THE EFFECTIVENESS OF TWO-TIER MULTIPLE CHOICE TEST AND MULTIPLE CHOICE TEST FOLLOWED WITH INTERVIEW IN IDENTIFYING MISCONCEPTION OF STUDENTS WITH DIFFERENT SCIENTIFIC REASONING SKILLS IN REACTION RATE

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Abstract: **The Effectiveness of Two-Tier Multiple Choice Test and Multiple Choice Test Followed with Interview in Identifying Misconception of Students With Different Scientific Reasoning Skills in Reaction Rate.** Many methods can be used to identify misconception. One of them is a multiple choice test followed with interview, but it is time consuming. Two-tier multiple choice test is one alternative method requiring less time. The purpose of this study was to find out effectiveness of two-tier multiple choice test compared with multiple choice test followed with interview in identifying misconception in reaction rate. Research subject were two groups of students consisting of 16 students of each group matched based on their scientific reasoning skills. Research result show that multiple choice test followed with interview is more effective than two-tier multiple choice test in identifying students' misconceptions in reaction rate. In addition, potency of misconceptions of concrete level students is higher than that of low formal and upper formal levels students.

Keywords: two-tier multiple choice test, multiple choice test followed with interview, misconceptions, reaction rate, scientific reasoning skills

Abstrak: **Keefektifan Tes Pilihan Ganda Dua Tingkat dan Tes Pilihan Ganda Disertai Wawancara untuk Mengidentifikasi Kesalahpahaman Siswa dengan Kemampuan Berpikir Ilmiah yang Berbeda terhadap Laju Reaksi.** Kesalahan konsep dapat diidentifikasi menggunakan berbagai metode. Salah satu metode tersebut adalah tes pilihan ganda disertai wawancara. Namun, metode tersebut memerlukan waktu yang relatif lama. Salah satu metode yang memerlukan waktu lebih singkat adalah tes pilihan ganda dua tingkat. Penelitian ini bertujuan untuk mengetahui keefektifan tes pilihan ganda dua tingkat dibandingkan dengan tes pilihan ganda disertai wawancara dalam mengidentifikasi kesalahan konsep pada materi laju reaksi. Subyek penelitian adalah dua kelompok siswa yang terdiri dari 16 pasang siswa yang dipasangkan berdasarkan kesamaan kemampuan berpikir ilmiahnya. Hasil penelitian menunjukkan bahwa tes pilihan ganda disertai wawancara lebih efektif dibandingkan tes pilihan ganda dua tingkat dalam mengidentifikasi kesalahan konsep pada materi laju reaksi. Selain itu, potensi kesalahan konsep pada siswa dengan kemampuan berpikir ilmiah *concrete* lebih besar dibandingkan siswa dengan kemampuan berpikir ilmiah *low formal* dan *upper formal.*

Kata kunci: tes pilihan ganda dua tingkat, tes pilihan ganda disertai wawancara, kesalahan konsep, laju reaksi, kemampuan berpikir ilmiah

Scientific reasoning skills are the skills required in understanding science (Coletta, 2013). Chemistry is a branch of science. Scientific reasoning skills are also required in learning chemistry. According to Lawson (2000) scientific reasoning skills may be identified based on tasks related to conservation of matter and volume, proportional reasoning, control of variables, probability reasoning, correlation reasoning, and hy-

pothetico-deductive reasoning. One of instruments used to measure scientific reasoning skills is Classroom Test of Scientific Reasoning developed by Lawson (2000). Based on the students' answers on Classroom Test of Scientific Reasoning, Lawson (2014) classify students into four categories, namely concrete level, low-fomal, upper-formal and post-formal.

