Mental models of atomic structure concepts of 11th grade chemistry students

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Received 3 Jul., 2017
Revised 26 Jun., 2018

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Abstract

This study aimed to obtain the characteristics of students' mental models and the difficulties experienced by students while studying in schools in developing the ability of creative imagination. The number of samples involved in this study was 89 students of grade 11. The instrument used to achieve that goal were a test mental models in the form of essay and interview guides. Results of the research show that (1) The majority of high school students still have an understanding of chemistry at the macro level, the ability of reasoning is only able to produce a very simple mental model that is still in the low category. (2) Students have difficulty in interpreting the chemical phenomena to develop their mental models. One implication of these findings is learning chemistry in senior high school need to be designed with a strategy that is able to optimize the ability of the creative imagination of students in an effort to improve the ability to reason, interpret and represent chemical phenomena in problem-solving.

Keywords: Atomic Structure; Chemistry Students; Mental Models.

Introduction

The mental model can be described as a conceptual model, mental representation, mental imagery, mental processes, a construction which cannot be observed, and personal cognitive representation (Chittleborough & Treagust, 2007; Johnstone, 1993). According to Buckley & Boulter (2000) that mental model is an intrinsic representation of an object, idea or process that generated individually for cognitive function. A person uses the mental model to express the reason, describe, explain, and predict phenomena in a model of expression in a variety of formats (eg, verbal descriptions, diagrams, simulations or models of concrete) to communicate their ideas to others or for troubleshooting.

A group of researchers in the field of education and learning of chemistry using the definition of mental models as "a representation of an idea, object, event, process or system" (Gilbert, 1997). A mental model is an internal representation, a cognitive representation that is used to understand the phenomenon, and to describe, explain, predict, and, sometimes, control them (Johnson-Laird, 1980; Johstone, 1993; Treagust, Chittleborough & Mamiala, 2003). By using this definition, a group of researchers in chemistry study has shown that learning with a variety of representations is essential to increase students' understanding of chemistry concepts, especially the use of visualization representations to explain the phenomenon of sub-micro (Devetak, Erna, Mojca & Glažar, 2009; Yakmaci-Guzel & Adadan, 2013), so that students' mental models can be recognized. Mental models are global and dynamic constructs, integrating various elements, which "may be understood as fully implemented representations of objects, states, or events" (Rickheit & Sichelschmidt, 1999) and serve as mental simulations that accomplish cognitive tasks such as understanding, reasoning, prediction, and creative problem solving (Johnson-Laird, 1980). For this reason, Franco et al. (1999) argued that studies of students' mental models may offer a better understanding of students' alternative conceptions. Students' mental models that are reported in the literature are inconsistent with the actual scientific or teaching models, and are not only considered flawed or found to contain some misconceptions (Coll & Treagust, 2003; Vosniadou & Brewer, 1992) but are also usually simplistic (Coll, 2008; Coll & Treagust, 2003). Therefore, the research reported in this paper seeks to add to the body of literature, by providing in-depth insight into students' understanding of atomic structure as expressed through their mental models.

Some research on mental models has indicated that indicated that many students have a very simple mental model of chemical phenomena, such as models of atomic and molecular are described as the discrete and concrete structure but do not have the skills to build a mental model (Johnstone, 1993; Buckley & Boulter, 2000; Park, 2006; Wang, 2007). In addition, students construct mental models it is possible to do through the transformation of learning that emphasizes the three levels of chemical phenomena (Coll, 2008; Yakmaci-Guzel & Adadan, 2013; Sunyono, Yuanita & Ibrahim, 2015). Park (2006) reported that a creative visualization of the history of the development of atomic theory by using visual representations to the level sub-micro to explain how the atomic structure was formed based on theories that developed. Theories of the development of the atomic model drawn visually ranging from particle model (assuming of Democritus and definition of Dalton), the core model initiated by the findings of Thomson and Rutherford, Bohr model and the model of quantum mechanics. The picture can evoke sensory involvement of students, enriching experience and further by drawing, then the sensory participation in the body can provide a better learning experience (Hsu, 2014). The pictures are examples of creative imagination that can help students in understanding the phenomenon of sub-micro because the image can facilitate the process of thinking, and this image will also be able to help students in growing and improving their understanding of the diverse curricular topics. Through the visualization of images of sub-microscopic phenomena, students will more easily in the reasoning of the physical object is encountered, so that their mental model can be built easily. Thus, in assessing mental models, researchers used models expressed by the respondents surveyed, so that an interpretation of the research findings of researchers whose understanding is based on the mental models of the respondents expressed (Coll & Treagust, 2003). Some researchers have used a description of the question to determine a student's mental model. An example of a descriptive question asked to explore the student menta model is "What is vapor pressure? Please explain your answer (Tumay, 2014). Through the students' answers to these questions, the researchers classify mental model into several categories, wait for the level of representation (physical or conceptual-symbolic, for examples, the idea about a chemical single bond as a pair of shared electron versus a pair of overlapped t orbitals from two atoms) and mobility (static or dynamic) models (Coll & Treagust, 2003; Wang, 2007).

