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Mental Model Profile of Indonesian Class X High School Students on the Concept of Covalent Bonds in the Era of the Covid-19 Pandemic

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Abstract. This research describes the mental model of covalent bonding for high school and vocational high school students involving 240 respondents from 5 provinces in Indonesia, namely Sumatera Utara, Lampung, Bali, Kalimantan Timur, and Nusa Tenggara Timur. The results of this study are very useful for knowing the mental models of students, especially in the era of the COVID-19 pandemic. Students' mental model on understanding covalent bonds in this study, obtained by distributing questions to students, aims to determine the level of understanding of each student by involving three levels of chemical phenomena, namely macroscopically by explaining a brief description of the questions in each question, then sub macroscopic by asking students to describe the Lewis structure, as well as the symbolic level by solving the equation for the formation of compounds. Data were obtained from the covalent bond mental model results and the results of interviews with student representatives. Based on Park's mental model classification (2009) found that 32% of students had a second intermediate mental model, while 29% of pupils had the first intermediary mental model, and 39% of pupils had an initial mental model or an unformed mental model.

INTRODUCTION

Chemistry is a natural science that explained the nature, structure, and changes of matter, principles, concepts, theories, and laws that support the direction of changes in a substance (1). Three types of chemical representations are namely a representation of phenomena experienced by the senses or observed directly in the surroundings; qualitatively explain the phenomenon in depth/micro, and explain quantitatively the phenomena representation or explanations that involve symbols and chemical formulas (2).

John K et al. illustrate the words/phrases used in the literature from several authors into three levels of representation, namely macroscopic, submicroscopic, and symbolic. Chemistry requires a deep and comprehensive understanding of the basic principles of chemical concepts. In this case, students' ability to convey and relate macroscopic, submicroscopic, and symbolic phenomena are needed to be able to understand these chemical concepts (3).

The students' understanding level in the three chemical representations is the reasoning and interpretation of phenomena representation results presented in various forms such as charts, visual images, mathematical calculation, and verbal explanations. It identifies as a mental model (4).

In general, chemistry learning that occurs today is only limited to two levels of representation, namely macroscopic and symbolic (5). Merging or integrating submicroscopic and macroscopic or symbolic phenomena is left to the students themselves to understand them through pictures and diagrams that exist in textbooks, without the guidance and direction of the teacher. In addition, students also learn to solve mathematical problems with or without understanding the real meaning (6). There is an assumption that students were successful in solving mathematical

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problems means that these students have understood the concept of chemistry. Many pupils who succeed in solving mathematical calculations do not understand the chemistry conceptual obviously, because they only memorize the algorithm. Most pupils only remember concepts related to abstract verbal and symbolic representations of submicroscopic and symbolic phenomena (describe words in the written and spoken text) for a result. They were unable to imagine how the process and substance structure undergo a reaction (7). It has been strengthened by research on misconception analysis where teacher explanations often simplify students' concepts and habits for memorizing, weak understanding of language and mathematical concepts, and the applied learning model has not combined macro, sub macro, and symbolic aspects, causing misconceptions in students' understanding ability of chemistry (8).

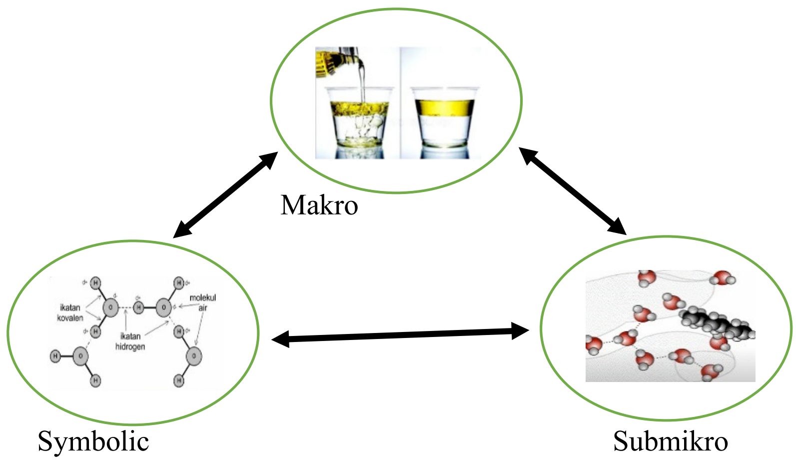


FIGURE 1. Bridge levels/types of chemical representation (modified from John stone, 1993).

Chemical bonding is fundamental chemistry and a base topic that pupils have to understand. Covalent bonding is one of the materials which students find difficult to learn this material. Then, it was still limited to learning for three-dimensional (3D) conventional chemistry, where learning using three dimensions can improve understanding of chemical structures, especially in the manufacture of hybrid orbitals (9). It had confirmed by Chang's research (10) on the submicroscopic visualization concept on covalent bond formation and valence bond theory. Another research's result shows that most students experience difficulties and misunderstandings when understanding the shape of the NaCl structure, the electro-conductivity of graphite, the concept of electron delocalization, and misunderstanding the concept of covalent bonds formed when a phase changes a substance.

Previous studies also support the view that the interaction between the macroscopic and sub macroscopic worlds is a source of difficulty for students in understanding and interpreting chemical concepts, especially submicroscopic representations, and tends to make their representations (11) (12) (13) (14) (15) (16) (17).

Research (18) states that students have an interpretation and understanding of chemical bonds. Students' knowledge is about the gravitational pull between two different atoms, namely positive and negative charges in the chemical bond formation. However, students do not understand repulsion force between the two nuclei refuses to reach a state of equilibrium. It has happened in some schools where the teachers do not teach how the phenomenon of repulsion rejects the concept of learning a chemical bond to achieve a state of equilibrium.

