

## Development of *Two-Tier* Diagnostic Test Pictorial-Based for Identifying High School Students Misconceptions on the Mole Concept

W Siswaningsih, H Firman, Zackiyah and A Khoirunnisa

Department of Chemical Education, Universitas Pendidikan Indonesia, Jl. Dr. Setiabudi No. 229, Bandung 40154, Indonesia  
E mail: wiwi2450@gmail.com

**Abstract.** The aim of this study was to develop the two-tier pictorial-based diagnostic test for identifying student misconceptions on mole concept. The method of this study is used development and validation. The development of the test Obtained through four phases, development of any items, validation, determination key, and application test. Test was developed in the form of pictorial consisting of two tier, the first tier Consist of four possible answers and the second tier Consist of four possible reasons. Based on the results of content validity of 20 items using the CVR (Content Validity Ratio), a number of 18 items declared valid. Based on the results of the reliability test using SPSS, Obtained 17 items with Cronbach's Alpha value of 0.703, the which means that items have accepted. A total of 10 items was conducted to 35 students of senior high school students who have studied the mole concept on one of the high schools in Cimahi. Based on the results of the application test, student misconceptions were identified in each label concept in mole concept with the percentage of misconceptions on the label concept of mole (60.15%), Avogadro's number (34.28%), relative atomic mass (62 , 84%), relative molecule mass (77.08%), molar mass (68.53%), molar volume of gas (57.11%), molarity (71.32%), chemical equation (82.77% ), limiting reactants (91.40%), and molecular formula (77.13%).

### 1. Preliminary

Chemistry became subjects difficult to understand for some students because they contain abstract concepts such as moles, molecules and particles [1]. In fact, there are some subject of chemistry that can be seen, for example, a solution, or demonstrated, for example, the combustion reaction, however, there are some subject of chemistry that can not easily be demonstrated so that students can not see directly, such as atoms and electrons [2]. According to Johnstone, chemistry consists of three levels of representation [3]. Three levels of representation are: (1) the representation of the macroscopic ie representations that describe the bulk properties of the phenomenon and is seen in the daily experience of students, (2) the representation of submicroscopic ie representations that provide explanations on the particulate levels are described as atoms, molecules, or ions , (3) the symbolic representation is the representation that involves the use of chemical symbols, formulas, equations, diagrams, models, and animations [4].

The ability to master the three-level representation makes students have difficulties in understanding chemical concepts. According Nakhlekh explained that one reason for the difficulties that students link the properties of matter at the level of representation used to illustrate and explain the chemical phenomena [5]. Many basic concepts of chemistry involving submikroskopis and symbolic representations are quite difficult to study by students [6].

The results of the study Steiner to the chemistry teacher stated that the concept of the mole is the toughest material as the initial concept in studying chemistry [7]. In this matter, the students do not have the ability to transfer meaning between the macroscopic level with submikroskopis [8]. This



relates to the concept of matter mole pretty abstract so it took a visualization in describing the phenomenon. Mole concept important to learn because as a basis for further study material. The concept of the mole is also important for other chemical concepts more complex such as stoichiometry [9]. Research study on the material concept of the mole has been done by Furio *et al* [8], the results found that students have difficulty in mastering the concept of the mole.

Students tend to build their own concepts in the brain that lead to concepts or visual images that they have become one, so that it can interfere with the ability of students to understand the true concept [10]. The inability of the students to understand the concept is right on the concept of the mole may result in conception is not intact. Incomplete conception can lead to misconceptions. The misconception is defined as the conceptions of different students with the conception of the experts [11]. One cause of the misconceptions that students often do not see the relationship between the three levels of the chemical representation [12].

The diagnostic test multiple-choice *two-tier* can be used in particular to identify misconceptions experienced by students on specific content [4]. Excess use of multiple choice tests *two-tier* compared to interview or a map of concepts such as planning and assessment test is easy to do [13]. A diagnostic test multiple-choice *two-tier* depicted as a diagnostic instrument with *the first tier* on each item consists of questions with answer choices of two to four options. *tier two* of each item containing reasons which refers to the first *tier* [14].