The research questions

In this study, the nature of students' mental models of various levels of education is examined to identify and consider their conception of atomic structure. This paper is expected later has the potential to provide a better understanding of the difficulties students in in learning of atomic structure concepts. Hence, this study was conducted to answer the questions:

1. *How are the characteristics of grade 11 students' mental models in understanding the concept of the structure of atoms?*
2. *What are the difficulties experienced by students in doing creative imagination to interpret chemical phenomena in growing mental model?*

Methodology

Research design

The study design followed the study design has been done by Sunyono & Yulianti (2015), that is qualitative with observation. The design of this study includes observational investigation, interviews, and tests of mental models filled out by the students. Observations aim to obtain data on the use of learning during this high school chemistry teacher in Lampung and data of students' mental models. Test of mental models conducted to reveal the reasoning abilities, interpretation, and representation of students' abilities. The ability is further defined as a mental model.

Interviews were conducted to reveal the students' difficulties in understanding, reasoning, interpret, and represent chemical phenomena.

Participants

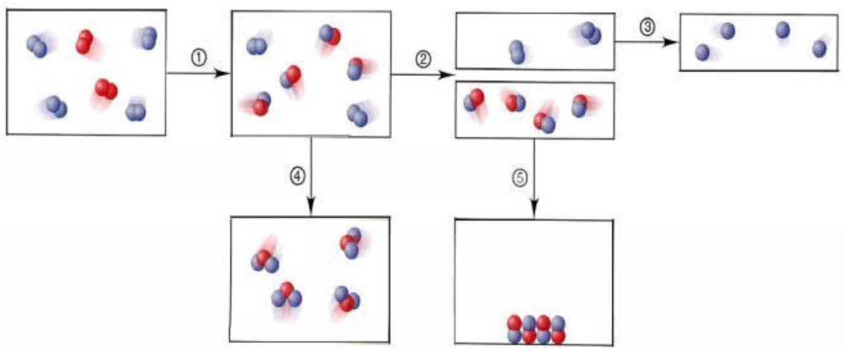
Participants of this study were taken from three districts/cities were selected randomly from all regions in Lampung province of Indonesia. The next randomly selected three high schools as a sample. Sampling the school used to get the respondent students with different backgrounds. Furthermore, each of the selected schools was taken randomly one class 11, in order to obtain three class 11 as a sample of a study with the overall number of students as many as 89 people. The three classes each derived from (1) senior high school in the provincial capital (School A: students who were in the neighborhood of employees and vendors) with the number of students as many as 30 people; (2) senior high schools near the provincial capital (School B: students in a farming environment) with the number of students as many as 29 people; and (3) senior high school far from the provincial capital (School C: students who are in the company's industrial/agro-industry) with the number of students as many as 30 people. Students from each school were given a questionnaire about learning undertaken by teachers, then given tests of mental models, further interviews after the student has completed the exam.

Instrument and Procedure

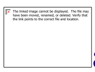
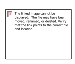
Selection of participants (high school students) as the sample has been done, then performed a survey/observation of these students. Surveying/Observation is assisted by a chemistry teacher from each school to be sampled, then students are asked to complete the observation sheet for 30 minutes. To ensure greater uniformity in the administration of the survey in all classes, teachers are asked not to provide opportunities for additional information beyond what is written in the survey. Investigative observations sheets include 10 items that must be answered students' questions related to the implementation of the study conducted by the teacher.
Tests of mental models used in the form of shaped test essay were adapted from a model developed by Park & Light (2009). The instruments of test of the mental model developed by Park & Light (2009) emphasize more on conceptual definitions ranging from atomic definitions, atomic structure explanations, identification of atomic parts, explanations of orbitals, orbital forms, and the number of electrons in each orbitals . In this study, Park & Light questions were modified starting from the

understanding of atomic structure in a process of chemical and physical change, representation of images of atomic structures (protons, electrons, and neutrons) of an atom based on experimental results from Rutherford, Thomson, Goldstein , and Chadwick. The question continues on the description of the Bohr atom model for a given atom complete with its energy level. The mental model of students as measured in this study is a conceptual mental model that appears in response to questions in the diagnostic tests on the topic of atomic structure (especially the nuclear model of the atom, Rutherford, Bohr, and wave mechanics). The instrument used to determine the appearance of students' mental models is a form of essay test, hereinafter called the Test of Atomic Structure Model (TASM). Question on diagnostic tests to see the emergence of mental models of the students in understanding the topic of atomic structure. Instruments of tests of mental models are validated in advance by the relevant experts, before being used in research. To validate the instrument used three experts in the field of chemistry and two experts in the field of psychology. Expert validation results show that 100% validators provide high assessment of the mental model test questions that have been made, so it can be said that the mental meodel test instrument has high content validity and can be used for research. The mental model test instrument consists of three TASM questions (see below).

