JPPS (Jurnal Penelitian Pendidikan Sains)
Homepage : https://journal.unesa.ac.id/index.php/jpps
Email : jpps@unesa.ac.id

p-ISSN : 2089-1776 ; e-ISSN : 2549-1597
JPPS, Vol. 11, No. 2, May 2022 : 113-129

(Jurnal Penelitian Pendidikan Sains)

Mental Models In Chemistry: Prospective Chemistry Teachers' Mental Models of Chemical Equilibrium

Kelly Sinaga
Universitas Pelita Harapan, Tangerang, Indonesia

DOI : https://doi.org/10.26740/jpps.v11n2.p113-129

Sections Info

Article history:
Submitted: May 18, 2022
Final Revised: May 25, 2022
Accepted: May 26, 2022
Published: May 29, 2022

Keywords:
Chemistry
Chemical equilibrium
Mental models
Prospective chemistry teachers

ABSTRACT

In this study, we described research into prospective chemistry teachers' mental models for chemical equilibrium. This research aimed to describe the profile of prospective chemistry teachers' mental models of chemical equilibrium. This study was held at one university in Tangerang. The subjects in this study were 22 students. The method used is the descriptive research method, using diagnostic tests as a research instrument. The research outcome showed 59.42% for the macroscopic stage, 51.34% sub-microscopic stage, and 66.18% symbolic stage. This outcome showed the variety of the understanding of prospective chemistry teachers for every level of chemical representation but generally, the understanding at the submicroscopic level was still relatively low. The profile of the mental models at each level of representation showed varied results but on average has a higher percentage in the Phenomenon Model and the Character-Symbol Model. The category of mental models at each level of representation mainly shows a linkage between the characteristic of the level of representation and the students' mental model type. The result of this work point to the need of developing a learning strategy that accommodates the multiple representations. The next study also should recognize that sub-microscopic level representation is very important as this level help the students understand the scientific concept and give the correct explanation to chemical phenomena and reduce the misconception.

INTRODUCTION

Chemistry is defined as the study of the structure of matter and the changes that undergo in natural processes and also in planned experiments (Landa et al., 2020) which are studied through the scientific method (Fernández-González, 2013; Hono et al., 2017). Furthermore, the concept of chemistry plays important role in chemistry as a strong foundation for students to carry out their next proper learning (Wu et al., 2021). The characteristics of chemistry are demonstrated by the chemical multiple representational that consists of macroscopic level, sub-microscopic level, and symbolic levels (Johnstone, 1991). Students are required to have a complete understanding of the subject matter of chemistry. Holistic understanding is produced when students can use and link the multiple representations, macroscopic, sub-microscopic, and symbolic in the learning process (Farida et al., 2011). Mastery of concepts in learning chemistry is significant (Avargil, 2019) as the concept is connected tightly one to another (Irawati, 2019). However, students will always have any prior knowledge, where among that are life experiences connect to scientific phenomena before reaching the scientific source (Cetin et al., 2015).

Previous studies have highlighted three levels of expression in chemistry (Taber, 2013) at list: (1) Macroscopic level; It describes the phenomena that can be observed through observation and It appears in the learner's daily experience as the learner observes changes in the properties of the substance like color change, gas formation, and precipitation in chemical reactions. (2) Submicroscopic level; Also known as the molecular view, it explains the particle stage where a substance consists of a single particle. The sub-microscopic level is closely related to the theoretical explanation of underlying phenomena at the molecular or particle level. (3) The macroscopic level and sub-microscopic could be stated symbolically. The symbolic stage includes the use of symbols in chemistry, equations, formulas, diagrams of molecular structure, diagrams, and symbols of substances. It gives data both macroscopically (number of substances used) and molecular stage (the number of matter used). When students can explain the three levels of representation and link them, then they could fully explain both phenomena and concepts that are associated with these phenomena. The three-level of representations relate to each other, represented in the triangle diagram that is the Johnstone triangle, as shown in Figure 1 (Johnstone, 2009).