This research had confirmed by JK Gilbert's research on a model-based curriculum. It should be improved to face challenges in teaching until it can produce good learning (Gilbert, 2004).

According to Sunyono (19), some difficulties in understanding chemical material when students related to their transformation ways of the three levels of chemical phenomena. The cause is students where cannot be accustomed to being trained in using learning methods by representing sub macroscopic phenomena with various other representations, so they tend to separate the three levels of chemical phenomena, and learning is done only through verbal and symbolic representations. In addition, this can explain that the relationship between mental models and students' mastery of concepts must be linear. Increasing mental model ability can enhance students' understanding of chemistry (20).

Various ways have to provide understanding to novice students about covalent bonds, by modeling activities through a low-cost kinesthetic approach, by using model kits to visualize molecular shapes and the relationship between atomic bonds (21). Another research on the understanding of covalent bonds through the fictional narrative method made by the teacher can have a positive effect on students' memory and retention abilities, students' interest and enthusiasm in learning, and understanding the topic of covalent bonds. Sunyono found a learning model to arouse students' creative imagination in overcoming students' mistakes and difficulties in understanding (misconceptions) in representing chemical concepts sub microscopically, using a learning method that uses the SiMaYang strategy (22), besides the SiMaYang model is practical and effective to improve mental models and mastery of students' concepts in the development of atomic theory material (3). Another study (23) showed that the utilize concrete models, image representations, animations, and simulations proved helpful for understanding chemical concepts, especially in terms of molecular or submicroscopic conceptual. Tasker and Dalton's statement relates to the transformation of external representations into internal representations. It is called a mental model.

Understanding the model has the potential to improve the epistemological perspective of students. A teacher must realize the importance of the model in the teaching and learning process. Understanding models and modeling in science is crucial and appropriate in utilizing models (24). Harrison and Treagust (1998) said that "modeling is at the heart of scientific thinking" (25).

Some models use in all sciences and humanities. They have particular importance in chemistry and physics because these disciplines involve many complex and abstract concepts. Zumdahl (26) asserts that models and modeling are necessary for chemistry learning. It is very arduous to understand the chemistry in the missing of a clear understanding of models and their use. SW Gilbert (27) suggests that it is more appropriate to define science as a model-building process than adherence to the scientific method. Such a view recognizes the similarities between scientific fields using diverse methodologies.

According to Grace and Moreira (13), a mental model is generally illustrated as something incomplete, inaccurate, and influenced by one's perception and develops through interaction with the concept or phenomenon to be represented. Mental models are considered by many authors to be functioning developing systems; That is, many mental models are incomplete and do not have clear boundaries (28) (29). Therefore, mental models are often unscientific and highly unstable. People's mental models tend to be lacking in several ways, which may include contradictory and erroneous concepts. Mental models are causal and functionally defined in the sense that they allow individuals to engage in description, explanation, and prediction (30). Based on the constructivist's view, mental models are formed by the students' thinking, where students represent personal experiences about objects or phenomena certainly (30).

Mental models have been expanded by an individual's experiences. It is hard to get a complete picture or representation. Mental models just help a person to give meaning to the physical world aspect by interpreting their information and experiences (31).

Based on the descriptions above, regarding the difficulties, misconceptions, and misunderstandings of the material in chemistry learning, as well as how students' mental models can affect the level of students' understanding of chemistry learning, seen from the three levels of chemical phenomena, the researchers conducted more specific research on the model. Students' mentality on covalent bond material for high school students in Indonesia, because the materials in chemistry learning require a high level of understanding, especially from sub-microscopic understanding concepts. This study hopes to provide an overview of the mental models of students in Indonesia, especially the mental models of students on the understanding concept of covalent bond material so that by knowing the mental models of high school and vocational students in class X who are beginners in understanding chemical bonding material, teachers wish to be able to do this. Innovation in chemistry learning, especially the topic of covalent bonding. In addition, by knowing students' mental models on the concept of covalent bond material, it is also hoped that the role of teachers can bridge beginner students to be able to interact, combine or integrate submicroscopic and macroscopic or symbolic phenomena so that students can understand the true meaning of covalent bond material, not can only solve mathematical problems without understanding and understanding the senses (7).

RESEARCH METHODOLOGY

This research aimed to determine the profile of students' mental models on the concept of understanding the chemical bond material in the sub-topic of covalent bonds. The analysis is done in some stages, such as a qualitative and descriptive approach from answers to mental model test questions and interview methods, involving three levels of chemical phenomena (macroscopic, sub macroscopic, and symbolic). Interviews were conducted outside of school hours, considering the COVID-19 pandemic conditions, so our interviews were conducted by telephone to 12 student representatives who were randomly selected, based on the category scores obtained from each student's answers. There are three questions given to students to describe three levels of chemical phenomena macroscopically by explaining the description of the answers to the questions according to students' understanding, then explaining sub-macroscopically. It is equipped with Lewis structure creation and explains the results of the description both macroscopically and sub-macroscopically in symbolic form. The questions posed to students were as follows:

Explaining the covalent nature of the two compounds between boron trifluoride in the gaseous form and silicon chloride in the liquid by determining the difference in electronegativity, then sub-macroscopic explanation according to the Lewis structure, and making the relationship between the bond and the compound form.

How students can interpret HCN into types of covalent bonds based on valence electrons, then explain sub macroscopically through making Lewis structures, and describe them in symbolic form through pictures of the bond formation process.

