Diagnosing Students’ conception on atomic structure using open ended questions

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Abstract. This study aims to diagnose students’ conception on atomic structure concepts using open ended questions. For this reason, a 7 items of assay test was administered to 135 senior high school students from different schools in West Sumatera. The data were collected using an open ended test which is covering the concept used in the topic Atomic Structure. The open ended test of students’ conceptual was developed to identify the alternative conceptions that student might have regarding the concepts in Atomic Structure, to measure the level of students’ conceptions, and the way of students’ thinking concerning the concepts. The results showed that students find difficulties about some concepts of Atomic structure such as atom, atomic model, electron configuration, period and group. The result of this study illuminated the concepts to be underlined in developing teaching and learning approach concerning the topic of Atomic Structure.

1. Introduction
Learning material in teaching learning is one of some factors that influence the students’ understanding of chemistry concepts and can help student in learning. Materials should achieve impact which is mean the materials have a noticeable effect on learners that is when the learners’ curiosity, interest, and attention are attracted [1]. In order to produce a good teaching and learning material, the preliminary research is done through the analysis of context, concepts, students and task [2]. The focus of this study are the concepts analysis and students analysis which means diagnose the students’ conception and the misconception to particular concepts as a consideration how to shows concepts in teaching and learning material. Rosser in Sagala [3] states that concept is an abstraction has one objects, events, activities, or connection of same attributes. They are derived from facts, events, experiences through generalizations and abstract thinking. The purpose of the concept is to explain and predict. It shows a simple connection as the basis of human predictions or answers for fundamental questions about why a phenomenon occurs. Concepts can be organized into coherent patterns. Furthermore, concepts can be used to get conclusions on situations when we lack of direct experience. It can also construct a person mental by applying prior knowledge to new situations [4].

Once the process in applying prior knowledge to new situations is broke by certain factors, the misconception will formed. Eryılmaz & Sürmeli stated that misconceptions are not mistakes or ignorance of knowledge. However, misconceptions are an understanding of concepts acquired because of false learning or incomplete learning but. If students are misconceptions, their conceptions are imprecise or incomplete but they assume that their conceptions are true [5]. The statement indicates that a concept is called misconception if it is interpreted inappropriately or incompletely. It means the
conception of students still interpretate the characteristics or attributes of the concept but it is not according to scientific conception or expert’s concept. This opinion is supported by Novak and Gowin which states that misconception is an interpretation of concepts in an unacceptable statement [6].

The previous research found that there are some misconception of SMA Adabiah students on atomic structure such as Dalton, Thompson and Bohr atomic concepts, Rutherford, Bohr and quantum mechanical atomic model, and electron configuration of ion [7]. Therefore, students’ understanding about these concepts was diagnose in larger population to found data which is represents all schools in Padang City, West Sumatera Indonesia.

2. Methods
This study was preliminary research of Research and Development focusing to analysis the students’ conception of atomic structure as the consideration to design teaching and learning material in the topic atomic structure. the instrument used to collect data is open ended questions which is define as the questions which enable student to answer in multianswer and require student to think deeper when give respons [Error! Bookmark not defined.]. It aims to identify how the student make an answer of a problem, not to mark their answer. It gave to 135 students who come from six different schools in Padang West Sumatra, they are SMA Pembangunan Labor UNP, SMAN 12 Padang, SMAN 5 Padang, SMAN 3 Padang, SMAN 4 Padang, and SMAN 7 Padang. The six schools represent every level of school that choose based on the result of latest national examination.

The conceptions of student were known by given them 7 open ended questions and analyze it based on the level of student answer of each questions. The questions and the answer level are shown as follow.

2.1. Question 1
Mention the definition of atom based on Dalton, Thompson, Rutherford, Bohr, and wave mechanic theory! (C1)
Level 0 = don’t know, false and misconception
Level 1 = mention Atom based on the Dalton atomic theory
Level 2 = mention Atom based on the Thompson atomic theory
Level 3 = mention Atom based on the Rutherford atomic theory
Level 4 = mention Atom based the Bohr atomic theory
Level 5 = mention Atom based on quantum mechanical atomic theory

2.2. Question 2
Draw the atomic model of Dalton, Thompson, Rutherford, Bohr and quantum mechanical atomic based on the definition of each theory! (C2)
Level 0 = don’t know, false and misconception
Level 1 = draw Dalton atomic model as circle/ ball
Level 2 = draw Thompson atomic model as the positively charge ball and the negatively charge were embedded inside.
Level 3 = draw the Rutherford atomic model which consist of positively charge nucleus and surrounded by negatively charge/ electron in the same energy level.
Level 4 = draw Bohr atomic model which proton and neutron as nucleus and surrounded by negatively charge/ electron in certain energy level.
Level 5 = draw the quantum mechanical atomic atomic model which proton and neutron as the nucleus and electrons in the orbital