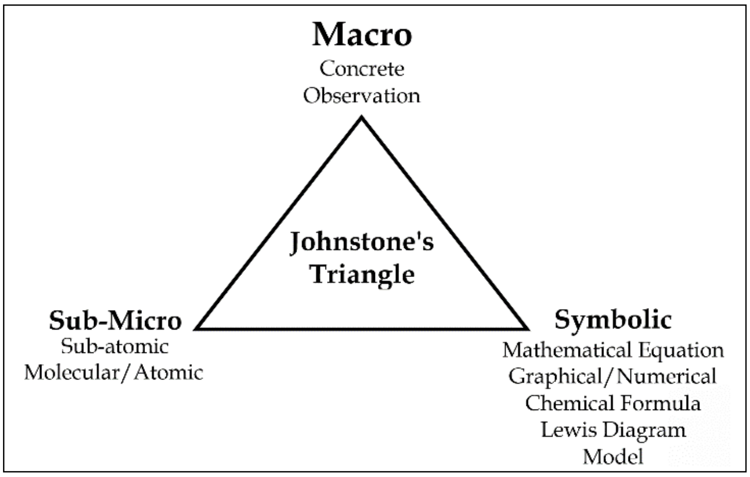


Figure 1. The chemistry triple representation.

Mental models represent the objects, ideas, thoughts, or processes of each individual that are used to describe and explain a phenomenon when studying science (Jansoon et al., 2009; Liu et al., 2014). Mental models are formed from experience, interpretations, and descriptions when studying chemistry. Mental models usually develop according to their needs in making predictions and solving problems in learning chemistry (Halim et al., 2013). The use of models is to build, explain, and make hypotheses for the prediction of scientific phenomena, processes, or systems. Mental models could come in some shapes to convey ideas and solve problems for others (Ibrahim & Rebello, 2013). Mental models are essentially used to predict and solve problems in chemistry (Chittleborough, 2004). It means when students hold a whole mental model, they will be able to make good explanations about problems in chemistry, on the contrary, if students have wrong or incomplete mental models, students will have difficulty solving chemical problems or even have misconceptions. Therefore, it is very important in building a complete mental model for students.

Mental models can be thought of as a significant part of building students' conceptual frameworks as well as have a qualified task in chemistry study for the molecular stage because many chemicals are involved at the molecular (microscopic) level which cannot be reached through direct perception (Bodner & Domin, 2000). Explaining the phenomena at a macroscopic stage continues to the sub-microscopic and symbolic stage. This process known as ITLS (Interdependence of Three Levels of Science) Concepts model described by Detevak as shown in Figure 2 to give an explanation of the relationships among these levels and the mental model as an integrated part that can keep knowledge into long-term memory (Devetak, 2005).

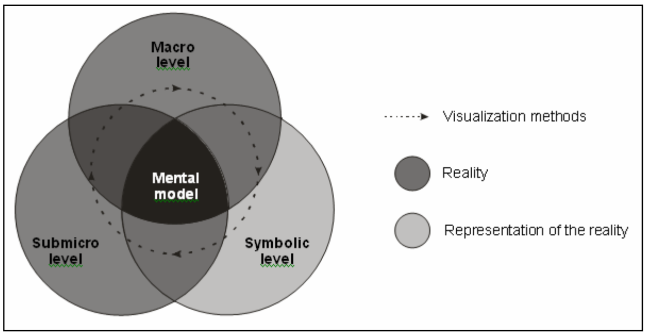


Figure 2. The ITLS concepts model.

The integrity of the mental model in chemistry can be seen in the ability of students to explain a chemical phenomenon in all types of representation. This is because chemistry is composed of concrete and abstract concepts so the connection between the three representations will lead to understanding in chemistry (Jansoon et al., 2009). The three levels of representation have an impact on students' mental models (Halim et al., 2013). The formation of a complete mental model of students, one of which is the role of the teacher as a student educator during learning. The teacher's teaching strategy and the processing of the teacher's teaching materials greatly affect the development of the students' mental models, so in building a complete student mental model, the teacher must create appropriate learning strategies.