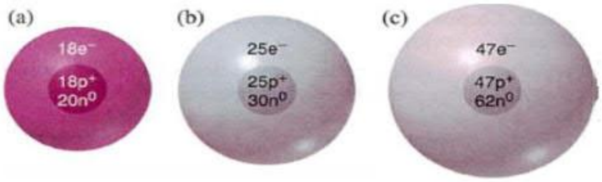
TASM-01. Amongst these following stages, which one of these describe the process of physics change and which one describes a chemical change. Give your explanation!



TASM-02.

a. Based on the experimental results of Rutherford, Thomson, Goldstein, and Chadwick. Give an explanation of the structure of atoms and draw an atomic model complete with its parts (protons, electrons, and neutrons) from the  and !

b. Write the element with the symbol  for each atom notation as described below.



TASM-03. Based on the Bohr model of the atom, the number of electrons for each energy level follows the equation $2\ n^2$. Draw a picture the Bohr atomic model based on the results of your imagination of fluor atoms (Z = 9) and sodium atom (Z = 11), complete with energy levels according to Bohr!

The interview guide was developed in this study is a semi-structured interview guide. The interview guidelines were developed by adapting of the interview guides developed by Park (2006), in the form of questions that ask students to provide an explanation for the student answers on tests of mental models. Interviews with students conducted to find out more about the answers to the students and the difficulties that arise in interpreting the phenomenon of a molecul ar level (sub-micro). Before being used in data collection, interview guides that have been prepared beforehand validated by relevant experts. Interview guides were validated by two psychologists and the results of all validators agreed that the interview guidelines could be used for the study. Interview guidelines of expert validation results are described in Table 1 below.
Interviews were conducted after scoring on a mental model test.. Interviews were conducted with three students were selected from the whole sample (89 students). Three students were randomly selected from three different schools and each school was chosen by one person as a respondent. The students selected for the interview were the students who scored highest on a mental model test. The consideration is students who have low test scores, ie students with mental models categorized "bad". Interviews with students were conducted to find out more about the responses of the students and the difficulties that arise in the creative problem-solving.

Table 1. Interview Protocol

Category	**Questions**
Definition of Atom	What is an atom?

Previous Knowledge	1. Have you studied the structure of atom before taking this course? 2. Are you able to identify any changes that occur in each process shown by the question No.1 (TASM-01)? How is your analogy in answering these questions?
General Knowledge	Please see the question on TASM-02 1. Please explain or describe the structure of an atom. 2. Please draw an atom.(you may use any atom as an example) 3. Tell me about the parts of your drawing of the atom. 4. Please explain more about your drawing. 5. Does your drawing help you to understand the structure of an atom? 6. Do you know what is meant by a "model" in science? 7. Can you give me a model of an atom? 8. Tell me about your understanding of the atomic model of an atom. 9. Do those models help you to understand the atomic structure? 10. Can you explain about it?

Data Analysis

Data obtained from the results of diagnostic tests and interviews were then analyzed through transcription and categorization, so initial mental models of students could be identified and common general difficulties that occur when dealing with the external representation of the submicroscopic level, especially in the problem solving of the atom model concept. Students' mental models were analyzed by interpreting the answers of students on each question of the test mental models. If the student answers to the questions of the test mental models vary widely, so do the answers grouping students into several types according to a similarity of answers. Types of student answers categorized (sorted) in accordance with the responses of the students starting from no attempts (no answer) to the most appropriate answer. Furthermore, the number of students in each type is expressed as a percentage. This is done by adapting the research conducted by Wang (2007) and Park (2006), where to know the features of an individual's mental model of the student, Wang (2007) and Park (2006) using coding to the explanation of verbal and nonverbal students, and the encoding using the types of student answers as explanations of nonverbal representation of students. Encoding mental model test data is done by giving a score to each student answers according to the type of student answers. Mechanical scoring is done by using a rubric, namely by assessing the students' answers on tests with descriptions use the label to determine the level of achievement solve the problem (Sunyono, Yuanita & Ibrahim, 2015). The level of achievement in problem solving are then categorized as a mental model of "very bad/unformed" (where a score = 1), "bad" (score = 2), "medium" or "moderate" (score = 3), "good" (score = 4), and "excellent" (score = 5).

Results of the research

The results of the analysis of the emergence of the mental model of students in response to the question No.1 diagnostic test of atomic structure model (TASM-01) will be described here. The results of the analysis of students' answers to TASM-01 are illustrated in Figure 1 below.