How students can explain the nature of water and oil in terms of covalent bonds, and why water and oil cannot be a mixture. Students must be able to describe macroscopically and explain the position of oil and water from the sub macroscopic level.

The data from the mental model test results were in the form of student answer sheets. It was evaluated and scored according to the mental model score rubric (13) (32), then calculated ordinal data which was transformed into interval data to determine the mental model category of each student. There are 240 grade X students as data respondent data from 5 provinces of 37 provinces in Indonesia representatively. West Indonesia is North Sumatra and Lampung, the Central Indonesia region in Bali, East Kalimantan, East Kalimantan, and East Nusa Tenggara. Each province is chosen a maximum of two schools and a maximum of 40 students per school. Mental model test questions were distributed to students in 5 target provinces which were carried out in May – June 2021.

TABLE 1. Mental Model Assessment Rubric (Wang 2007, Sunyono 2015)

Score	Description
Score 5 Excellent	• All verbal and visual representations as to the embodiment of the expressed mental model, both those built by students and those given, have compatibility with each other. • Able to interpret given external representations and transformations between levels of chemical phenomena with excellent (accurate and complete) explanations/descriptions.
Score 4 Good	• Representations of mental models are built by each other, but still, have a little difference with given representation in the matter. • Able to interpret the given external representation and transformation between phenomena levels with a fairly good explanation/description (correct but incomplete)
Score 3 Enough	• There are at least verbal or visual representations created. Even it has a difference between the representation of mental models that are built with that given in the matter. • Already able to interpret external representations, but unable to perform transformations between chemical phenomena and the explanation given is not correct. • Provide verbal and visual representations are appropriate but were unable to do the interpretation and transformation.
Score 2 Poor	• Provide only one type of representation (verbal or visual) as an embodiment of mental modeling abilities. • Perform interpretations and transformations that are wrong and inaccurate, or do not carry out interpretations or transformations.
Score 1 Fair	• There is no attempt to provide verbal or visual representations as an embodiment of mental modeling abilities. • Improper interpretation, transformation, and explanation/description.

RESULT AND DISCUSSION

Result

There were five questions on chemical bonding sent to 10 schools spread across five provinces in Indonesia. Two schools were be elected to represent each province. There were 25 students selected as respondents from each school. The questions given contain two questions about ionic bonds, two questions about covalent bonds, and 1 question about covalent bonds in everyday life. All of the questions have been checked for validity and reliability tests. Based on the calculation of the reliability and validity test with an r-table value (0.388), it means that the questions compiled are valid and reliable to be examined on students. The results of the calculation of the validity and reliability tests can be seen in Table 2 below.

TABLE 2. Validity And Reliability Test Results About Chemical Bonds

Item	Scale Mean If Item Deleted	Scale Variance If Item Deleted	Corrected Item-Total Correlation	Correlations	Cronbach's Alpha if Item Deleted
Ik_1	13.65	7.435	0.665	0.761	0.693
Ik_2	13.85	6.055	0.549	0.756	0.704
Ik_3	14.31	6.382	0.444	0.693	0.750
Ik_4	14.00	6.240	0.617	0.780	0.675
Ik_5	13.12	7.386	0.455	0.637	0.734

Student respondents are students of grades X Senior High School in the academic year 2020/2021 and have received material on chemical bonds. The chemical bond mental model test is shared after students finish taking the final semester exam. It is designed to know students still remember the chemical bonding material that has been taught previously. The students were requested to solve the questions according to their respective understandings so that the researchers could determine the category of students' mental models. Students did it online. Then, students send answers in pdf or photo form to the chemistry teacher because due to the covid19 pandemic condition according to the Indonesian government health protocol.

Review of Understanding Covalent Bonds Based on Three Levels of Chemical Phenomena Through Mental Model Problems

The first question is about covalent bonds. This research is expected students to interpret according to think logically "which compound has the greater covalent properties between boron trifluoride in the form of liquid gas or silicon chloride in liquid form?"

Researchers provide illustrations to make it easier for students to think in a structured and systematic way in interpreting the problem. Researchers stated that the bonds formed between the atoms of elements in a compound depend on the electronegativity of the constituent element.

Then students are expected to explain the submacroscopic level by completing the description of the Lewis structure.

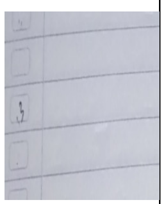
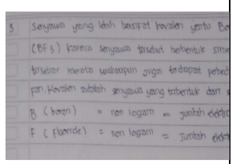
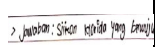
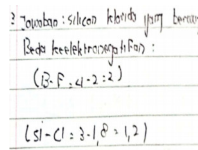
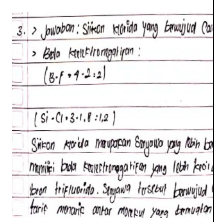
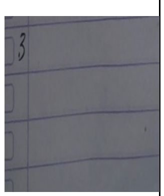
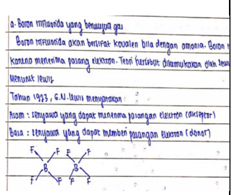
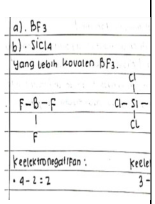
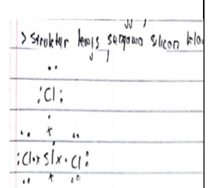
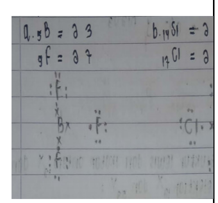
The second question concerns chemical bonds between atoms. The research expected students to interpret types of chemical bonds atomic of Hydrogen Cyanide (HCN) compounds in gaseous form at room temperature. The researcher expected students to explain at the submacroscopic level by describing the process of bond formation and the solubility of hydrogen cyanide compounds in water.