One of the ways to create the right strategy can be supported by the teacher's knowledge of students' initial mental models. The initial mental model can provide an overview of how students process the information that has been given in solving chemical problems so that teachers can find out students' difficulties and even misconceptions that students usually have. Armed with this knowledge, the teacher improves the way of teaching and processing teaching materials. The importance of knowledge about students' mental models can also be seen in the many studies that have been carried out in analyzing students' mental models on chemical concepts such as the concepts of hydrolysis, thermochemistry, chemical bonds, and solubility.

Previous research on mental models gives various results. The application of experiments using an inquiry learning approach gives a positive impact on students' mental models of related concepts (Supasorn, 2015). The alternative mental models on the topic of electrolyte and nonelectrolyte solutions (Suja et al., 2021). The students' mental models for the atomic structure were not coherent for different everyday contexts (Zarkadis et al., 2017). A connection between participants with more sophisticated to their variate reasoning (Wright & Oliver-Hoyo, 2020). The idea of using Augmented Reality (AR) to enhance mental model chemistry (Latipah et al., 2021).

In this study, the material raised by the researcher is a chemical equilibrium. Research on mental models on the concept of chemical equilibrium is still limited even though the topic of chemical equilibrium include as one of the important concepts that need to teach to students because it relates a lot to other chemical concepts. The concept of chemical equilibrium is one of the concepts that are difficult to teach or learn because the concept is related to several other concepts such as oxidation-reduction, acid-base, and reaction rate and requires the use of representations at the level of macro, micro, and symbolic

(Mensah & Morabe, 2018). The results of other studies also show that many students at different age levels have many misconceptions about the concept of chemical equilibrium (Ulinnaja, 2019). Based on the importance of growing students' mental models intact, the importance of knowledge of students' initial mental models, and the limited research on students' mental models on the material chemical equilibrium, it is necessary to research Student Mental Model Profile on Equilibrium Material.

Research on prospective chemistry teachers' mental models of the chemical equilibrium is important to conduct as they are the future teacher later. Prospective chemistry teachers should build the correct mental model because they will transmit it to their students through their teaching. The teacher needs to know how the construction of mental models by the students so they can avoid constructing the wrong mental models because it is important in learning Chemistry (Coll, 2008; Nahum et al., 2004). The knowledge of students' mental models is significant as teachers use increasingly complex models throughout the degree program (Johnson-Laird, 1983; Vosniadou, 1994). Based on that thought, this study aimed to analyze the profile of the initial mental model of prospective chemistry teachers on the topic of chemical equilibrium.

RESEARCH METHOD

Participants

The subjects of this research were all the prospective student teachers in their second year of a four-year study in the Chemistry Education Study Program at one of University in Tangerang. All the students took General Chemistry and Fundamentals of Chemistry courses in two semesters. Each course involved two 50 minutes lectures and three 50 minutes of laboratory sessions per week and was compulsory for all undergraduate students in the second and third year, respectively. All the students enrolled in the courses had completed the study of the chemical equilibrium concept, which was discussed in Fundamentals of Chemistry in the third semester.

Instrument and Procedures

This study was conducted using a descriptive method. This research describes the prospective chemistry teachers' mental model profile on the topic of chemical equilibrium using descriptive research methods. The instrument test uses a diagnostic test to construct a profile of a student's mental model on the subject of chemical balance. Diagnostic tests are the instrument to find the weaknesses students understand and supply suitable remedies based on the weaknesses (Arikunto, 2009). Procedure of tis research could be found at Figure 3.

The diagnostic test used in this research is an open question (accompanied by pictures and description). This instrument uses open-ended questions to find data that describe the three representations of chemistry. Along with that, the mental model's category will be defined based on their responses. The description of students' understanding of the topic of chemical equilibrium in all categories of representations is based on predetermined learning indicators. The learning indicators derive into indicators to evaluate students' understanding of the chemical equilibrium topic in terms of macroscopic, submicroscopic, and symbolic levels. All questions in the mental model diagnostic test have been declared valid by two chemistry education lecturers at Pelita Harapan University and also have good reliability.