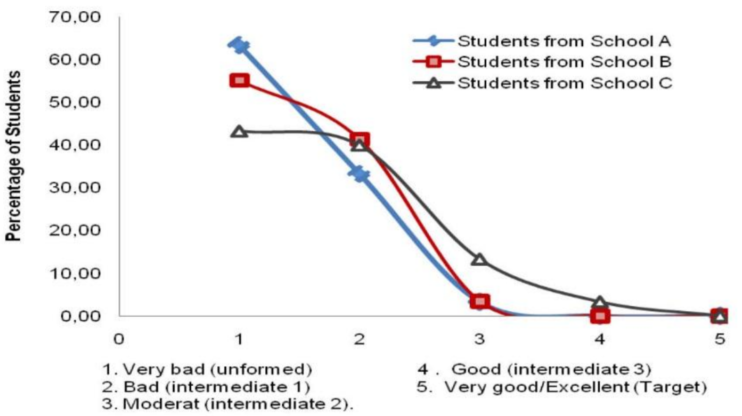


Figure 1. Percentage of Students with Initial Mental Model on Specific Characteristics for Question TASM-01.

Based on the students' answers to the TASM_01 question (Figure 1), it can be said that students from three schools (with differing backgrounds) provide responses that are not different, resulting in the same initial mental model, namely "very bad or unformed" and "bad".

Figure 1 shows that the majority of high school students (> 67,5%) consider that the third stage is the process of physical change and only 5,62% who answered that the third stage is the process of chemical change. This means that students do not have sufficient understanding of the structure of atoms and molecules. However, students from school C (students who are in the company's industrial/agro-industry) have a better ability to distinguish the structure of atoms and molecules rather than students from school A (students who were in the neighborhood of employees and vendors). This is indicated by the responses of students better than students in schools located in the the provincial capital (School A) and near the provincial capital (school B: students in a farming environment). Students who are in the company's industrial/agro-industry (school C) can understand that the second and the fifth process are physical changes, while the third is a chemical change, but it is still not appropriate for explaining why the processes depicted in the diagram are the process of physical and chemical changes. Based on interviews found that students consider splitting diatomic molecule into monatomic molecules (2 separation handball) is a physical change to the analogy "paper torn into two parts" or "wood is broken."

The study provides information that grade 11 students, who have studied the structure of atoms, are still not able to read the submicroscopic diagram well enough to distinguish the structure of atoms and molecules, and also in recognizing the changes of molecules when turning into atoms, the change of compounds into elements, and changes in a substance that does not change the structure of the substance itself. It shows that the senior high school students' initial mental models in understanding the physics and chemical changes are still dominated by the macroscopic level.

Based on interviews found that students consider splitting diatomic molecule into monatomic molecules (2 separation hand ball) is a physical change to the analogy "paper torn into two parts" or "wood is broken." Results of interviews to three students (S1: Students from school A; S2: Students School B; and S3: Students from School C) the following:

R (Reviewer): Are you able to identify any changes that occur in each process shown by the question No.1? How is your analogy in answering these questions?

S1 : Yes, partly. I think the process of 1, 2, and 3, are physical processes, while 4 and 5 are chemical processes. Because I hesitate to read the images, I can hardly make an analogy.

S2 : No, so I did not answer the question 1, because the time in high school before, I have never seen pictures like that, explanation and questions were text-only with words. The pictures given puzzle me. Process 2 and 3 are physical processes. In the second process, itcircle do not change, only the colour of their partners are exchanged, while the third process, the ball remains blue-ball just split it, that had *kept the breakaway coupling. Then I think, process 3 is as if we tore the paper into 2 parts or broken wood.*

S3 : Yes, partly. I think in the 2 and 3 are the processes of change in physics, while the fifth is a chemical change. My understanding, that chemical changes like the ionic bonds, whereas the physical changes if there are more similar objects repel each other. For the second way: the pictures in pairs balls red and blue are not bound to secede only. While the process 3, is like a ball similar hand in hand. Similar balls will repel each other, so that the balls were split into two due to mutual repulsion. Ehmmm ... it was like we tear the paper or break the wood, so it breaks into two parts.

The results of interviews with three of the respondents indicate that students' mental models are not good. From the interview, it appears that students are not able to distinguish the structure of molecules and the atomic structure at the level of sub-microscopic. Students have difficulty in distinguishing between molecules and atoms when dealing with a visual representation of sub-microscopic images. This finding is consistent with the Park (2006) that students' mental models of chemical phenomena depend on the ability to distinguish between the sub-microscopic structure of molecules and atoms. Therefore, it is necessary strategies that are able to develop the ability to reason, interpret, and represent chemical phenomena well, so that students early mental model hybrid (Vosniadou & Brewer, 1992) can be established to reduce the conflict between the conceptual definition of experts, with the visual images that the students in the molecular structure at the sub-microscopic level.

The question on test number 2 (TASM-02) shows that students are still experiencing difficulty in making the transformation from a verbal representation to a visual representation regarding the nuclear model of the atom. The difficulty is caused by the lack of creative imagination being used by the senior high school students because they did not practice in the instruction that took place. According to students that the learning of chemistry that lasted so far was only done verbally, students were never trained with the visualization of atoms and molecules. The question on TASM-02 is the question of student understanding on the atomic structure model according to the core model.