The third problem is a covalent bond in everyday life. Students observe an illustration of a mixture of oil and water. The researcher is expected students to find covalent bonds in everyday life and explain macroscopically through the description "why can't water and oil come together?". Submacroscopically, students were asked to describe hydrogen bonds in oil molecules.

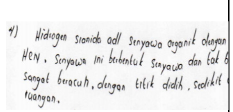
FIGURE 2. Oil and Water Mixture

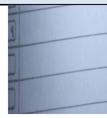
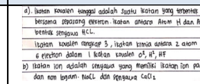
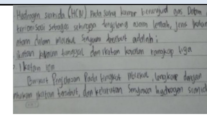
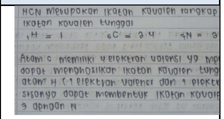
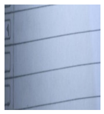
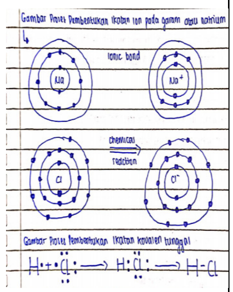
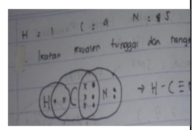
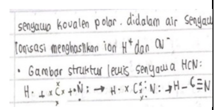
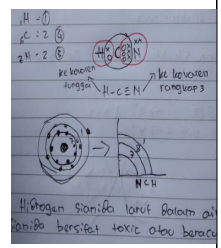
TABLE 3. Examples of Student Answer Results Based on the Level of Understanding According to the Level of Chemical Phenomena

1st Question

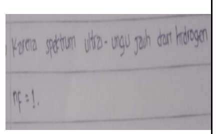
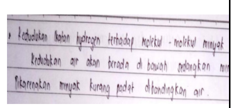
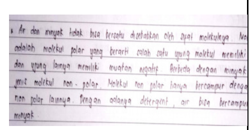
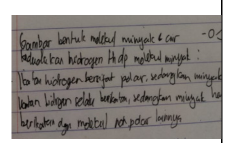
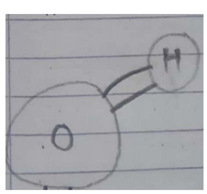
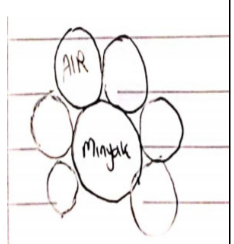
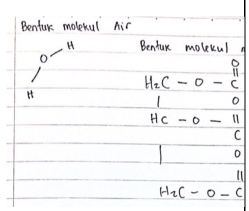
Chemical Phenomenon Level	Steps to solve the problem	Answer category				
		Very bad	**Bad**	**Enough**	**Good**	**Very well**
Macroscopic	Making choices mathematically by determining the difference in electronegativity	Can't answer. 	Wrong answer. 	Using mathematical calculations but misinterpreting. 	The answer is correct but does not use mathematical calculations. 	Correct answer using mathematical calculations. 
Submacroscopic	Describe the Lewis structure	Can't draw. 	Wrong answer. 	Can answer and draw Lewis structures, but misinterprets. 	Drawing lewis structure but not right. 	Correct answer using mathematical calculations. 

2nd Question

Chemical Phenomenon Level	Steps to solve the problem	Answer category				
		Very bad	**Bad**	**Enough**	**Good**	**Very well**
Macroscopic	Making choices mathematically by determining the difference	Can't answer.	Wrong answer. 	Explain conceptually understanding theory.	The answer is correct but does not use mathematical calculations.	Correct answer using mathematical calculations.

Chemical Phenomenon Level	Steps to solve the problem	Answer category				
		Very bad	**Bad**	**Enough**	**Good**	**Very well**
	in electronegativity					
Submacroscopic	Describe the Lewis structure	Can't draw. 	Wrong answer. 	Can answer and draw Lewis structures, but misinterprets.. 	Drawing of Lewis structure but incomplete. 	Correct answer using mathematical calculations. 

3rd Question

Chemical Phenomenon Level	Steps to solve the problem	Answer category				
		Very bad	**Bad**	**Enough**	**Good**	**Very well**
Macroscopic	Deciphering logically by combining the concept of covalent bonds	Can't answer.	Wrong answer. 	The answer is close to the truth scientifically. 	The answer is correct but incomplete with an illustration of the polarity of a compound. 	Answers are correct and appropriate according to science. 
Submacroscopic	Describe hydrogen bonds in water and oil molecules	Can't draw.	Wrong answer. 	Misinterpreted. 	The answer is close to the truth scientifically. 	The picture is in accordance with the theory and scientifically correct. But no one can answer correctly.

Furthermore, the answers above are assessed based on the level of students' understanding of the concept of covalent bonds according to the level of chemical phenomena shown in table 4 and figure 3.