According to Edens and Potter, in presenting scientific concepts visually through images, incorporating text is elaborative process that includes three levels of representation [15]. Context display can become more effective tools and an important tool to be applied to activate the relevant scheme which required students to understand the text [16]. Therefore, the test involved the pictorial form. According Tavassoli *et al*, the pictorial comes from the word "*picture*" which can be defined as everything that is poured in the form of images [16]. Pictorial representations submikroskopis emphasis on problem-solving chemistry [17].

Research on the misconception diagnostic test on the material concept of the mole has been done by Grace (2013, p. 41), but still a test narrative. Questions can be tiring long narrative that students in understanding the crux of the matter in question [18]. According to Hanson, misconceptions students may be examined through pictorial representations [19]. The study focused on mendiaagnostik misconceptions with good reliability and validity have an important role in science education research [20].

Based on the exposure, researchers conducted a study with the title "Development of *Two-Tier* Diagnostic Tests to Identify Miskonsepi pictorial Based High School Students at Material Concept Mol". *Two-tier* diagnostic tests based on the material pictorial concept of the mole hereinafter referred TDMKM.

The purpose of this study is to determine the structure of a test developed in diagnostic tests *two-tier-based* pictorial on the material concept of the mole, produce diagnostic tests *two-tier-based* pictorial in the material concept of the mole who meet the criteria of content validity and reliability, and identify misconceptions students on the material concept mol through *two-tier* diagnostic test developed pictorial-based.

## 2. Method

The method used in this study is based on method development and validation conducted by Adams and Wieman [21]. Development of an activity increases one thing to perform certain steps. Validation is the process of an investigation carried out in describing the items, so that each item can measure what is to be measured [22]. Validation is an important part of evaluation that aims to assess a feasible thing or not according to the criteria tertentu. Penelitian TDMKM development carried out through four stages, namely (1) the development stage items, (2) the validation phase, (3) the stage of determining determination key, and (4) the test phase of development aplikasi. Tahap items carried by adapting and modifying the development stages of *the two-tier* diagnostic test performed by Chandrasegaran *et al* [4] with reference to the proposed Treagust stages [14]. These stages, namely, (1) the determination of the purpose and scope of the test, (2) the prediction data collecting student misconceptions, and (3) development TDMKM items.

In defining the purpose and scope of tests done through a literature review about the material concept of the mole which further developed into the concept map material concept of the mole. In a

concept map consists of a number of labeling concepts used to develop essays. Essay aims to collect data prediction misconceptions experienced by students. Essays given to high school students who have studied the concept of the mole and the material is then compiled in the form of a matrix table misconceptions. Items are developed in the form of a *two-tier* test with each consisting of four possible answers. In the first *tier*, involved *stem* pictorial form. Problem on the first *tier* is based on a literature review of research journal teksdan book. The second *tier* items developed four possible answers with a matrix based on misconceptions obtained from essay. Distractor on the matter which was developed based on identified students' conceptions of the students' answers on the test essay [4].

The validation phase was conducted in order to determine the quality TDMKM instruments are developed in accordance with certain criteria. Phase validation is performed to test the validity of the content. The validity of the content is based on *judgment* or consideration by experts in the field kimia. Hasil *judgment* of the validators on each item on developed, processed using techniques CVR (*Content Validity Ratio*) is expressed by Lawshe [23] by using the formula (1):

$$CVR = \frac{(n-N/2)}{N/2} \quad (1)$$

Information:

CVR = ratio of content validity  
 = Number of validators declared "valid"  
 = Number of validator

CVR acquisition value is then compared with the minimum value of the CVR (Lawshe, 1975, p. 568). Items considered valid in terms of content validity if the value of the CVR is equal to or greater than 0.99 ( $CVR \geq 0.99$ ), whereas if the items have a CVR value less than 0.99 ( $CVR < 0.99$ ), the items were declared invalid.