2.3. Question 3
Write the sub particles of atom! (C1)
Level 0 = don’t know, false and misconception
Level 1 = positively charges, negatively charges and no charges particles
2.4. Question 4
Write the electron configuration of Carbon atom \(_{6}^{12}C\) based on electron configuration of Bohr atomic theory and quantum mechanical atomic theory! (C3)
Level 0 = don’t know, false and misconception
Level 1 = electron configuration based on bohr atomic theory
Level 2 = electron configuration based on wave mechanic atomic theory

2.5. Question 5
Li atom has atomic notation as \(^7\text{Li}^\). Draw the atomic model of this atom based on bohr atomic theory and wave mechanic atomic theory! (C3)
Level 0 = don’t know, false and misconception
Level 1 = student draw Li atomic model based on bohr atomic theory
Level 2 = student draw Li atomic model based on quantum mechanical atomic theory

2.6. Question 6
Na atom has 11 protons, 11 electrons and 12 neutrons. Write electron configuration of Na\(^+\) ion! (C4)
Level 0 = don’t know, false and misconception
Level 1 = student write electron configuration of Na\(^+\) ion based on bohr atomic theory
Level 2 = student write electron configuration of Na\(^+\) ion based on quantum mechanical atomic theory

2.7. Question 7
Some atomic notations are given as follow:
\(7\text{K, } 11\text{L, } 15\text{M, } 35\text{N, dan } 18\text{P}\)
Determine the atoms that place in the same group and period! (C4)
Level 0 = don’t know, false and misconception
Level 1 = student analyze the questions using bohr atomic theory
Level 2 = student analyze the questions using quantum mechanical atomic theory

The analysis of open ended questions was done by classify the student answer according the answer level. In addition, misconception of student of each concepts was also identified by analyze the uncorrect answers

3. Results and Discussion
The student answers classified based on answer level of instrument and uncorrect answer of students analyzed to identify their misconception. The results are shown in the Figure 1.

![Figure 1. Students’ Conception on Atomic Structure Concepts](image-url)
Based on the bar chart, knowing that most of students understand about the particles of atom consist of neutron (non charge) and proton (positively charge) called as nucleus and also consist of electrons (negatively charge). Student have scientific concepts or also called as target concepts which means the concept that stated by scientist that is the target of learning.

However, The data show students’ conception about concept of atom based on the 1st open ended question that 1.5 % didn’t understand about any concept of atom. Most of students understand concept of atom based on Dalton atomic theory. They know the atom is the smallest or the tiny particles of matter [Error! Bookmark not defined.] but some of them know the atom of dalton as the analogy of massive tiny ball, not as a concept of atom. Atom based on thompson atomic theory were written by 28% students as the particle that consist of diffuse cloud positively charge with negativel electron embadded randomly in it [Error! Bookmark not defined.] but many others understand atom of thompson as plump pudding. The concept of atom based on Rutherford atomic theory answer correctly by 21% of students there are several students answer it as planetary model. The misconception number 1,2 and 3 that show in the table 1 isn’t the real misconception but many student conception of atom as the analogy. The analogy was found in many Chemistry book for SMA and text book of [Error! Bookmark not defined.] and [Error! Bookmark not defined.] which shows atom of Thompson as plump pudding. So does with planetary model is also shown in some text book of chemistry that show atom rutherford like solar system which nucleus as the solar and one electrons in each trajectory move around the nucleus like planets. Unfortunally less than quarter of student understand concept of atom based on Bohr atomic theory and wave mechanic atomic theory. It means most of students didn’t comprehend the concepts that they must master although they studied it before.