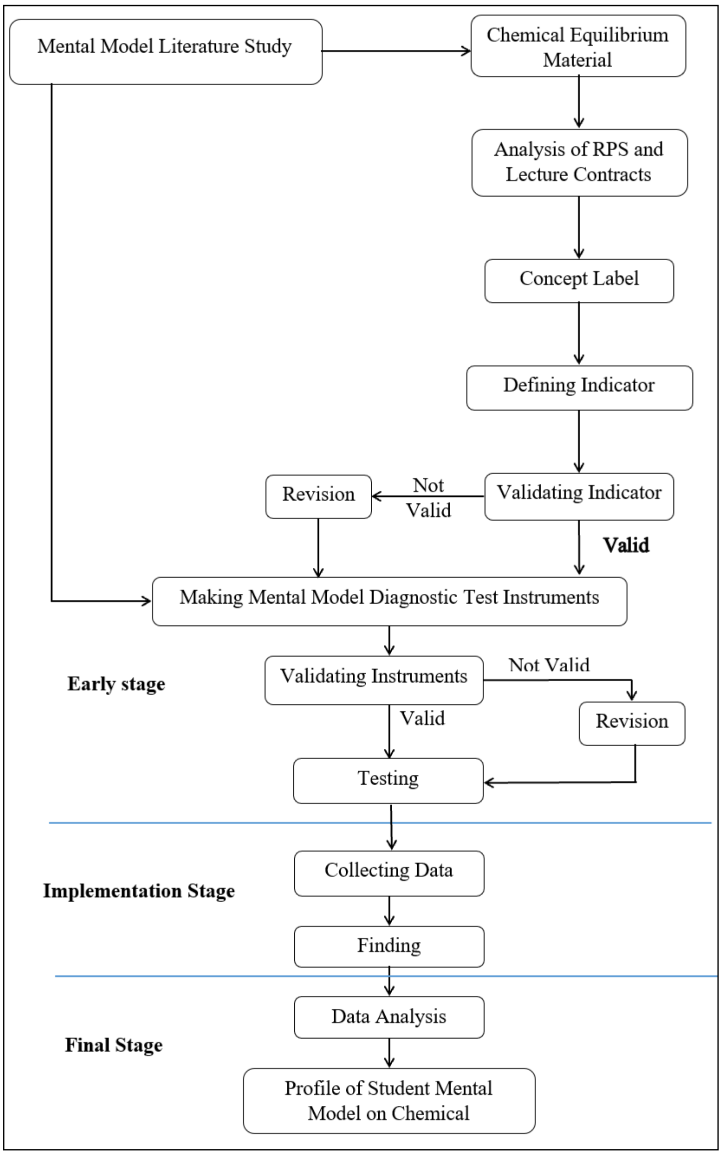


Figure 3. Research flowchart.

Table 1. Learning indicators with indicators of diagnostic test question items and its representation.

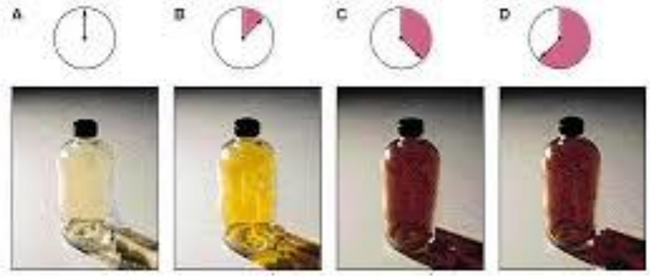
Learning Indicator	Indicator Item Problem	Representation
Understand the concept of dynamic equilibrium	▪ Estimating the substances present when equilibrium is reached ▪ Explain the process of achieving equilibrium and the conditions at which equilibrium is achieved based on changes in the composition of the molecule and the color of the reaction mixture as long as the reaction takes place	▪ Macroscopic ▪ Sub-microscopic
Understanding the concentration equilibrium constant, K_c	▪ Determine the equilibrium constant mathematical equation based on the reaction equation ▪ Calculates the value of the concentration equilibrium constant, K_c, based on data on	▪ Symbolic ▪ Symbolic