Items that have been considered and declared valid by the validator, corrected based on the suggestions given validator, and then tested on a number of students who have studied the material concept of the mole. The results of the students' answers acquisition assessed by giving a score of 1 (one) when a student answers correctly on the second *tier*, while a score of 0 (zero) if only one or both *tier* one. This is done to determine reliability. Reliability in this study is used to calculate the Cronbach alpha values. To obtain a Cronbach alpha values, the results of students' answers on each item on processed using SPSS (*Statistical Package for Social Science*) version 20.0. Criteria Cronbach alpha values are presented in Table 1 below [24].

**Table 1.** Criteria cronbach alpha value

Cronbach Alpha Criteria	Classification
$a \geq 0.9$	Very good
$0.8 \leq a < 0.9$	Good
$0.7 \leq a < 0.8$	Be accepted
$0.6 \leq a < 0.7$	Doubtful
$0.5 \leq a < 0.6$	Bad
$a < 0.5$	Not acceptable

Determination key is determined by the pattern of responses the students' answers to each item on. The test was developed in the form of multiple choice diagnostic tests *two-tier* thus obtained 16 possible answers students' response patterns. The pattern of response to the students' answers are presented in Table 2 below.

**Table 2.** Response patterns answer students in each item problem TDMKM.

<i>Tier</i> second The first <i>tier</i>	(1)	(2)	(3)	(4)
a	a (1)	a (2)	a (3)	a (4)
b	b (1)	b (2)	b (3)	b (4)
c	c (1)	c (2)	c (3)	c (4)
d	d (1)	d (2)	d (3)	d (4)

Questions have been declared valid and reliable applied to the students to be identified misconceptions. The students' answers were analyzed based on the predetermined determination key. Revealed misconceptions can be seen from the students' answers on the first *tier* and second *tier*. Answer students are classified into several categories. Here is presented Table 3 on the classification of students' understanding [25].

**Table 3.** Classification of understanding students.

Combination Answers First Tier Second Tier	Classification
True - True	understand the concept
True - False	Misconceptions
False - True	misconceptions
False - False (related)	specific misconceptions
False - False (not related)	Do not understand the concept

Each possible answer students are calculated as a percentage by the formula (2):

$$KNP = \frac{X}{N} \cdot 100\% \quad (2)$$

Information:

KNP = % criteria

X = the number of students who answered

N = the total number of students

### 3. Results and discussion

#### 3.1. Grain development problem

Development of items TDMKM on the first *tier* is based on text books and research journals regarding the material concept of the mole. *Stem* in the first *tier* in the form of pictorial with consisted of four answer options, while the second *tier* in the form of the reasons which refers to the answer to the first *tier* with consisted of four possible answers. The reason the second *tier* is a basic concept in the material concept of the mole. Each *tier* consists of a selection of the correct answer and three distractors. Correct answers obtained from literature review based on the book teksdan research journal. Three distractor on the second *tier* is obtained from answers to students based on predictions of student misconceptions in the material concept of the mole.

#### 3.2. Quality Tests

Items considered valid in terms of content validity if the value of the CVR is equal to or greater than 0.99 ( $CVR \geq 0.99$ ), whereas if the items have a CVR value less than 0.99 ( $CVR < 0.99$ ), the items were declared invalid. A total of 20 items validated, the result is a total of 18 items declared valid by the CVR value is equal to one. After that, each item on revised based on suggestions validator.

A total of 18 items are declared valid, then tested to 34 high school students of class X that has been studying the concept mol. Berdasarkan material calculations, the value alpha Cronbach of 0.659 which is in the range  $0.6 \leq \alpha < 0.7$ . The range is included in the category of "doubtful" that provisions are about to be obtained Cronbach alpha values  $\geq 0.7$  were included in the category of "acceptable". As many as one problem aside, judging by the item total correlation is low, at about fifteen numbers on the concept of limiting reagent, so the Cronbach alpha value becomes 0,703. So the total TDMKM items that have a valid and accepted that as many as 17 items.

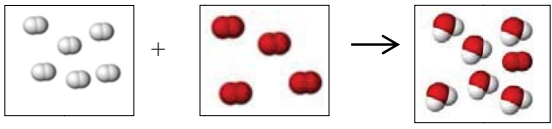
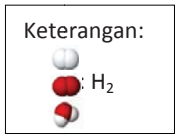
Based on the consideration to reduce errors in identification of misconceptions students' answers on the test results of the application, then the election items. Selection of items is based on the representation of each concept in test and item total correlation on each item on, in order to obtain 10 questions with a Cronbach alpha value of 0.707 which remain in the category of "acceptable".