Table 4. Percentage of Number of Students Based on Score Answers to Questions

School name / Province	Questions answer based on the level of Chemical Phenomena (Mental Model Assessment Rubric)									
	Question 1 (number of students)					Question 2 (number of students)				
	Excellent	Fair	Good	Enough	Poor	Excellent	Fair	Good	Enough	Poor
P1S1	0%	4%	26%	41%	30%	0%	15%	26%	59%	0%
P2S1	0%	58%	21%	16%	5%	0%	58%	16%	26%	0%
P2S2	0%	33%	48%	19%	0%	0%	24%	48%	29%	0%
P3S1	8%	76%	4%	12%	0%	0%	108%	32%	0%	0%
P3S2	0%	23%	61%	12%	0%	0%	19%	54%	27%	0%
P3S3	0%	18%	5%	18%	59%	0%	18%	9%	0%	73%
P4S1	0%	12%	6%	76%	6%	0%	21%	9%	45%	24%
P4S2	0%	47%	16%	37%	0%	0%	53%	26%	21%	0%
P5S1	29%	32%	11%	18%	11%	7%	43%	25%	14%	11%
P5S2	5%	25%	40%	30%	0%	5%	20%	40%	30%	5%

School name / Province	Questions answer based on the level of Chemical Phenomena (Mental Model Assessment Rubric)				
	Question 3 (number of students)				
	Excellent	Fair	Good	Enough	Poor
P1S1	0%	7%	7%	81%	4%
P2S1	0%	47%	26%	21%	5%
P2S2	0%	10%	81%	10%	0%
P3S1	0%	60%	36%	0%	4%
P3S2	0%	12%	81%	8%	0%
P3S3	0%	14%	23%	55%	9%
P4S1	0%	39%	36%	18%	7%
P4S2	0%	15%	45%	35%	5%
P5S1	0%	63%	11%	26%	0%
P5S2	0%	6%	30%	42%	21%

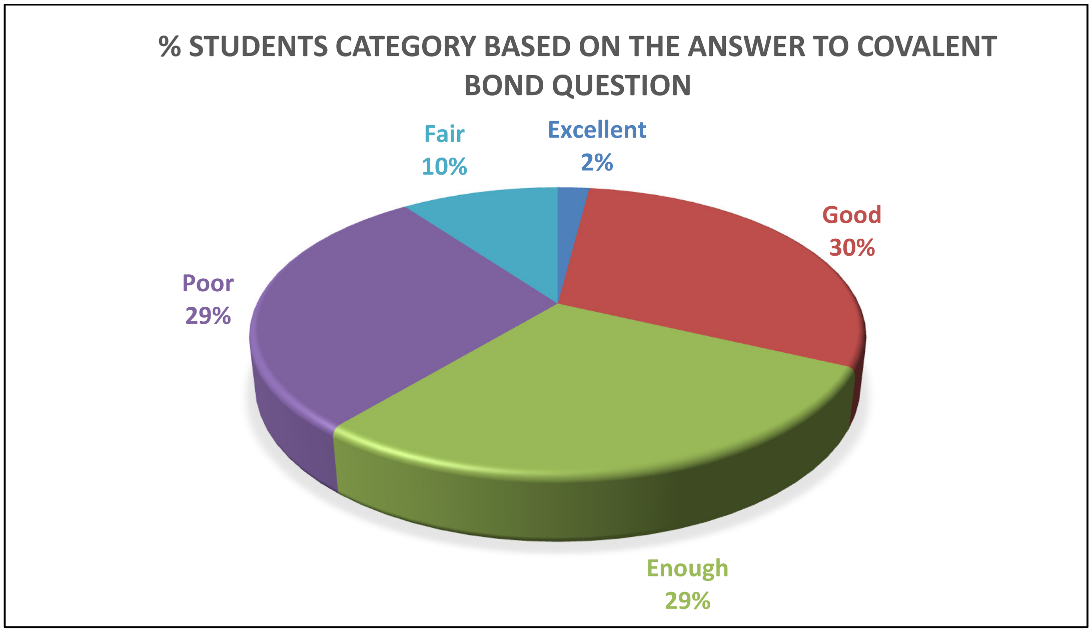


FIGURE 3. Grouping of Students Based on the Answers to the Covalent Bond Question

Understanding the review Covalent Bonds Based on Level Three Phenomena Chemistry Through Interview

Researchers conducted interviews to review the level of students' understanding of the answers. Additionally, the researchers want to make sure that the students do the work independently and the answer given was valid. It is caused by is the work being online.

The interview has the potential and the opportunity to obtain information on the level of students' mental models. Students have the opportunity to express their perspectives through their eyes based on the level of student understanding (11).

Grouping of students based on scores in diagram 1 above, namely Group A (group of students who are excellent and well worth), Group B (the group of students that is worth being), and Group C (the group of students that is worth bad and very bad). Here is the translation of the interview on the answers to questions submitted by students.

Group A

I: *What are your thoughts about the relationship between electronegativity and the covalent properties of a compound?*

- SA1: Good Afternoon sir. Yes sir. In my humble opinion, It's measured by the difference in electronegativity, sir. If the electronegativity difference is large, then the covalent characteristic is not large, how say it. I think it is more covalent if the difference in electronegativity is smaller.
- SA2: I could be wrong but the questions given are too difficult and understandable. I asked my friend about 3 questions such as 3, 4, and 5. I don't understand the material and the presentation language is unclear, sir. I searched the internet for answers to difficult questions. I have never received an explanation like this at school because learning is still online.
- SA3: Sorry, sir. Honestly, I searched all the answers from the internet, sir. I understood some of the questions and I tried to search also from the internet. I think these questions were difficult, sir.

I: *Can you explain the answers to the pictures in the 2 questions you gave? Does the picture make it easier for you to understand covalent bonds?*

- SA1: I forgot to draw a covalent bond. As far as I remember, there are 2 types of covalent, namely single and triple covalent. In my opinion, the questions with pictures make it easier for me to understand the meaning of the questions. I have a hard time understanding without a lewis structure drawing, sir.
- SA2: I quite understand how to describe Lewis structures because I've watched it on youtube. But, I have forgotten because I have not reviewed this topic. I don't understand the narrative. I need someone who can explain in detail or through animation. The teacher described it on the blackboard so that I could better understand the material.
- SA3: It's easier, sir. It's easier for me to understand from pictures and this is very helpful. Although this research was difficult due to online learning conditions.