Table 1. Students’ Misconceptions on Atomic Structure Concepts

| No | Misconception | Percentage of student (%) |
|----|---------------|--------------------------|
| 1  | The students said that atom of dalton as ball (analogy) | 22.2 |
| 2  | The students said that atom of thompson as pullm pudding (analogy) | 47.4 |
| 3  | The students said that atom of rutherford as solar system (analogy) | 1.48 |
| 4  | Rutherford atomic model : the students draw the electron in trajectory but didn’t draw the nucleus | 6.6 |
| 5  | Rutherford atomic model : the students draw the trajectory but didn’t draw the nucleus and electrons | 13.3 |
| 6  | Rutherford atomic model : the students draw inappropriate size of nucleus and electrons | 0.74 |
| 7  | Rutherford atomic model : the students draw nucleus and trajectory but didn’t draw electrons | 13.3 |
| 8  | Bohr atomic model : the students draw the energy level and electrons but didn’t draw the nucleus | 7.4 |
| 9  | Bohr atomic model: the students draw the nucleus and energy level but didn’t draw the electrons | 11.85 |
| 10 | Bohr atomic model : the students only draw energy level but didn’t draw electrons and nucleus | 3.7 |
| 11 | Bohr atomic model: the students draw more than 2 electrons in first energy level | 6.67 |
| 12 | Bohr atomic model: the students draw less than 2 electrons in first energy level then draw the electrons in the next energy level | 14.8 |
| 13 | Bohr atomic model: the students draw less than 8 electrons in second energy level then draw the electrons in the next energy level | 35.56 |
| 14 | Bohr atomic model: the students draw inappropriate size of nucleus and electrons | 6.67 |
| 15 | Bohr atomic model of Li atom : the students draw the shell and electron | 7.4 |
| No | Misconception                                                                                                                                  | Percentage of student (%) |
|----|-----------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|
| 16 | Bohr atomic model of Li atom: the students draw nucleus and 2 electrons in the first shell but didn’t draw 1 electron in the second shell | 3.70                      |
| 17 | Bohr atomic model of Li atom: the students draw less than 2 electrons in the first shell then draw the electron in the second shell           |                           |
| 18 | The student didn’t release 1 electron from the third shell for the electron configuration of Na\(^+\) based on Bohr atomic theory         | 10.3                      |
| 19 | The student add an electron in the third shell for the electron configuration of Na\(^+\) based on Bohr atomic theory                     | 0.74                      |
| 20 | The student didn’t release 1 electron in the 3s orbital for the electron configuration of Na\(^+\) based on wave mechanical atomic theory | 5.18                      |
| 21 | The student add an electron in the 3s orbital for the electron configuration of Na\(^+\) based on wave mechanical atomic theory         | 0.74                      |

There are 2 questions about atomic model that are the question number 2 in the cognitive level C-1 (knowledge/memory) and question number 5 in the cognitive level C-3 (application). This question gave to the student to know atomic model of each atomic theory. Ideally the student can draw all atomic model because they did learn it before. However, there are 5.2% of students who can’t draw any atomic model correctly. Dalton atomic model is the most popular atomic model for students because 87% of them draw it as shown in figure 3 it relate with their answer about the analogy of atom. They understand it easily because they understand it as tiny massive ball which explained before.

Thompson atomic model were drawn by 30% of students correctly as shown scientifically which is look like positively charge ball with negatively charge in it or called as pulp pudding model as the figure 3 and 4.

**Figure 2.** Student draw of Thompson atomic model  
**Figure 3.** Thompson atomic model [7]

Some misconceptions happened to 35. 29% students about Rutherford atomic model and only 10% of student draw rutherford atomic model correctly as seen in figure 4. Based on rutherford atomic theory, atom consists of nucleus which positively charge and surrounded by electron in each trajectory. The trajectories have the same size. The atomic model is shown in [Error! Bookmark not defined.].

**Figure 4.** Rutherford atomic model
Some student didn’t draw it correctly but still draw some attributes of Rutherford atomic model. 6.67% students draw the electron in trajectory but didn’t draw the nucleus. 13.33% only draw the trajectory. 0.74% draw inappropriate size of nucleus and electrons. They make electrons have bigger size than nucleus, in contrast the discovery of subatomic particles showed that electron is $1/1800$ size of proton or neutron [Error! Bookmark not defined.]. Another misconception is students draw nucleus and trajectory with same size but didn’t draw the electron. The students’ picture is shown as figure 5, 6, and 7.

The questions number two asked the students to draw bohr of atomic model of any atom and the questions number 5 required students to draw bohr atomic theory of Li atom. Majority of students can’t draw the model correctly even in answering question number two which is let them choose any atom they want to draw. Evenmore, There are some misconceptions happened to most of students in drawing bohr atomic model and conclude that students didn’t understand electron configuration rule so that they do not draw two electrons in the lowest energy level but draw the next electrons in the higher energy level. They also do not understand that eighth electrons must draw in the second energy level before draw them in the next energy level.