A total of 10 items that have been declared valid and acceptable to the test content validity and reliability then compiled into a determination key based student response patterns. From this response pattern can be seen in the mindset of the students answered each item on that misconception experienced by students can be identified.

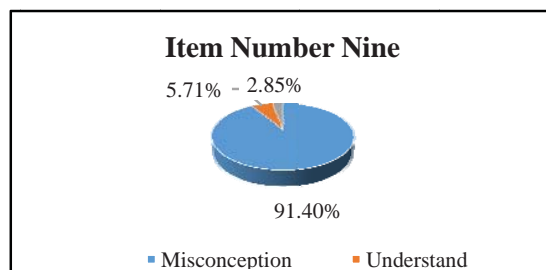
### 3.3. Students misconceptions on limiting reagent material

Items that have been declared good and acceptable validity and reliability were then applied to 35 high school students of class X science in high school who has studied the material concept of the mole. According to Peterson [11], misconceptions considered significant if it is found at least 10% of the total sample of students.

**Table 4.** Answers students at Grain Boundary problem concepts reagents number nine.

Butir Soal Nomor Sembilan	Pola respon	Jumlah Siswa	Persen-tase (%)
Note the following reaction illustration.			
 <p>3 mol                  2 mol</p>	a(1)	9	25,71
	a(4)	2	5,71
	b(1)	5	14,28
	b(3)	12	34,28
	b(4)	5	14,28
	c(1)	1	2,85
	d(4)	1	2,85
<p>Keterangan:</p>  <p>Reactant molecule that acts as a barrier is ....</p> <p>a. H<sub>2</sub> b. O<sub>2</sub> c. H<sub>2</sub>O d. H<sub>2</sub> and O<sub>2</sub></p> <p>The reason is ....</p> <p>(1) reagent is the limiting reagent smallest coefficient (2) the limiting reagent is the mass of the smallest reagent (3) the limiting reagent is a reagent that most small amount molnya (4) limiting reactant is completely reacted first reactant</p>			

A response pattern (1) with a total percentage of 25.71% stated that the molecule that acts as a limiting reagent is H<sub>2</sub> because the limiting reagent is a reagent that most small coefficient. The pattern of response b (1) with a total percentage of 14.28% stated that the molecule that acts as a limiting reagent is O<sub>2</sub> as reactants limiting reagent coefficient is the smallest. The pattern of response b (3) with a total percentage of 34.28% stated that the molecule that acts as a limiting reagent is an O<sub>2</sub> for limiting reagent is the reagent the smallest amount molnya. The pattern of response b (4) with the total percentage of 14.28% stated that the molecule that acts as a limiting reagent is the limiting reagent O<sub>2</sub> as the first reactant is completely reacted. Percentage who have misconceptions response pattern that is equal to 91.40%, to understand the concept as much as 5.71%, while the do not understand the concept as much as 2.85%. From these data, we can see a comparison of three categories of students' understanding shown in Figure 1 below.



**Figure 1.** Percentage of students on item response pattern problem number nine concepts limiting reagent.

Based on the test results of the application, the student misconceptions identified in all the label concept. The misconception that many experienced students on each label concept, namely: the amount of 1 mole of oxygen a different structure, namely  $O_3$  and  $O_2$ , each consisting of one molecule for 1 mol of  $O_2$  and  $O_3$  each contain a number of substances produced from the calculation results in an element or compound (45.71%); one mole of sulfur molecules have a number of particles  $6.02 \times 10^{23}$  for  $6.02 \times 10^{23}$  is a number that becomes the benchmark in calculating the amount of the element / compound (25.71%); relative atomic mass is the atomic mass ratio of the mass of atoms of other elements (34.28%); molar mass is mass divided by the number of moles of these substances (45.71%); molar volume of 1 mole of gas (A) was 22.4 L because it has a number of 22.4 liters of gas at a particular mole, occurs in conditions of  $25^\circ C$  and 1 atm (45.71%); the equation is the reaction of a compound of formula which is formed of two or more atoms (22.85%); the limiting reagent is the number of moles of reagents smallest (34.28%); the molecular formula is the formula compound / molecular multiple of the empirical formula (34.28%).