I: *Can you give an illustration of why oil cannot solve in water?*

- SA1: Water and oil don't mix because of their molecular nature, sir. Water is a polar molecule so one end is positively charged and the other is negatively charged. This is different from oil because oil is a nonpolar molecule.
- SA2: Yes, sir. Question number 5 is about water and oil. Water and oil don't mix, sir. Water has positive and negative poles, resulting in an attractive force between these two compounds. This is different from oil. Oil is a nonpolar molecule. If we want to combine other compounds with water, then the compound must be a polar molecule. I took a figure of Lewis structures on the internet, sir.

Group B

I: *Can you answer 2 questions from the questions that have been given to you? What is the reason?*

- SA1: Evening too, sir. Silicon chloride in liquid form. Therefore, there is a difference in electronegativity. This causes silicon chloride to be more covalent because it has a smaller electronegativity than boron or barium compounds. Sorry sir, I forgot boron. Compounds are liquids because of the attractive forces between molecules.
- SA2: Yes sir. I haven't studied this topic, sir. I'm still learning the basics so I'm having a hard time understanding this topic. Because I'm self-taught, sir. If the teacher explains it offline, I will understand this material, sir. But, online learning because it's online so I'm having a hard time. There are hard and easy lessons, sir. If I have understood the lesson, the lesson feels easy and fun. However, if I don't understand the lesson, the lesson will be very difficult, sir.
- SA3: Sorry, sir. I looked for the answer on the internet last time, sir. In my opinion, the questions were difficult so I looked on the internet. Honestly, I do not understand this material, sir.

I: *Can you explain single, triple, and ionic covalent bonds?*

- SA1: Single covalent bond and triple covalent bond, I still don't understand, sir. I don't understand because I'm looking for an answer from google, sir. I'm browsing the Lewis structure because I don't understand it. I did not understand from the beginning of the lesson because it was difficult to understand the explanation, sir.
- SA2 : Rank covalent bond. (fall silent). I don't understand sir.
- SA3: Honestly, I don't know much, sir. I find it difficult to answer even though this material has been studied. We're still learning online so it's hard to understand, sir. If only offline learning, it would be easier for me to understand because the teacher explained directly.

.

I: *Can you answer the question about why oil and water don't mix?*

- SA1: Honestly, I'm looking for answers from google sir. I understand a little that this is due to the difference between polar and nonpolar, sir. This makes it difficult for oil and water to mix. But if my drawing can only describe the Lewis structure for water, sir (pause).
- SA2: Yes, sir. I can. This is because oil and water have different molecular properties. Oil does not have positive ionic bonds and negative ions so it can not be fused. If I don't understand the picture and I'm looking for an answer from Google, sir.

Group C

I: *Can you explain the meaning of a covalent bond?*

- SA1: I don't understand, it's difficult and I haven't received this material, even though I have received the report card. So far online, this material has never been explained. So, I don't understand at all, sir.
- SA2: Understood, sir. Forgot the covalent bond, sir. This material has been studied for a long time and I have forgotten, sir.
- SA3: Difficult, sir. I have a hard time understanding it. It's hard to understand in my head. Covalent bond (quiet). I forgot that, sir. Master once explained it, but it was very difficult for me.

I: *Why can't you answer the question no. 3 and 4?*

- SA1: Yes, sir. I don't understand this question. I find it very difficult to answer. Maybe because I don't understand, sir.
- SA2: I find it difficult to answer.
- SA3: I ran out of time doing that. So, I can't answer. I'm not good at chemistry, sir.

I: Do you think oil and water can be combined?

- SA1: No, sir. Water and oil don't mix because they have different molecular properties, sir. I'm confused, sir.
- SA2: In my opinion, we cannot unite, sir. But, I don't understand the reason why they can't unite. I don't understand describing oil molecules, sir (pause).
- SA3: Sorry, sir. I know that oil and water don't mix. However, I don't know what the cause is because I still don't understand the material of chemical bonds online, sir.

Based on the results of the mental model test and interview, the criteria for the mental model of class X students were taken randomly as a sample from 5 provinces in Indonesia (32). The results of the mental model of class X high school students can be seen in figure 4 below :

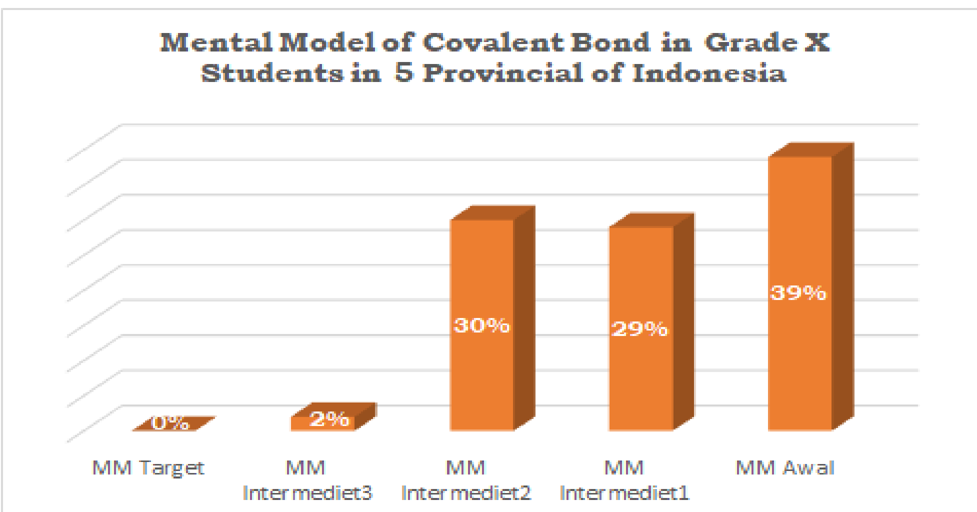


FIGURE 4. The mental model of Covalent Bond in Grade X Students in 5 Provincial of Indonesia