The results of the analysis of students' answers to the TASM_02 test question showed that the majority of students are still not able to understand the atom core model, be they students from schools in cities or students from schools in areas far from cities. As TASM-01, the analysis of the students' answers to TASM-02 has a resemblance (Figure 2). These results indicate that students with their knowledge of chemistry they have learned and taught by teachers are still not able to perform the transformation of macroscopic (experimental phenomena Thomson, Goldstein, Chadwick, and Rutherford) for the sub-microscopic and symbolic phenomenon. Similar to TASM-01, an analysis of students' answers to questions TASM-02 shows that students from school C (students who are in the company's industrial/agro-industry) has the capability to provide a visual representation of the arrangement of atoms based on the theories of Thomson, Goldstein, Chadwick and Rutherford more better than students from school A (students who were in the neighborhood of employees and vendors) and students from school B (students in a farming environment)

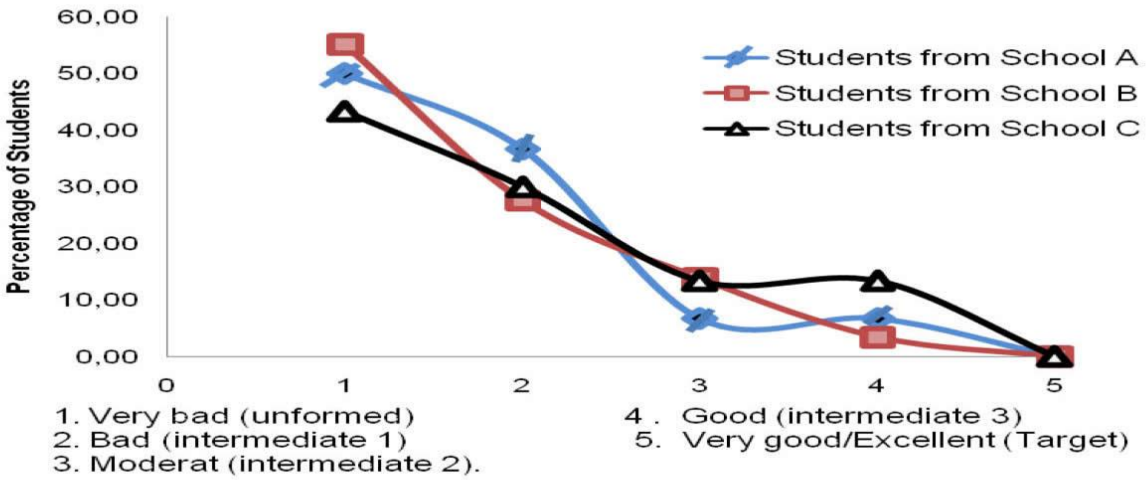


Figure 2. Percentage of Students with Initial Mental Model on Specific Characteristics for Question TASM-02.

Based on questionnaires filled out by the students, it appears that a study on the concept of atomic structure implemented by teachers are not trained 'skills of interpretation and visual representation of the phenomenon of sub-microscopic particles in the atom, so students are not used to the visual representation of the particles in the atom. Students transform the phenomenon of visual to verbal or otherwise through the ability of creative imagination on the structure of the particles in atoms, then adjust the image sub-microscopic of parts of atoms, then the student is asked to write the arrangement symbolic of electrons, protons, and neutrons in the atom based on the visual image. The visual image that has made the students be very simple and most (43.82%) are unlikely to distinguish between the atomic model of Rutherford and Bohr atomic model. Students' mental models in response to questions TASM_02 showed that students had difficulty in making the transformation of chemical phenomena of submicroscopic to macroscopic and symbolic or otherwise.

The difficulties of the students in understanding the atomic theory (Thomson, Goldstein, Chadwick, and Rutherford) is due to students not involved with sub microscopic phenomena in the learning undertaken by their teachers at school. Nonetheless, students are able to put the symbols correctly. Where the symbol of chemistry is used to define a substance or represent a process or any changes that take place (Park, 2006). This finding appropriate studies before that the understanding of chemical concepts cannot be achieved only by involving rote verbal only, but also requires an understanding of the phenomenon of representation of the structure of sub-microscopic molecules or atoms (Coll & Treagust, 2003; Hilton & Nichols, 2011; Park, 2006). In this case, Coll (2008) found that the ability of learners to operate or use their mental models to explain the events that involved the use of representations of sub-microscopic very limited, so there is a need to train learners in interpreting the phenomenon of sub-microscopic through instruction involves three levels of chemical phenomena.

