Identification of student’s misconceptions in chemical bonding topic using four-tier diagnostic test

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Abstract. The purpose of this study was to identify misconceptions by measuring the level of students understanding in chemical bonding topic using four-tier multiple choice diagnostic test. The research method was descriptive and involved 77 students of senior high school in South Tangerang. The results shows that the overall the students misconception on chemical bonding topic was in low category (15.14%). The level of confidence in this study was highly significant because it can provide information about student’s conceptual understanding. Students encountered the most misconceptions when determining bonds in microscopic scale. As an evidence, misconceptions in the concept of determining microscopic ionic and covalent bonds results to medium category (41.56%), and metal bonds with medium category (37.66%). This student’s misconception was due to the limited conceptual knowledge and low visual-spatial abilities.

1. Introduction
Misconception is a term used when the ideas of students are not relevant towards the scientific perspectives. Misconceptions could be an inhibitor to the interpretation of knowledge therefore this issue must be addressed [1]. According to Firman, misconceptions could be identified using one test, a standardized test, which uses valid and reliable instruments [2]. Various researches make use of multiple choice diagnostic test in determining the misconceptions of students [3]. Teachers can use the test which consists of items designed primarily to reveal the misconceptions of students. This kind of diagnostic test will help teachers to identify the student’s misconceptions [4].

According to Karataş, Köse & Coştu (2003), one of the multiple choice tests designed to reveal the misconceptions of students is the two-tier diagnostic test. This test is analyzed through the answers of the students on the first-tier on every question as well as the percentage of the reasons that the students give on the first-tier [5]. However, the two-tier diagnostic test is not able to distinguish between students that are less knowledgeable and students that have misconceptions. Therefore, the researcher developed the said test into a three-tier diagnostic test. This test evaluates the level of confidence of the students when giving their answers. [6]. According to KaltakiçGurel, Eryılmaz, dan McDermott (2015) The downside of this three-tier diagnostic test is the imbalance score ratio between students who experience misconceptions and students who are less knowledgeable [7]. The most recent diagnostic test besides the three-tier diagnostic test, would be the four-tier diagnostic test. The format of this test basically reflects the format of the two-tier diagnostic test, however it consists of a scale of self confidence for
students to show how certain they are about their answers to the question that they have given and their reasoning level [8].

Chemistry has been a subject that is difficult to be processed and understood by students due to some of the concepts that cannot be easily shown therefore students cannot directly see it in real life [9]. One of the topics would be chemical bonding that has an abstract concept with no correlation with real life encounters of the students. This is the reason why the topic is really difficult to take in for students [3]. Treagust, Peterson and Patrick [10] did a research on identifying misconceptions on chemical bonding topic using two tier multiple choice diagnostic test instrument. They concluded that misconceptions of students from year 11 to 12 did not show any changes. A diagnostic test to analyze and identify the misconceptions of chemical bonding is a necessity [2]. As diagnostic tests develop through time, Yan and Subramaniam [8] conducted a research using a four-tier multiple choice diagnostic test instrument which was being tested on 137 students. They discovered that nearly 70% if students had alternative concepts on a topic called kinetic reaction. This has proven that the four-tier diagnostic test is more accurate in determining and identifying student’s misconceptions.

The results of previous studies has become a basis for this research which is to identify the misconceptions of grade 10 students on a topic in Chemistry using the four tier multiple choice diagnostic test instrument. The purpose of this research is to identify misconceptions and to measure the level of understanding of students on the topic called chemical bonding.

