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SECONDARY SCHOOL STUDENTS' PERSPECTIVE MODELS ON ATOMIC STRUCTURE AND CHEMICAL BONDING

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Abstract

This study analyzed concepts of atomic structure and chemical bonding in the perspectives of secondary school students. The analysis focused on the level of academic ability and grade level. Data were taken through clinical interview technique using picture cards. Interviews were conducted toward nine students, consisting of three participants in 10th, 11th, and 12th grade. The participants were determined through stratified random sampling technique. The data obtained were analyzed qualitatively and grouped into the perspective model type of the students. The results showed that there are three types of perspective models. Each type provides a distinctive character in accordance to the concept. Students of high academic category and class level of students tend to have a category of perspective models that fit to their scientific concepts. Academic ability and class level also affected the perspective model of students. The present results showed that classroom learning has an influence on students' perspective.

Keywords: Atomic structure, Chemical bonding, Perspective models, Sub-microscopic.

1. Introduction

Chemical learning is essential as a process to improve understanding of chemical concepts. Chemical learning involves three types of chemical representations, which are macroscopic, sub-microscopic, and symbolic representations [1]. Students are required to illustrate the three levels of representation. Students' ability to reconstruct their learning outcomes can help students to master the concept in its entirety. The abundance of abstract concepts in chemical causes the difficulty of conveying conceptual materials in the chemical learning process. There is a need for continuous learning to develop students' perspective models and improve the ability to link to three levels of representation [2].

A perspective model gives ideas in the mind of an individual, which are used to describe and explain a concept, an object, and a phenomenon. The perspective model is constructed on the perception, the imagination or the comprehension of a discourse [3]. A student will obtain knowledge of the scientific perspective model when studying science [4, 5]. Perspective models will awaken by themselves as they learn and understand scientific knowledge through the learning process [2]. The results of the learning process will be yielded in a conceptual understanding of the students. For example, in the learning of chemistry, student conception can be seen from the student representation ability about the concepts [6, 7].

The learning process influences the student's representation of a concept [8]. The ability of this representation will construct a students' perspective model. The student's representation of concepts is a form of the students' perspective model [9]. Perspective model can be described as a conceptual model, including perspective representation, perspective description, perspective processes, an unobservable construction, and personal cognitive representation [10]. Identification of concepts is done to analyze and understand the concepts that are somewhat difficult to understand by students.

One of the difficult subjects in chemistry is atomic structure and chemical bonding. The students' perspective models of the subject are important parts of learning chemistry in secondary school. Both materials contain the basic concepts needed in the study of further chemistry concepts. The material in the topic of atomic structure and chemical bonding contain abstract concepts that require understanding of representation. Atomic structure and chemical bonding are prerequisite concepts important to be studied in the development of chemical learning process [11].

Several studies have investigated students' perspective models on atomic topics. The concepts of 'probability' and 'energy quantization' were found to be predictors for describing the structure to understand students' need for learning atomic structure [12]. Study on students' perspective models of atoms and molecules reveals that students can make models in both discrete and concrete ways [13]. Detailed investigation on student perspective model related to macroscopic, sub macroscopic and symbolic representation has not been conducted. Thus, it is necessary to explore the students' perspective model through the relationship of macroscopic, sub macroscopic and symbolic representation using descriptive method. Descriptive research method allows researchers to detailed explored attributes of certain phenomenon or situation based on observational ways [14].

The purpose of this study was to evaluate the students' understanding of atomic structure and chemical bonding and concept related to accessing their perspective models. Further, it is interesting for understanding the perspective model profiles through relationships between representational levels [15, 16].

2. Methods

Participants of this study were 71 students in science program at one of high schools in West Java, Indonesia. The students consisted of 31 students of grade X (S_{X-1}, S_{X-2}, S_{X-3}), 18 students of grade XI (S_{XI-4}, S_{XI-5}, S_{XI-6}), and 23 students of grade XII (S_{XII-7}, S_{XII-8} and S_{XI-9}). We classified students into three categories (Group A: Students with high academic ability (S_{X-1}, S_{XI-4}, S_{XII-7}); Group B: Students with moderate academic ability (S_{X-2}, S_{XI-5}, S_{XII-8}); Group C: Students with low academic ability (S_{X-3}, S_{XI-6}, S_{XII-9}) based on the results of daily test of chemistry for grade X, XI and XII. The grouping of students was based on the daily test results of chemistry lessons. This daily test result provides accurate information about the level of academic ability and individual student abilities. Test results were processed for making manual grouping of students. High, medium, and low academic groups were based on the results of the value processing, which were used as references in determining the participants to be interviewed.