Coletta & Phillips (2005) found a moderate correlation between scientific reasoning skills and students' learning outcomes in science (correlation coefficient, $r = 0.51$). Coletta, Phillips, & Steinert (2007) also found a moderate correlation between scientific reasoning skills and students' understanding ($r = 0.53$). Based on these studies, it could be presumed that students not fully developed scientific reasoning skills tend to have difficulty in understanding chemistry. This difficulty may produce understanding different from those generally accepted by scientific community commonly called misconceptions if it occurs consistently (Nakhleh, 1992:191). According to Berg (1991:66) students are regarded to have misconceptions if lack of complete understanding occurs continuously and shows certain sources.

Reaction rate is one of difficult topics to study (Cakmakci, Donnelly & Leach, 2003; Kurt & Ayas, 2012). Many studies reported students' misconceptions in reaction rate. Some of misconceptions revealed are reaction rate is defined as reaction time (Cakmakci, 2005), reaction rate is defined as increasing concentration of reactant or decreasing concentration of product (Marganof, 1999), concentration of reactants increases, reaction will take longer because of there will be much more particles to collide (Kurt & Ayas, 2012), the increase in size of reactant particle will increase reaction rate (Marganof, 1999; Amarlita, 2010; Arviani, 2011)

Students' misconceptions can be identified by using some methods including concept maps (Goh & Chia, 1991), open-ended test (Kolomuç & Tekin, 2011; Calik & Ayas, 2005; Sözbilir, Pinarbaşi, & Canpolat, 2009), interview (Thompson & Logue, 2006), open-ended test followed with interview (Kalin & Arikil 2010; Taştan, Yalçinkaya, and Boz, 2010), and multiple choice test (Erdemir, Geban, & Uzuntiryaki, 2000). Each method has its advantages and disadvantages. Among these methods, multiple choice test is often more preferable since it is considered more practical. However, multiple choice test has limitation. It could provide possibility that students' answer is not their actual understanding (Dindar & Geban, 2011:600). One effort to overcome the limitation of multiple-choice test in identifying students' misconceptions is interview. Interview is used as a complement of students' answers on a multiple choice test. Students' reason in answering questions on a multiple choice test can be known during the interview. Through interview, consistency of answer may be identified.

Interview as a solution to overcome limitation of multiple choice test further have other issues. It is time consuming. The interview can only be administered one by one, different with written test that can be administered simultaneously at the same time. Thus, two-tier multiple choice test developed. Two-tier multiple choice test, in principle, adopt a multiple choice test followed with interview. Two-tier multiple choice test is not only ask students to choose the correct answer, but also to determine reason of their answers. Consistency of students in determining answers at first tier and reasons at second tier may be known. Hence, it could be determined whether the students understand a concept properly or having misconception.

Some studies about development of two-tier multiple choice test have been reported (Tan, *et al.*, 2005; Chandrasegaran, *et al.*, 2007; Tüysüz, 2009). Based on those studies, two-tier multiple choice test considered effective to assess students' concepts understanding and also identify their misconceptions. However, different opinions suggested by Dhindsa & Treagust (2009). Dhindsa and Treagust suggested that two-tier multiple choice test still require interview as triangulation since students have opportunity to guess the answer and the reason. It shows that two-tier multiple choice test also has its limitation.

Study about effectiveness of two-tier multiple choice test compared to multiple choice test followed with interview was conducted by Ariyani (2013). However, this study has some some limitations. *First*, identification of each misconception used only one question. This may lead to difficulty in identifying of consistency of students' answer. *Second,* same students was given multiple choice test followed with interview first, then two-tier multiple choice test. It could give a biased effect in research results.

First limitation may be solved by using at least two questions in identifying each misconception. Second limitation may be solved by selecting two groups of students with similar ability based on one having strong relation with students understanding of concepts. So far there is no such ability match with this criterion. Students' scientific reasoning skills is apparently the only reported variabel having correlation with students' understanding of concepts. This tudy was aimed to compare the effectiveness of two-tier multiple choice test and multiple choice test followed with interview in identifying misconception

related to reaction rate on two groups of students having similar scientific reasoning skills.