2. Methods
The method used in this study was descriptive. There are steps in performing this research including analyzing basic competencies and indicator from chemical bonding topic, development of questions and modification validation of two tier multiple choice diagnostic test [11], development into a four tier multiple choice test and then validation judgement that is validation test conducted to determine the content of the chemical bond on four-tier multiple choice diagnostic test done by experts. The validity is calculated using CVR (Content Validity Ratio) and CVI (Content Validity Index). The value of CVR acquisition is compared to the minimum CVR. Items are considered valid if the CVR is equal to or greater than 0.736 because the number of validators is 5. Following with this identification of sub-questions on the validation page using CVR, proceeding with calculating CVI [12]. The field test was performed on 30 students of grade 10 at one of the Islamic high school in South Tangerang. The reliability test was conducted using SPSS version 18. The subject of this research was 77 students of grade 10 at one of the senior high school in South Tangerang. The subject of this research was chosen at random. Moreover, the analysing process on misconceptions about chemical bonding topic was done based on literature such as university Chemistry books and journals. Students were categorized based on their answers on the four-tier multiple choice diagnostic test.

Students are categorized based on the answers given during the four-tier multiple choice diagnostic test [13]. The data processing of this research used an equation as follows:

\[ KTP = \frac{X}{N} \times 100 \% \]  \hspace{1cm} (1)

Notes:
- \( KTP \) = % percentage value criteria
- \( N \) = the total of students who responded
- \( X \) = the total of students who encounter misconception

After the misconceptions has been calculated, determining misconceptions category of the students is next. Misconceptions of the students is categorized into low, medium, and high misconception [14].

3. Result and Discussion
The results of the instrument validation done by experts show that instruments arranged are valid with a CVI value of 0.98 and it falls on a perfect category. The test results of the cronbach alpha on instrument gives a conclusion that the instruments used in this research is reliable. The cronbach alpha test results can be seen on the Table 1.
Table 1. Cronbach alpha test diagnostic four-tier values

| Tier                          | Cronbach alpha |
|-------------------------------|----------------|
| Answer                        | 0.663          |
| Reason                        | 0.610          |
| Answer and Reason             | 0.782          |
| Level of Confidence (answer)  | 0.693          |
| Level of Confidence (reason)  | 0.652          |

Table 1 shows the cronbach alpha test value based on the four tier diagnostic test for every level. As shown below that the reliability value of the cronbach alpha for each and every level satisfy a high reliability category. This was mentioned by Guilford [15] that with the gap between the reliability values $0.66 < r_{11} \leq 0.80$ is considered in a high reliability category. The results of the research show that misconceptions that are encountered by students on the chemical bonding subject is at 15.14% being in a low misconception level. The Table 2 is the misconception identification table.

Tabel 2. Identification of chemical bond misconceptions

| No. | Topic                        | Question Concept                          | Misconception | Number of Students that Responed | Total Percentage | Category        |
|-----|------------------------------|-------------------------------------------|----------------|----------------------------------|------------------|-----------------|
| 1.  | Stability of Element and Octet Rule | Determining atoms and ions that are stable | Only ion F⁻  | 10                               | 1.18%            | Low misconception |
|     |                              |                                           | Only atom O   |                                  |                  |                 |
|     |                              |                                           | Atom O and Na | 4                                |                  |                 |
| 2.  | Lewis Theory in Chemical Bonding | Drawing the lewis dot structure of Nitrogen | N₂, N₂⁻      | 3                                | 12.98%           | Low misconception |
|     |                              |                                           | N₂, N₂⁻       | 5                                |                  |                 |
|     |                              |                                           | N₂, N₂⁻       | 2                                |                  |                 |
| 3.  | Ionic and Covalent Bond      | Representing ionic bonds in molecules     | ClO₃⁻, PCl₃, NaCl | 8                                | 8.76%            | Low misconception |
|     |                              |                                           |               |                                  |                  |                 |
|     |                              | Determining molecule bonds that consist of covalent bonds | Only Cl₂      | 1                                |                  |                 |
|     |                              |                                           | CH₄ and MgO   | 1                                |                  |                 |
|     |                              |                                           | CO₂ and MgO   |                                  |                  |                 |
|     |                              | Determining molecules that consist of single covalent bond | N₂            | -                                |                  |                 |
|     |                              |                                           | CO            | 1                                |                  |                 |
|     |                              |                                           | O₂            |                                  |                  |                 |
|     |                              | Determining molecules that have double covalent bonds | HF and N₂     | 1                                |                  |                 |
|     |                              |                                           | HF and CO₂    | -                                |                  |                 |
|     |                              |                                           | N₂ and CO₂    | 1                                |                  |                 |
|     |                              | Determining molecules that have triple covalent bonds | CO₂           | 1                                |                  |                 |
|     |                              |                                           | H₂O           | 1                                |                  |                 |
|     |                              |                                           | SO₃           | -                                |                  |                 |
|     |                              | Determining coordination of covalent bond coordination from: | Number 1      | 5                                |                  |                 |
|     |                              |                                           | Number 3      | 2                                |                  |                 |
|     |                              |                                           | Number 4      | 1                                |                  |                 |
Table 2 shows the identification misconceptions from students who experience misconceptions on the topic of chemical bonds. On the topic of elemental stability and octet rules, students who experience misconceptions appear to have incorrectly applied the principle of octet rules and have not understood the duplet rules. It can be seen from the reasons they gave to tier 3. Treagust, Peterson, & Patrick (1986) also revealed that misconceptions in element stability and octet rules are caused by students misinterpreting octet rules so students have their own views [10].