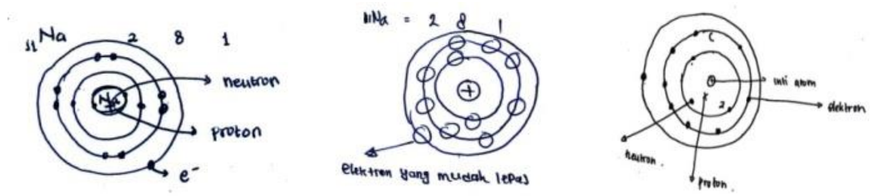
The participant's selection for the interview was conducted through random stratified random sampling technique resulting nine students to be interviewed. The data was taken qualitatively through clinical interview technique using picture card for nine students (five males and four female students). The process of data retrieval was done through recording of conversation, small note and drawings made by students. Research data were analyzed and grouped according to student's answer. The perspective model grouping type was based on the category of students' perspective models, including.

- Type 1: students' perspective models intact and able to express concept representation according to scientific concept.
- Type 2: Partial students' perspective models and able to express some representation of concept that fit with scientific concept.
- Type 3: Partial students' perspective models and able to express concept representation but not in accordance with scientific concept.

3. Findings and Discussion

3.1. Students' perspective models of atomic structure

The results showed that the students can explain the meaning of atomic structure verbally. All participants answered the researchers' questions about atomic structure with almost identical answers. In general, students understand the atomic structure as "the smallest particle". Some students answered the definition of atomic structure as "the smallest particle, is abstract and cannot be seen directly with the eye (S_{XI-6})". Further, when students were asked to describe the electronic structure of sodium atom (Na), including the configuration of electron, the position of electron in atom, atomic nucleus, and the position of proton and neutron in the nucleus of atom, the result of the image given by the student shows three types of representation (see Fig. 1).



Type 1(S_{XI-5}) **Type 2(S_{X-2})** **Type 3 (S_{XI-6})**

Fig. 1. Type of students' perspective models of sodium atom.

Based on Fig. 1, type 1 (S_{XI-5}, S_{XII-8}, S_{XII-9}) described the atomic structure completely. The atomic model refers to the Bohr atom model, showing the completeness of the concept. Students can correctly describe electron configuration on each orbital and show the position of electron, proton and neutron correctly. In type 2 (S_{X-2}), students are able to determine the correct electron configuration, the number of orbitals correctly and the core position correctly. Students have difficulty in determining the position of proton and neutron. For the representation of type 3 atom, the students are able to make electron configuration. They determine the atomic nucleus and the position of the proton. Students in type 3 have a perception that neutron is positioned between the core with the first shell (K) that is conceptually in appropriate.

To clarify the students' perspective model of the atomic reactivity, the investigation was conducted by interview based on valence electron. Different answers have been given by some students. According to the students, valence electrons easily escape because of several factors:

- S_{X-1}: The valence electron is in the outermost layer of orbital and no other electron is blocking, so easily separated.
- S_{X-3}, S_{XI-5}, S_{XII-8}: The valence electron is the outermost, largest fingers, the tensile force is weakened so that the electron is more easily separated.
- S_{XII-9}: The farther from the core electron binding energy diminishes, so the more easily separated.

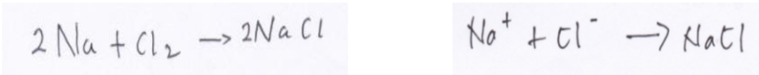
The above answers showed that the students have different perceptions about the outer electron. Students connect with the absence of obstacle, the position of electron, the radius of the atom and the energy of the nucleus to the electron.

3.2. The students' perspective models of ionic bonding

The concept of ionic bonding involves the process of handling electron and electrostatic forces between ions. Students are able to answer verbally the meaning of ionic bonding. Almost all students replied that ionic bonding is "bonding between metal atom and non-metallic atom". Only two students (S_{X-2} and S_{XII-7}) answered that ionic bonding is "bonding that occurs between positive and negative ions." We asked for an example of the reaction of NaCl formation. Students response to NaCl formation reactions result (R2 are resulted instead of result) in two types of perspective models, which is shown in Fig. 2.