Based on interviews found that the difficulties faced by such students are more due to students not getting experience in making an interpretation of the electron orbit according to Bohr. On interviews appears that students from school A and school B had difficulty in explaining, describing, and interpreting visual images of the atom and its structure is based on the theory of Thomson and Rutherford. While students from school C has more ability in explaining and interpreting visual images. The interview results showed that students had difficulty in maintaining his understanding of the phenomenon of electrons in atoms through learning only made orally, so the mental model does not form properly. These results also indicate that students have been able to image the atomic structure sub-micro in a simple manner, namely by means of symbols, but the difficulty in translating the verbal image.

Associated with the understanding of the electron orbit according to Bohr poured into question TASM_03, where students are asked to make the transformation from verbal to visual and symbolic representation or otherwise regarding the determination of electron orbit according to Bohr then create a visual image through an energy level diagram.

The result of the analysis of student answers to the TASM-03 question is illustrated in Figure 3 below. Analysis of the students' answers to the TASM-03 question showed similar results with the results of the analysis of TASM-01.

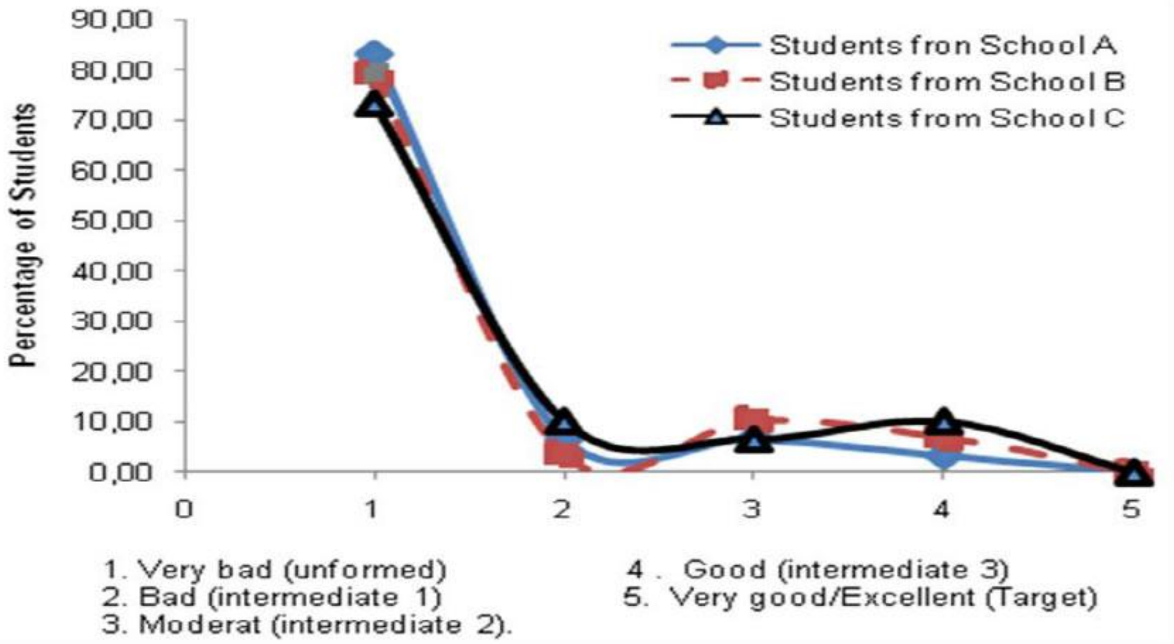
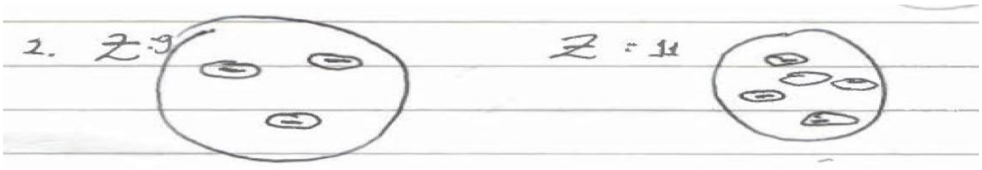


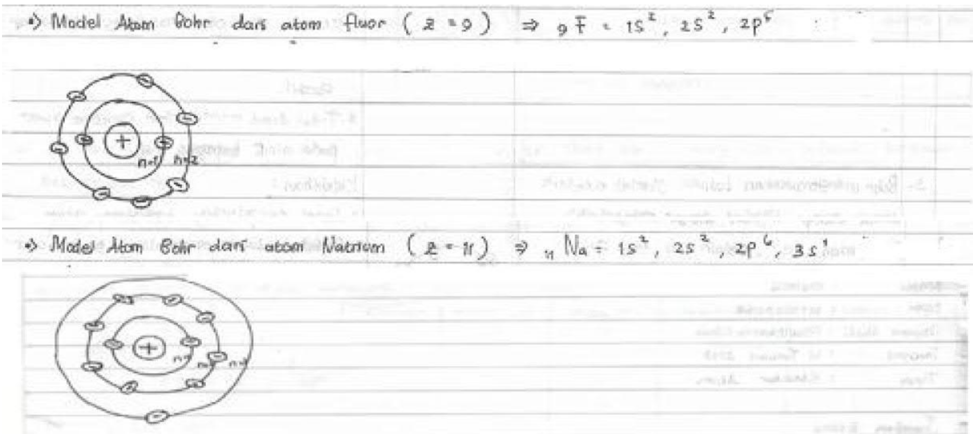
Figure 3. Percentage of Students with Initial Mental Model on Specific Characteristics for Question TASM-03.