| No. | Topic                                      | Question Concept                                      | Misconception Answer | Number of Students that Responed | Total Percentage | Category       |
|-----|--------------------------------------------|-------------------------------------------------------|-----------------------|----------------------------------|------------------|----------------|
| 1.  | Determining the polarity in the HF molecule | F:F                                                   | 2                     | 5                                |                  |                |
|     |                                            | H:F                                                   | 2                     |                                  |                  |                |
| 2.  | Determining molecules that have non polar covalent bonds | F₂ and HF                                              | 6                     |                                  |                  |                |
|     |                                            | Only HF                                               | 5                     |                                  |                  |                |
|     |                                            | Only Na₂                                              | 4                     |                                  |                  |                |
| 4.  | Metallic bond                              | Representing submicroscopic bonds in stainless steel  | 13                    | 37.66%                           | Medium misconception |
|     |                                            |                                                        | 10                    |                                  |                  |                |
| 5.  | Ionic and Covalent Bond in a molecule      | Determining the molecular structure of NaCl crystal  | 25                    | 41.56%                           | Medium misconception |
|     |                                            |                                                        | 5                     |                                  |                  |                |
| 6.  | Molecular Geometry Using VSEPR             | Determining the number of electron pairs and free electron pairs of ClF₃ | 2 and 3               | 5                                | 13.64%           | Low misconception |
|     |                                            |                                                        | 4 and 0               | 4                                |                  |                |
|     |                                            |                                                        | 4 and 1               | 4                                |                  |                |
| 7.  | Interaction particles (atoms, ions, and molecules) and the correlation with their physical characteristic | Determining the shape of molecules using VSEPR from N and Cl Linear | 5                    |                                  |                  |                |
|     |                                            |                                                        | Pyramidal trigonal   |                                  |                  |                |
|     |                                            |                                                        | Tetrahedral          |                                  |                  |                |
|     |                                            | Determining molecules conduct electricity when in the state of a solvent or molten NaCl and Logam Ag | 1                    | 9.09%                            | Low misconception |
|     |                                            |                                                        | NaCl and CH₄         |                                  |                  |                |
|     |                                            |                                                        | CH₄ and Logam Ag      |                                  |                  |                |
On the Lewis theory topic, judging from the reason that students choose in the answer of tier 3, students who experience misconceptions on Lewis topics was due to the misinterpreting writing method of the physical structure in an element. Students also misunderstand the concept of valence electrons. Most students argue that atomic numbers are equal to valence electrons.