#### 4. Conclusion

*Two-tier* diagnostic tests based on the material pictorial concept of the mole, hereinafter referred TDMKM developed with *stem* on the first *tier* in the form of pictorial with four possible answers and the second *tier* in the form of reason with four possible answers. Results validation TDMKM 20 items declared valid by as much as 18 about six validator. A total of 18 items tested reliability and alpha values obtained Cronbach 0.659 so that no one items that must be set aside. It improves the Cronbach alpha value becomes 0,703. Based on the test content validity and reliability, as many as 17 items have been categorized as good and acceptable. Misconceptions students identified on the labels on the material concept with the concept of the mole concept of the mole percentage of (60.15%), the Avogadro constant (34.28%), relative atomic mass (62.84%), a period of relative molecular (77.08%), molar mass (68.53%), molar volume of gas (57.11%), molarity (71.32%), equation (82.77%), the limiting reagent (91.40%), the molecular formula (77.13%).

#### 5. References

- [1] Uce M 2009 *ProQuest Education Journals* **129** 683-91
- [2] Taber K S 2009 *Educació Química EduQ* **4** 13-20
- [3] Johnstone A H 2000 *Chemistry Education Research and Practice in Europe* **1** 9-15
- [4] Chandrasegaran A L, Treagust D F and Mocerino M 2007 *Chemistry Education Research and Practice* **8** 293-300
- [5] Nakhleh M B and Krajcik J S 1994 *Journal of Research in Science Teaching* **31** 1077-96
- [6] Ahiakwo M J 2013 *African Journal of Chemical Education* **3** 29-38
- [7] Steiner R P 1986 *Journal of Chemical Education* **62** 1048
- [8] Furio C, Azcona R and Guisasola J 2002 *Chemistry Education Research and Practice in Europe* **3** 277-92
- [9] Staver J R 1993 *Journal of Research in Science Teaching* **30** 321-37
- [10] Modic A L 2011 *Student Misconception-Identifying and Reforming What They Bring to The Table Chemistry* (Bozeman: Tesis, Master of Science, University of Montana)
- [11] Tan K C D, Taber K S, Goh N K and Chia L S 2005 *Chemistry Education Research and Practice* **6** 180-197
- [12] Barke H D, Hazari A and Yitbarek S 2009 *Misconception in Chemistry* (Berlin: Springer)
- [13] Tüysüz C 2009 *Academic Journal* **4** 626-31
- [14] Treagust D 2006 *Journal of Science and Mathematics Education Centre* **23** 1-9
- [15] Edens K M and Potter E F 2001 *Studies in Art Education-Spring* **42** 214-33
- [16] Tavassoli A, Jahandar S and Khodabandehlou M 2013 *Indian Journal of Fundamental and Applied Life Science* **3** 553-65
- [17] Noh T and Scharmann L C 1998 *Journal of Research in Science Teaching* **34** 199-217
- [18] Halakova Z and Proksa M 2007 *Journal of Chemical Education* **84** 172-4
- [19] Hanson R 2015 *International Journal of Innovative Research & Development* **4** 115-22
- [20] Gurel D K 2015 *Eurasia Journal of Mathematics, Science & Technology Education* **11** 989-1008
- [21] Adams W K and Wieman C E 2010 *International Journal of Science Education* **33** 1-24

- [22] Haladyana T M and Rodriguez M C 2013 *Developing and validating test items* [Online] (Newyork: Routledge)
- [23] Lawshe C H 1975 *Personnel Psychology* **28** 563-73
- [24] Gliem J A and Gliem R R 2003 *Midwest Research to Practice Conference in Adult, Continuing, and Community Education (Columbus)* (Indianapolis: ScholarWorks) pp 82-8
- [25] Tarakci M, Hatipoglu S, Tekkaya C and Ozden M Y 1999 *Journal of Education* **15** 84-93