These results indicate that the 11th graders who have studied the topic of atomic structure are still having trouble in making the transformation phenomenon of verbal to the visual phenomena of the atomic theory of Bohr. However, the percentage of students from schools located far from the provincial capital, which has high mental models, is higher than the percentage of students who were in the neighborhood of employees and vendors, and students in a farming environment (Figure 3). Thus, it can be said that the majority of students have difficulty in representing the sub-microscopic phenomena of the Bohr atomic theory, whether students from schools in the provincial capital, as well as students from schools far from the provincial capitals. Interviews showed that the difficulties faced by such students is more due to students not getting experience in making an interpretation of the electron orbit according to Bohr. Student difficulties in representing the sub-microscopic phenomena of the Bohr atomic model can be seen from the examples of student answers the following:

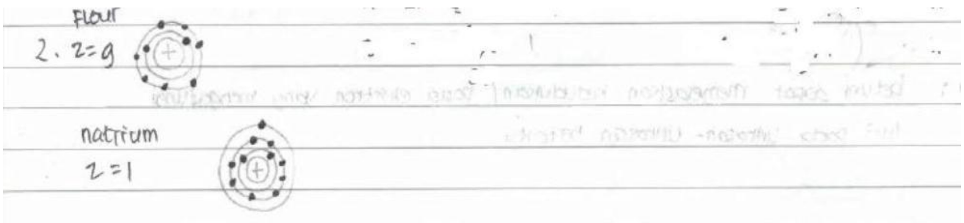
S1: student from School A



S2: student from school B



S3: student from school C



Overall, for all the students from the three schools of different categories, the analysis shows that the majority of students (> 70.00%) have a mental model in understanding the Bohr orbit is within the category of "very bad" and "bad", or the characteristics of mental models "unformed" and "intermediate 1.

Analysis of the students' answers to questions TASM-03 showed that some students (16.85% students in a farming environment and 14.61% students who were in the neighborhood of employees and vendors, and students who are in the company's industrial/agro-industry) is actually able to interpret and make the transformation to a particular phenomenon, but there are a misunderstanding in describing the atomic model of fluorine and sodium. Students from school A is not able to represent the Bohr model of the atom fluorine and sodium through the visualization of images, where the arrangement of electrons is placed entirely inside the circle is created. The image is contrary to the theory of the Bohr atomic model. Furthermore, students from school B and students from schools C to draw models of fluorine and sodium are in accordance with the Bohr model, but there is a mistake in preparing the skin of electrons in atoms. Before they make the visualization of images, students draw up electrons in the s and p orbitals in advance. This is not the Bohr model, but the model of wave mechanics.

Based on the analysis of students 'answers, it seems that the students' answers to questions about the atomic model of Bohr have disturbed with mechanical model of waves, namely by creating electron configuration using a system of orbital of s, p, d, f, whereas what is required is the Bohr model are familiar with the term orbital. However, students who are in the company's industrial/agro-industry has the more precise answer than students from both schools the other. As a result of an error in interpreting the arrangement of electrons in an atom, the students' answers to questions TASM-03 produces the mental model with the category of "very bad" and "bad." The results of interviews with three students showed that the ability to make the interpretation in distinguishing Bohr model of the atom and the wave mechanics model visually is not trained in the instruction by the teacher. According to students, the atomic model of wave mechanics was not studied in detail as they learn. During the study the atomic structure of matter, the students only learn verbally, students are not given the experience in interpreting Bohr electron orbit and the energy that accompanies the movement of the electron in its path, nor trained in understanding how to model the mechanical waves in explaining the position and behavior of electrons in atoms.

Discussion

The results of this study indicate that learning only emphasizes the verbal representation will result in the student having difficulty in understanding the chemical material, especially on the concept of atomic structure. The student difficulty lies in the interpretation of the phenomenon of sub-micro about models of atoms and distinguishes based on visual images created by students. The difficulties can also be caused due to the characteristics of the atomic model of an abstract nature of sub-microscopic scale, and in learning, students are not trained in conducting imagination representation of the phenomenon of sub-micro. These results are consistent with studies of Suits & Hypolite (2004) reported that students were not given learning with visual representation model of the atom, would have difficulty in understanding the phenomenon of the Bohr model of the atom when they learn, this is probably due to the abstract nature of the atomic model representation. Chemistry learning can be done through visualization or conceptual model expressed through the image of the structural model that describes the relationship between the concepts chosen by the students in creative problem-solving (Hilton & Nichols, 2011). Therefore, learning the concept of an atomic structure should be done through modeling. Modeling structures used in learning are able to lower cognitive positively, so that the effectiveness of learning within easy reach, the level of student understanding becomes higher, and eventually, students will experience satisfaction in learning (Hsu, 2014). In addition, it is also necessary a strong effort in learning to form a mental model of students, so that students' awareness in learning can be improved (Chudzicka-Czupała, Lupina-Wegener, Borter & Hapon, 2013).