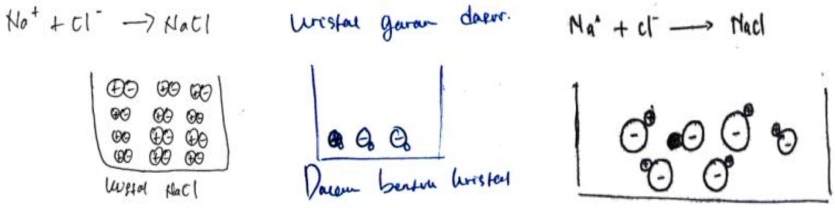
Based on Fig. 2, there are two types of perspective models. Type 1 (SX-3) is students that are able to give correct answer about the reaction process between sodium and chlorine gas. Other types (S_{X-1}, S_{X-2}, S_{XI-4}, S_{XI-5}, S_{XI-6}, S_{XII-7}, S_{XII-8}, and

S_{XII-9}) were missing about one step of reaction, namely the sodium ionization process. The students assumed that the reaction was between sodium and chlorine ion. To understand deeper perception of the students about the bonding in NaCl, students are required to describe the NaCl crystal. There are three types of students' representation. The three types of representations can be seen in Fig. 3.



Type 1 (S_{X-3}) **Type 2 (S_{X-1}, S_{X-2}, S_{XI-4}, S_{XI-5}, S_{XI-6}, S_{XII-7}, S_{XII-8}dan S_{XII-9})**

Fig. 2. The students' perspective models of the reaction NaCl formation.



Type 1(S_{XI-4}) **Type 2(S_{XI-6})** **Type 3(S_{XII-9})**

Fig. 3. The students' perspective models of the bonding between the Na^+ and Cl^- in NaCl crystal.

Based on Fig. 3, there are three types of students' perspective models on NaCl crystal. Type 1 is illustrated by students (S_{X-4}) depicting the NaCl crystal to be arranged and bonded between positive and negative ions. Each crystal is described to have a different distance between the NaCl constituent ions. These images show that students' representation of crystal bonding and lattices. Type 2 describes NaCl crystals with positive ion (Na^+) that is smaller than negative ion (Cl^-). Each NaCl crystals are far apart and arranged in the same direction. For type 3 (S_{XII-9}), the NaCl crystals were represented by two positive ions with spherical form and negative ion with random and irregular arrangement. The three types of NaCl crystal representation that were presented by students are almost similar. First, the students represent the ion properly for both sodium and chlorine ion. The difference lied in the size of the spherical ion that attack the magnitude of the atomic finger and the arrangement of NaCl crystal. Students have not been able to connect between ionic bonding and the interaction between NaCl crystals. Students also were not able to explain the interaction and crystal orientation.

To find out the students' representation of the interaction between Na^+ and Cl^- ions in the solvent (water), the students were interviewed to describe molecular structure of the NaCl solution. The results are shown in Fig. 4.

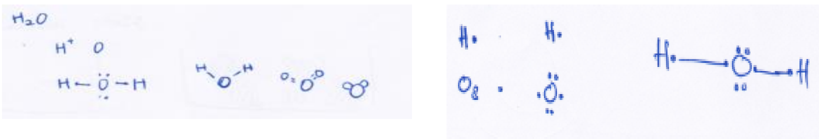
In type 1, the students represent sodium ions attacked oxygen atom from water molecules and chlorine ions connected to hydrogen atoms from water molecules. Type 2 students represented that sodium and chlorine ions were trapped in the water molecules, but the two ions joined to the hydrogen atoms of the water molecules. For type 3, NaCl crystals seemed to have no interaction in water molecules. Thus, they did neither dissolve nor interact. Based on the three types of perspective models, type 1 is most closely related to the correct concept. The positive ions were trapped by the oxygen from the negative component in water molecules. The negative ions (Cl^-) were trapped in water molecules, attached to positively charge atomic hydrogen. Type 2 students explained that sodium and chlorine ions were trapped in water molecules. However, they did not explain the tensile attraction of the ions in the solution with the solvent. In type 3, students did not understand the concept of ionic bonding. They described the NaCl crystals that did not undergo ionization in the solution.

Type 1 (S_{X-2}) **Type 2 (S_{XI-6})** **Type 3(S_{XII-7})**

Fig. 4. The students' perspective models of the bonding between Na^+ and Cl^- ions in water molecules.

3.3. The Students' perspective models of covalent bonding

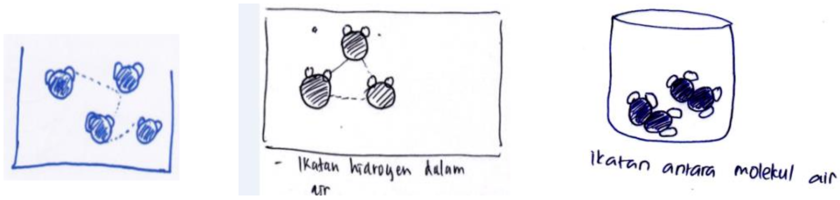
A covalent bonding is a bonding involving the use of joint electron pairs. The bonding takes place between the non-metallic atoms. Students are asked to explain the notion of covalent bonding and give examples of covalent bonding processes in water molecules using the Lewis structure. From nine students, all gave almost the same answer verbally. Students generally understood the definition of covalent bonding as "bonding between non-metals and non-metals involving joint use of electron pairs". The students' answers are shown in Fig. 5.