Discussion

Based on Figure 3, the researcher found 32% of students in excellent and satisfactory categories. Students have the best and above-average abilities. Students can explain the concept of covalent bonds and describe the Lewis structure of the compound that formed correctly (see table 3). In addition, students categorized in the excellent category said that they did not understand the material. Students look for answers from the internet.

Researchers found that 26% of students were in a medium category who did not understand the material and looked for answers from the internet. Students can answer the questions given and can describe the Lewis structure almost accurately (Table 3).

The researcher found that 39% of students were in a poor category who were needy explaining the concept of covalent bonds and were unable to describe the Lewis structure correctly (Table 3). Based on the results of interviews with students in this poor category, students do not seem to have a good understanding of covalent bonds and Lewis structures.

Based on the discussion and research's result explained, chemical bonds and covalent bonds are difficult to understand by students in representatives of 5 provinces in Indonesia. This result is reinforced by the results of research (4) states that chemical bonds are difficult to understand and learn by students in all categories in several schools in Lampung.

In addition, other studies support the results of this study (33) that some high school students in Turkey still have wrong concepts about chemical bonds and covalent bonds. Based on the student interviews results, It was be known some difficulties and misunderstandings in online learning. Students had difficulty understanding abstract concepts without the help of the teacher. This is supported by research on some teachers who reject online learning. Student involvement is less online than offline learning (34).

Researchers do not link the level of success with student failure in terms of academic achievement. The researcher only wanted to know the students' mental model of the concept of a covalent bond material in the era of the covid19 pandemic.

The researcher can describe it. According to the mental model's theory to explain the mental model of students of 5 provinces in Indonesia. According to Sunyono (5), the mental model in learning is a model expressed by students on the concepts of the subject matter they have learned and the ability to respond to the questions asked. This study reveals the same theory as above the result, to see students' responses to the questions posed as students' mental model's representation. Based on the answers given and the category scores of students' answers in this study, the researchers found several mental models of students in understanding the concept of covalent bond material (35). In the group, A category as many as 32% of students have a second-intermediate in the mental model. It can see through the explanation of the concepts and pictures provided that are close to scientific truth. Although the results of the students' answer sheets in this group are correct, the researcher concludes that the answers given are not purely from students' concepts because students take answers via the internet and other sources.

Group B category is 29% of students have an intermediate level mental model 1. It can be known mental model has been formed as the explanation of the concept given is close to the truth. However, the illustrated image is still not quite right.

Group C category is 39% of students have an initial mental model and did not detect. Students in this category have poor abilities and are very poor at understanding the material presented. It observed that the concepts and pictures given are inaccurate and do not fit the theory. Students have absolutely no conceptual and cannot answer the questions given.

Teachers need to know students' mental models. It means teachers can make better and more appropriate learning strategies for learning chemical bonds and covalent bonds. According to Senge (36), the difficulty in building a mental model results in a person having difficulty in developing thinking skills so it is a problem to do problem-solving well.

CONCLUSION

Based on the results of the research, the researchers can conclude as follows: (1) The mental model in covalent bond learning by students classified into three categories is a second intermediate-level mental model by 35%, a first intermediate-level mental model by 26%, and the initial mental model by 39%. (2) Students still need to build and redevelop mental models in learning covalent bonds. (3) Difficulty in learning by being one of the inhibiting factors for students' understanding of the material of chemical and covalent bonds. (4) Teachers can use the student's mental models to choose the right learning strategies in improving students' internal and external representation.

