Behav.* **35** 234–242
[26] Calik M, Kolomuc A and Karagolge Z 2010 *J. Sci. Educ. Technology* **19** 422-433
[27] Gall M D, Gall J P and Borg W R 2003 *Educational Research: An Introduction 7th Ed* (New Jersey: Pearson Education) p 389
[28] Turkrmen H and Sertkahya M 2015 *WJEIS* **5** 74-84

[29] Kim K H 2012 *Creativ Res. J.* **23** 285-295
[30] Alghafri A S and Ismail H N 2014 *Int. J. Soc. Sci. Humanity.* **4** 518-525
[31] Lee K H 2005 *Int. Educ. J.* **6** 194-199
[32] McIntyre F S, Hite R E and Rickard M K 2003 *J. Mark. Educ.* **25** 143-150
[33] Azwar S 2012 *Penyusunan Skala Psikologi* (Yogyakarta: Pustaka Pelajar) p 30-38
[34] Kolomuc A and Calik M 2012 *J. Balt. Sci. Educ.* **11** 333-346
[35] Devetak I, Erna D L, Mojca J and Glazar S A 2009 *Chem. Educ. Res. Pract.* **10** 281-290

Acknowledgments
Thanks to the UNY graduate school that has facilitated the funding of this research and for Mrs. Atina Rizanatul who assist in the collection data. Thanks to the reviewers for the suggestions and feedback.