METHOD

This study was a descriptive one. Research subjects were grade XI students of SMAN 1 Lawang consisting of 5 homogeneous classes. Sample of this research consisting of matched students selected from 2 classes having same scientific reasoning skills score. Determination of matched students based on this score because of a fact that scientific reasoning skills and misconceptions have a negative correlation. Students who have developed scientific reasoning skills tend to have a good understanding in chemistry. It means, they tend to have less misconceptions than those not fully developed scientific reasoning skills, and vice versa. Classroom test of scientific reasoning used was translated from *Classroom Test of Scientific Reasoning* developed by Lawson. This test consisting of 24 items with reliability coefficient, calculated using KR-20 formula, of 0.74, that was close to original test's reliability coefficient, calculated with the same formula, of 0.79. Based on the score collected, 16 matched students were obtained. Instruments used to identify misconception were multiple choice test followed with interview and two-tier multiple choice test. Multiple choice test consisting of 25 items with content validity of 97.3% and reliability coefficient, calculated using KR-20 formula, of 0.60. Two-tier multiple choice test consisting of 25 items with content validity of 92% and reliability coefficient, calculated using KR-20 formula, of 0.65. Students' misconceptions in first class were identified using multiple choice test followed with interview while students in another class were identified using two-tier multiple choice test. Data were analyzed using descriptive analysis. The effectiveness of test was determined based on the amount of misconceptions identified by both test. A test able to identify more misconceptions is regarded more effective than the other.

The pattern of students' answers on a multiple choice test followed with interview and two-tier multiple choice test can be classified into the criteria that used by Ariyani (2013) presented in Table 1.

Students' answer patterns which are categorized into misconceptions is a consistent false answer. Consistent false answer must appear on two or more items that contain same concept. If students have any consistent answers only on one item, it can not be classified as a misconception.

RESULTS

Misconceptions in reaction rate that can be identified by multiple-choice test followed with interview and two-tier multiple choice test are presented in Table 2. The data in Table 2 shows that multiple-choice test followed with interview found 19 kinds of misconceptions while two-tier multiple choice test found 8 kinds of misconceptions. Based on these findings it can be seen that the multiple-choice test followed with interview could identify misconceptions more than two-tier multiple choice test.

Misconceptions based on scores of students in scientific reasoning skills which can be identified by multiple choice tests followed with interview and two-tier multiple choice test are presented in Table 3. The data in Table 3 shows that misconceptions majority occur in students who are at concrete level. A little misconceptions found in students who have reached upper formal level.

DISCUSSION

Research results in Table 2 and Table 3 show that multiple-choice test followed with interview is more effective than two-tier multiple choice test for concrete, low formal, and formal upper levels of students. Multiple choice test with interview identify more misconceptions than two-tier multiple choice test since interview able to obtain deeper information about students' understanding. Students also be able to develop their answers and reasons at the time of the interview. Students can express their reason without affected with reasons stated in the paper test as two-tier multiple choice test.

In contrast to the interview, two-tier multiple choice test can not reveal misconceptions completely. In two-tier multiple choice test, students tend to choose answers and the reasons provided. Students tend not to develop their own answers and reasons. Two-tier multiple choice test also give opportunities for students to guess the answer. Students have opportunities to have a correct answer in both of tier by guessing, not based on their understanding. Students' opportunity to guess the answers cause the results of two-tier multiple choice test cannot describe truly students' understanding.