REFERENCES

1. Effendy. A-level chemistry for senior high school students. Malang: Bayumedia; 2008.
2. Gilbert JK, Treagust DF. Multiple representations in chemicals education. Vol. 4, Journal of Chemical Information and Modeling. 2009. 1–367 p.
3. Lathifa U. Improving chemistry teacher candidates' mental models in the kinetics course using SiMaYang type II learning. J Phys Conf Ser. 2020;1594(1).
4. Sunyono, Yuanita L, Ibrahim M. Supporting Students in Learning with Multiple Representation to Improve Student Mental Models on Atomic Structure Concepts. 2015;26(2):104–25.
5. Suryani I, Sunyono, Efkar T. Pembelajaran Model SiMaYang Tipe II untuk Meningkatkan Model Mental dan Penguasaan Konsep Sisw. J Pendidik dan Pembelajaran Kim. 2015;4(3):807–19.
6. Farida I, Liliasari, Sopandi W. Pembelajaran Berbasis Web untuk Meningkatkan Kemampuan Interkoneksi Multiplelevel Representasi Mahasiswa Calon Guru pada Topik Kesetimbangan Larutan Asam-Basa The Implementation of web-based Learning to Enhance Interconnection of Multiple Levels of Repres. J Chem. 2011;12:14–24.
7. Farida I, Helsy I, Fitriani I, Ramdhani MA. Learning Material of Chemistry in High School Using Multiple Representations. IOP Conf Ser Mater Sci Eng. 2018;288(1).
8. Nurhalimah SR, Suhartono S, Cahyana U. Jurnal Riset Pendidikan Kimia ARTICLE. J Ris Pendidik Kim [Internet]. 2017;7(1):38–51. Available from: http://journal.unj.ac.id/unj/index.php/jrpk/article/view/3067
9. Lin CY, Wu HK. Effects of different ways of using visualizations on high school students' electrochemistry conceptual understanding and motivation towards chemistry learning. Chem Educ Res Pract. 2021;22(3):786–801.
10. Bergqvist A, Chang Rundgren S-N. The influence of textbooks on teachers' knowledge of chemical bonding representations relative to students' difficulties understanding. Res Sci Technol Educ. 2017;35(2).
11. Lajium D. Students' mental models of chemical reactions. Waikato J Educ. 2013;18(2).
12. Park EJ. Student perception and conceptual development as represented by student mental models of atomic structure. 2006. 226 p.
13. Wang C-Y. The role of mental-modeling ability, content knowledge, and mental models in general chemistry students' understanding of molecular polarity. [Internet]. Vol. 70, Disertasi. 2007. 835 p. Available from: http://gateway.proquest.com/openurl?url_ver=Z39.88-2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&res_dat=xri:pqdiss&rft_dat=xri:pqdiss:3351673%5Cn http://ovidsp.ovid.com/ovidweb.cgi?T=JS&PAGE=reference&D=psyc6&NEWS=N&AN=2009-99170-580
14. Halim NDA, Ali MB, Yahaya N, Said MNHM. Mental Model in Learning Chemical Bonding: A Preliminary Study. Procedia - Soc Behav Sci [Internet]. 2013;97:224–8. Available from: http://dx.doi.org/10.1016/j.sbspro.2013.10.226
15. Sarawan S, Yuenyong C. Thai students' mental model of chemical bonding. AIP Conf Proc. 2018;1923(February).
16. Hidayat J, Firman H, Sunarya Y, Redjeki S. The profile of high school student's mental model on chemical bonding concept. 2019;
17. Kozma RB, Russell J. Multimedia and Understanding: Expert and Novice Responses to Different Representations of Chemical Phenomena. J Res Sci Teach. 1997;34(9):949–68.
18. Zohar AR, Levy ST. Students' reasoning about chemical bonding: The lacuna of repulsion. J Res Sci Teach. 2019;56(7):881–904.
19. Sunyono S, Sudjarwo S. Mental models of atomic structure concepts of 11th-grade chemistry students. Asia-Pacific Forum Sci Learn Teach. 2018;19(1):1–21.
20. Chittleborough, Gail, and Treagust DF. The Role Of Teaching Models And Chemical Representation In Developing Mental Models Of Chemical Phenomena. 2007, Interrelated between Innov Mark Oriental SMEs, Manag Res news, vol 30, no 12, pp 878-891. 2007;30(12):878–91.
21. Turner KL. A Cost-Effective Physical Modeling Exercise to Develop Students' Understanding of Covalent Bonding. J Chem Educ. 2016;93(6):1073–80.
22. Anwar K, Sunyono, Kadaritna N. Pembelajaran Model SiMaYang Tipe II untuk Meningkatkan Model Mental dan Penguasaan Konsep. J Pendidik dan Pembelajaran Kim. 2015;4(3):795–806.
23. Jones LL, Jordan KD, Stillings NA. Molecular visualization in chemistry education: The role of multidisciplinary collaboration. Chem Educ Res Pract. 2005;6(3):136–49.

24. Mitrevski B. Prospective science teachers' views about models and modeling. J Phys Conf Ser. 2021;1882(1).
25. Harrison AG, Treagust DF. Modeling in Science Lessons: Are There Better Ways to Learn With Models? Sch Sci Math. 1998;98(8):420–9.
26. Coll RK. Chemistry learners preferred mental models for chemical bonding. J Turkish Sci Educ. 2008;5(1):22–47.
27. Gilbert JK. Models and modeling: Routes to more authentic science education. Int J Sci Math Educ. 2004;2(2):115–30.
28. Hafner R, Stewart J. Revising explanatory models to accommodate anomalous genetic phenomena: Problem-solving in the "context of discovery." Sci Educ Int. 1995;79(2).
29. Rapp DN. David N Rapp Chapter 3 Mental Models : Theoretical Issues for Visualizations in Science Education. Science (80-). 2005;43–60.
30. Gilbert JK, Boulter C, Rutherford M. Models in explanations, Part 1: Horses for courses? Int J Sci Educ. 1998;20(1).
31. Coll RK, Treagust DF. Investigation of secondary school, undergraduate, and graduate learners' mental models of ionic bonding. J Res Sci Teach. 2003;40(5):464–86.
32. Sunyono. Model Multi Representasi. 2015. 1–105 p.
33. Kiray SA. The Pre-service Science Teachers' Mental Models for Concept of Atoms and Learning Difficulties. Int J Educ Math Sci Technol. 2016;4(2):147.
34. Lapitan LD, Tiangco CE, Sumalinog DAG, Sabarillo NS, Diaz JM. An effective blended online teaching and learning strategy during the COVID-19 pandemic. Educ Chem Eng [Internet]. 2021;35(May 2020):116–31. Available from: https://doi.org/10.1016/j.ece.2021.01.012
35. Sarawan S, Yuenyong C. Thai students' mental model of chemical bonding. AIP Conf Proc. 2018;1923(January).
36. Senge PM. The fifth discipline: the art and practice of the learning organization. Vol. 44, Choice Reviews Online. 2007. p. 44-2797-44–2797.