On the topic of ionic and covalent bonds, judging from the analysis of the reasons they gave for the answers they chose, students who experienced misconceptions incorrectly applied the principle of ionic and covalent bonding to the answers they gave. Some students make a mistake in answering questions, but they are sure of the answers they choose. The misconceptions they experienced regarding ionic and covalent bonds, influenced the subsequent concepts so that in the concept of single, multiple, coordinating, polar and nonpolar covalent bonds students also experienced misconceptions. Ozmen (2004) states that the knowledge built by an individual is influenced by prior knowledge and learning experience [9].

On the topic of metal bonds and also ionic and covalent bonds in the form of compound molecules, students cannot represent bonds at the molecular (submicroscopic) level because they are abstract. Students cannot relate sensory information to what they observe because of limited conceptual knowledge and low spatial visual abilities. This was also revealed in Chandrasegaran's research, students often make their own interpretations of a concept because they cannot link sensory information to what they see because of abstract concepts. This happens because the teacher does not relate the three aspects of representation (conceptual, visual, spatial) in classroom learning [3].

On the topic of molecular shape using VSEPR theory, judging from the answers and reasons given, students experience incomplete/incorrect reasoning so students make their own interpretations to solve a problem. Students know about the VSEPR theory but because of incomplete reasoning / wrong students, students cannot solve the problems given by the teacher.

On the topic of interactions between particles and their relation to the physical properties of substances, from the reasons students give to the answers they choose, concepts that are embedded in student thinking are incomplete, so that when students are assigned to solve a problem related to the topic of interaction between particles and connecting with the nature of the substance students cannot relate to students' low conceptual knowledge. This happens because the teacher does not relate the three aspects of representation (conceptual, visual, spatial) in classroom learning [3].

On the topic of molecular shape using VSEPR theory, judging from the answers and reasons given, students experience incomplete/incorrect reasoning so students make their own interpretations to solve a problem. Students know about the VSEPR theory but because of incomplete reasoning / wrong students, students cannot solve the problems given by the teacher.

Figure 1 is an example of analyzing student answers to a four-tier multiple choice diagnostic test. Analysis of answers is very helpful for researchers in identifying misconceptions.

| Item Number 1 | Response Pattern | The Number of Student | Percentage |
|---------------|-----------------|----------------------|------------|
|               | A(2), B(3)    | 5                    | 6.19%      |
|               | A(2), C(3)    | 3                    | 3.80%      |
|               | A(2), D(3)    | 2                    | 2.59%      |
|               | A(2), E(3)    | 5                    | 6.49%      |
|               | A(2), F(3)    | 2                    | 2.59%      |
|               | A(2), G(3)    | 10                   | 12.09%     |
|               | A(2), H(3)    | 15                   | 19.04%     |
|               | A(2), I(3)    | 9                    | 11.68%     |
|               | A(2), J(3)    | 5                    | 6.49%      |
|               | A(2), K(3)    | 3                    | 3.83%      |
|               | A(2), L(3)    | 2                    | 2.59%      |
|               | A(2), M(3)    | 4                    | 5.19%      |
|               | A(2), N(3)    | 1                    | 1.26%      |
|               | A(2), O(3)    | 6                    | 7.79%      |

The reason is that stable atoms have...

- Electron configurations are similar to noble gas electron configurations
- Valence electrons are the same as noble gases
- Stable atoms have eight electrons
- Stable atoms have balanced numbers of electrons and protons

2. Level of confidence for your answer:

| Level of confidence | Not sure | Sure |
|---------------------|---------|------|
| 1                   | 2       | 3    |
| 4                   | 5       | 6    |

Note: red writing answers is to misconceptions
V: sure
T: not sure

Figure 1. Example analysis of student answer
4. Conclusion
Based on the results of the study it can be concluded that the student’s misconceptions on chemical bonding topic are still classified as low misconceptions with a percentage of 15.14%. The most common misconceptions are in the concept of metal bonding with a percentage of 37.66% (medium misconception category) and the misconception of the concept of ionic and covalent bonds in the form of microscopic molecular compounds with a percentage 41.56% (medium misconception category).

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