Type 1 (S_{XI-5}) **Type 2 (S_{X-2})**

Fig. 5. A students' perspective models of covalent bonding and the shape of water molecules.

Based on Fig. 5, the students' perspective models of covalent bonding are divided into two types. Type 1 (S_{XI-5}) students were able to describe Lewis structure, the direction of the correct molecular space and make representation of water molecules with two different magnified spheres. Both spheres have already shown the shape of water molecular space with V form. In-depth answer is given by the students. In short, the molecular form V is due to "the presence of two pairs of bonding electrons and two free electron pairs that free rejection". Students with type 2 were able to describe the Lewis structure. However, they did not explain the representation of the molecular space. In the next stage, students are asked to describe the water shape molecule and bonding between molecules in water. Students described hydrogen bonding with three types (see Fig. 6).



Type 1 (S_{X-2}) Type 2(S_{XI-6}) Type 3 (S_{XII-7})

Fig. 6. A students' perspective models of hydrogen bonding between water molecules.

There are three types of student representations about hydrogen bonding. Type 1 (S_{X-2}) showed some criteria that fit the scientific concept. Students were able to clearly illustrate the water molecule with three unified circles representing 2 hydrogen atoms (H) and 1 oxygen atom (O). The hydrogen bonding was represented by a dotted line between the oxygen atom and the hydrogen atom of different molecules. In type 2 (S_{XI-6}), students were able to describe the shape of water molecules, represented by two small spheres representing a hydrogen atom and a larger sphere representing an oxygen atom. The shape of the molecular space has been correctly indicated (V-formed molecule). But, they were still doubt in determining the hydrogen bonding. Students still provided dashed lines between oxygen and oxygen atom from different water molecules. Further questions were given to the students, including the reason for a bonding between oxygen atoms in water molecules. Students gave the reason that the bonding occur because of "the presence of free electron pairs in oxygen which will cause the attraction between oxygen atoms". Type 3 (S_{XII-7}) showed representation of the bonding between molecules actually that occurred between two oxygen atoms with different molecules. The participants SXII-8 stated "between water molecules all bonded together, then oxygen atom with other oxygen have free electrons will bind each other".

The results indicated that students generally had different perspective models in each concept. But, they have similar thinking about resembled. Their concepts were also influenced by the ability to understand molecule and atom relationship [16]. In particular, they understand the degree of sub-microscopic representation and are able to integrate to further level [10, 17, 18]. In some cases, the results showed that the level of students was not so influential on the students' perspective model. In contrast, higher academic ability of students showed a perspective model that is closer to the main target perspective model and is able to provide a more complete sub-microscopic representation than students of low and middle academic levels. Higher class students are able to provide more complete perspective model than the lower classes, so this class distinction has produced a varied perspective model for the concept of atomic structure and chemical bonding [15].

The main reason for some misunderstanding on the sub-microscopic and symbolic levels is because students did not understand concepts at both levels [16]. Russell et al. [19] and Treagust et al. [20] argued that in order to understand the concept of chemical, students must be able to represent their perspective models at the three levels of Johnstone's ideas [16]. Then, they can further relate these to further levels.

Some students showed that they are very dependent on the learning outcomes as they receive in the classroom. These findings suggested that the classroom learning has an influence on students' perspective models. To improve students' understanding, we also recommend that teachers attempt to use concrete models as suggested by Wu et al. [18]. In the classroom, teachers are still the source of knowledge. Students obtained an advantage by generating their own understanding. We believed that this is because the level of comprehension in chemical teacher concepts. The selection of appropriate model for teaching and learning, especially in visual representation, is also required [21]. Indeed, teacher weaknesses and misunderstanding can contribute the result of students' perspective model [22].

4. Conclusions

The students' perspective models about atomic structure and chemical bonding are influenced by student's academic ability and grade level. The perspective model is also influenced by the student's learning process in the classroom. Students with high academic ability have more complete understanding. Students with higher grade level also tend to represent better concept than that with the lower class. The implications of this research shows that the learning process in the classroom influences the students' perspective model. Teachers are required to use appropriate media and teaching materials to support the mastery of concepts through chemical representation.

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