The research findings show that most students have an understanding of chemistry on a macro scale with a simple structure, as a result of the lack of students' understanding of the relationship between the macro, sub-micro, and symbolic levels. If the students' understanding can be improved, then the mental model's students will be able to be cultivated and persist longer in their brains. The effects of scientific imaginative are not always direct, but tend to be durable (Hu et al., 2013) and mental models students will be easier to upgrade to a "target" (Sunyono & Yulianti, 2015). So, students use models to connect the observed phenomena and scientific explanations, and through this process, they form their own mental models (Park, 2006)

One implication of this research is the study of chemistry at the high school need to be established with a strategy that is able to optimize the ability of the creative imagination of students in an effort to improve the ability to reason, interpret and represent the molecular scale chemical phenomena. Learning by involving multiple representations is that students have the ability to reason, interpret, and represent a molecular level chemical phenomena, so that students can more easily solve chemical problems associated with abstract concepts, such as the concept of atomic structure. Referring to the statement some experts that the mental model is an internal representation that can be used by a person to think, to reason, interpret, predict, and provide an explanation of an object encountered (Cañas, Antoli & Quesada, 2001; Greca & Moreira, 2000) , it can be said that the mental models affect the cognitive development of students. Thus, the model student mental models can be built from the experience, training, and learning. Therefore, learning by involving visual representations related to chemical phenomena will be very helpful in fostering students' mental models (Sunyono, Yuanita & Ibrahim, 2015). Learning chemistry with a focus on image/visualization is part of the imaginative pedagogy that can expand and enrich the students' ability to reason.

Another indication of the results of this study is the implementation of learning chemistry in some schools in the province of Lampung - Indonesia is still not oriented to the optimization capabilities of the creative imagination of students. Learning that takes place has not been able to facilitate students in using the imagination's ability to develop the skills of thinking and reasoning power is high. The difference between the results of students from different schools because of differences in the application of learning strategies from teachers. In this case, the school is located far from the provincial capital (School C: students who are in the company's industrial/agro-industry) are likely to be able to excite the imagination of students, so that students' mental models that appear better than students who were in the neighborhood of employees and vendors or students in a farming environment. The results of interviews with students illustrate that schools located far from the provincial capital have implemented learning by using visualization to describe the structure of atoms and molecules. Visualization is done simply by using materials that exist around students such as fruits (oranges, guava, fruit distance, and others). This can be seen from students' answers to the mental model tests that provide a better visual representation of atomic structure than schools in the provincial capital (school A) and schools close to the provincial capital (school B). Thus, it can be said that the learning strategy applied in schools located far from the provincial capital is more appropriate in generating the students' creative imagination compared to schools located in the provincial capital and schools close to the provincial capitals.

Conclusions

Based on these results be can be concluded that (1) Based on these results we can say that (1) The majority of high school students still have an understanding of chemistry at the macro level, the ability of reasoning is only able to produce a very simple mental model that is still in the low category. Lack the ability to reason, to represent and interpret the phenomenon of sub-microscopic concepts of atomic structure can blunt of the power of students' mental models in understanding chemical phenomena become less well established. (2) Students who are in the company's industrial/agro-industry generally have a mental model of verbal and visual in category intermediates_3 and the target. While students in a farming environment and students who were in the neighborhood of employees and vendors has a mental model that is dominated by the verbal model to the category of "very bad" and "bad" or characteristics of mental models "unformed" and "intermediate_1". It is very difficult to produce a mental model "target" or "very good". (3) Students who do not use their creative imagination to the fullest ability, they will have difficulty in interpreting the phenomenon of chemistry students to develop a mental model. This is due to among others: (a) identifying external representations (verbal and visual) about the position of electrons, protons, and neutrons in an atom according to each model of the atom (particle models, core models, and wave mechanics). (b) transforming the sub-microscopic representation (visual) to verbal and symbolic or vice versa. It shows that the students have a poor ability to do creative imagination to construct their mental models. (c) the imagination of the students has not focused properly, the ability to draw and describe the phenomena of atomic structure deviates from the supposed image. This causes the student's ability to comprehend visual images (sub-microscopic level) becomes lower, consequently to achieve mental models with the category of "target" becomes difficult. Therefore, there should be an effort to cultivate a mental model "intermediate" or a mental model of "hybrid", i.e. mental models that can foster the ability to think to bridge the conflict between conceptual knowledge with visual images at the sub-microscopic level.

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