It is often in two-tier multiple choice test, students' answers and reasons are not consistent. Students may choose correct answer but wrong reason or vice-verca. Dhindsa & Treagust (2009) suggest that the use of two-tier multiple choice test may be supported with interview as data triangulation. Taştan, Yalçinkaya, and Boz (2010) states that interview may indi-

Table 1. Criteria of Pattern of Students' Answers on A Multiple Choice Test Followed with Interview and Two-Tier Multiple Choice Test

Answer in Multiple Choice Test/First Tier	Answer in Interview/Second Tier	Criteria
True	The reason is identical with an answer on multiple choice test/first tier	Consistent true
	The reason is not identical with the answer on multiple choice test/first tier	Inconsistent
False	The reason is identical with an answer on multiple choice test/first tier	Consistent false
	The reason is not identical with the answer on multiple choice test/first tier	Inconsistent

Table 2. Misconceptions which Identified by Multiple Choice Test Followed with Interview and Two-Tier Multiple Choice Test

Concepts	Misconceptions	Number of Students Who Have Misconception	
		MC + I	TT
General rate	General reaction rate is reaction rate with respect to reactant/product multiply by its coefficient	3	1
Catalysts	Catalysts increases activation energy, so the reaction rate is increasing	1	3
Rate constant	Unit of rate constant is mol/L.second since rate constant is the change in concentration per unit of time	2	3
Reaction rate	Reaction rate is defined as increasing concentration of reactant or decreasing concentration of product	1	
Surface area	The increase in size of reactant particle will increase surface area, so the reaction rate will increase	1	
Catalysts	Reaction is faster without catalysts	1	
Collision theory	Students could not identify factors that affect reaction rate	2	
Effective collision	All orientation of collision could produce reaction	2	
Effective collision	Effective collision could not be affected by activation energy	2	
Rate constant	Rate constant have no unit	3	
Rate constant	Unit of rate constant is mol/L for all reactions	1	
Concentration	Increasing concentration will decrease reaction rate		1

Table 3. Distribution of Students' Misconceptions Based on Scientific Reasoning Skills

Misconceptions	Number of Students with Scientific Reasoning Skills in Level					
	Concrete		Low formal		Upper formal	
	MC+I	TT	MC+I	TT	MC+I	TT
General reaction rate is reaction rate with respect to reactant/product multiply by reactant's/product's coefficient	1	1	1		1	
Catalysts increases activation energy, so the reaction rate is increasing	1	2		1		
Unit of rate constant is mol/L.s since rate constant is the change in concentration per unit of time	1					3
Reaction rate is defined as increasing of the concentration of reactant or decreasing of the concentration of product	1					
The increase in size of reactant particle will increase surface area, so the reaction rate will increase			1			
Reaction is faster without catalyst	1					
Students could not identify factors that affect reaction rate	2					
All orientation of collision could produce reaction	1		1			
Effective collision could not be affected by activation energy	1		1			
Rate constant have no unit			2		1	
Unit of rate constant is mol/L for all reactions	1					
Increasing concentration will decrease reaction rate		1				

cate the level of understanding of the concept in detail. A similar study conducted by Ariyani (2013). Ariyani found 7 misconceptions that can be identified by multiple choice test followed with interview while two-tier multiple choice test is only able to identify 2 kinds of misconceptions.

This study also revealed that students with concrete level suffering more misconceptions than those in the higher level. This indicated that students in the concrete level tend to have difficulties in studying rate of reaction. They have high potency of misconception compared to those in the higher level. One of misconceptions of students in concrete level is reaction rate is defined as increasing concentration of reactant or decreasing concentration of product.

However, there are some misconceptions that occur in low formal and formal upper level students. Students with low formal and formal upper level allegedly still in a transition phase. Reasoning skills in a transition level are between low and high scientific skills so that students still have difficulty in understanding chemistry that consist of abstract concepts.

CONCLUSION

Multiple choice test with interview more effective than two-tier multiple choice test in identifying misconceptions in reaction rate. Misconceptions that was found are about the concept of the general rate, activation energy, reaction rate constant unit, and factors affect reaction rate. In addition, potency of misconceptions of concrete level students is higher than the low formal and upper formal levels students. The application of this research is identification of misconceptions should use a multiple-choice test followed with interview because the two-tier multiple choice tests are still give students opportunities to guess the answer so detail and depth students' understanding can not be obtained.

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