Figure 5. Student draw of Rutherford atomic model without nucleus
Figure 6. Student draw of Rutherford atomic model with inappropriate size of particles
Figure 7. Students draw of Rutherford atomic model without electrons

Pupils also have misconception in drawing the sub atomic particles size so that they draw electron with inappropriate size compare to nucleus. The students draws of bohr atomic model is represented by figure 8-13.

Figure 8. Students draw of Bohr atomic model without nucleus
Figure 9. Students draw of Bohr atomic model without electrons
Figure 10. Students draw of Bohr atomic model with more than 2 electrons in first energy level

Figure 11. Students draw of Bohr atomic model with less than 2 electrons in first energy level
Figure 12. Students draw of Bohr atomic model with less than 8 electrons in second energy level
Figure 13. Student draw of Bohr atomic model with inappropriate size of particles
Figure 14-16 show misconception of students in drawing Li atoms. It compare to the correct concepts of Li atomic model based on Bohr atomic theory.

**Figure 14.** Students’ draw of Li atoms without nucleus  
**Figure 15.** Students’ draw of Li atoms with less than 2 electrons in first energy level  
**Figure 16.** Students’ draw of Li atoms without electrons

The same problem also happened to the students in drawing wave mechanic atomic model. none of students can draw Li atomic model based on wave mechanic atomic theory and only 2.2 % students who can draw general wave mechanic atomic model. it means they do not comprehend the wave mechanic theory that stated that atom consist of proton and neutron as nucleus and electrons exist in the orbital which the area of probability to finding electrons.

**Figure 17.** Students’ draws of Quantum Mechanical Atomic Model  
**Figure 18.** Students draw of Li atomic model based on quantum mechanical atomic theory

Pupils more understand how to make electron configuration both neutral atom and ion based on bohr atomic theory than abbau rule of wave mechanic theory. It is proof by the percentage of students’ answer of electron configuration based on bohr atomic theory is 66% and 27 % for wave mechanical theory. Moreover students have misconceptions in writing electron configuration of ion Na. There are 4 misconceptions of student about electron configuration of ion. Two misconceptions based on bohr atomic theory and two misconceptions based on wave mechanic atomic theory. The X grade student didn’t release an electron of in the third shell. They wrote electron configuration of Na\(^{+}\) as 2 8 1. This is the electron configuration of Na. The second misconception about electron configuration of ion is the student add an electron in the third shell of Na so that the electron configuration of Na\(^{+}\) to be 2 8 2. Based on bohr atomic theory the electron configuration of Na\(^{+}\) is 2 8 because an electron of Na was
released to make it to be Na\textsuperscript{+} \[\text{Error! Bookmark not defined.}\]. Students wrote electron configuration of Na\textsuperscript{+} as 1s\textsuperscript{2} 2s\textsuperscript{2} 2p\textsuperscript{6} 3s\textsuperscript{1}. This is the electron configuration of Na based on wave mechanic theory. The fourth misconception about electron configuration of ion is the student add an electron in the 3s orbita of Na so that the electron configuration of Na\textsuperscript{+} to be 1s\textsuperscript{2} 2s\textsuperscript{2} 2p\textsuperscript{6} 3s\textsuperscript{2}. The correct is an electron was release from 3s of Na to make it to be Na\textsuperscript{+}. Therefore, the correct electron configuration of Na\textsuperscript{+} as 1s\textsuperscript{2} 2s\textsuperscript{2} 2p\textsuperscript{6} \[\text{Error! Bookmark not defined.}\]. From the analysis know that many students didn’t understand about the formation of positively ion and negatively ion. Scientifically atom will gain electron to be an anion and will lose electron to be cation \[\text{Error! Bookmark not defined.}\].

The last question asked the students to determine atoms that place in same group and period. Based on the analysis conclude that more than half students do not understand how to determine period and group and 34 % student determine period and group based on electron configuration of wave mechanical theory and others based on bohr atomic theory.

4. Conclusion

The conclusion of this study is many students do not comprehend the conception about bohr atomic theory and wave mechanical theory well, so that these concepts have to emphesize in teaching material. Students also posses some misconceptions in drawing rutherford and bohr atomic model so that teaching learning material must modeling atom using picture with submicroscopic representation. in addition they do not understand how to write electron configuration of ions. The conception that is posessed by students correctly or scientifcily is the conception of subatomic particles.

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Acknowledgments
We would like to thank Dirjen Dikti to funding us and also to the headmaster and teacher of SMA N 3,4,5,7,12 and SMA Laboratorium UNP Padang who helped us to finish this research.