Learning Indicator	Indicator Item Problem	Representation
	the number of substances before and after equilibrium is reached ▪ Calculates the value of the concentration equilibrium constant, K_c, based on data on the number of substances before equilibrium is reached in several experiments	▪ Sub-microscopic
Understanding the pressure equilibrium constant, K_p, and its relation with K_c	▪ Calculates the value of the partial pressure equilibrium constant, K_p, based on the equilibrium constant value of concentration, K_c, at the same temperature of a reaction ▪ Formulate an equation that states the relationship between K_c and K_p of a reaction equation ▪ Calculates the value of the partial pressure constant, K_p, based on the quantity data the value of the equilibrium constant, K_c	▪ Symbolic ▪ Symbolic ▪ Symbolic
Understanding the quotient reaction	▪ Calculating the value of the reaction community, Q, based on data on the concentration of substances in a reaction ▪ Estimate whether or not equilibrium is achieved in a reaction based on the data of the value of the reaction cient, Q, to the value of the concentration equilibrium constant, K_c ▪ Predict the movement of a reaction to achieve equilibrium based on the data quantity of the reaction cient, Q, to the value of the concentration equilibrium constant, K_c	▪ Symbolic ▪ Sub-microscopic ▪ Sub-microscopic
Predict the equilibrium shifting when concentration increase or decrease	▪ Estimate the direction of the equilibrium shift when the reactant concentration is added ▪ Describe changes in the concentration of substances when there is a shift in equilibrium due to the addition of the concentrations of one of the reactants	▪ Macroscopic ▪ Symbolic
Predict the equilibrium shifting when pressure increase or decrease	▪ Describe the process of shifting equilibrium when system pressure is added ▪ Describe changes in the concentration of substances when there is a shift in equilibrium due to the addition of system pressure	▪ Sub-microscopic ▪ Symbolic
Predict the direction of the equilibrium shift when temperature increase	▪ Describe the process of shifting equilibrium when system pressure is added ▪ Describes changes in the concentration of substances when there is a shift in equilibrium as the temperature is raised	▪ Macroscopic ▪ Symbolic

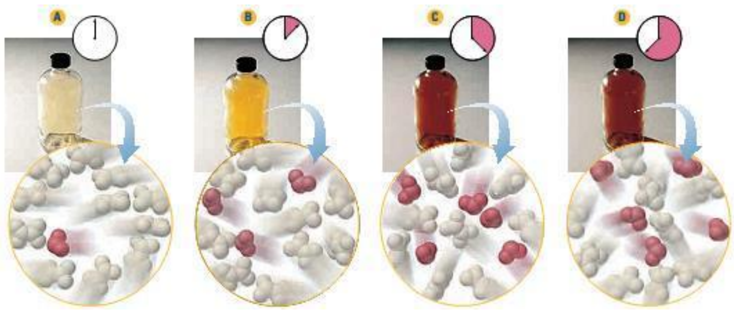
Here are one example questions that can access three levels of student representation according to indicators that have been compiled. The question in this diagnostic test has passed the content validation stage carried out by two experts and declared valid.

Below is a reversible chemical reaction at 25°C:

$$N_2O_{4(g)} \leftrightarrows 2NO_{2(g)}$$



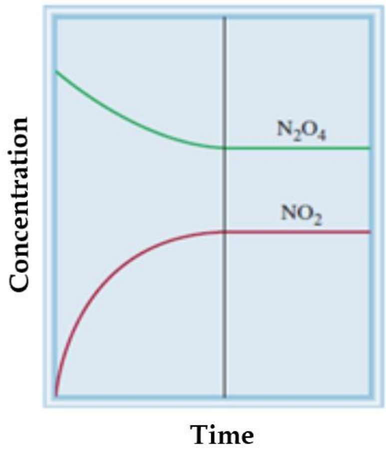
a) What gas is present when equilibrium is reached?
b) Briefly explain the reasons behind your answer. Use the image below to help with your explanation.



Description:

 : NO_2 molecule

 : N_2O_4 molecule



c) State the equilibrium constant for the reaction mathematically.
d) In an experiment at a temperature of 25°C there are 0.670 M of N_2O_4 gas. After equilibrium is reached, 0.0547 M of NO_2 gas is obtained. Calculate the value of the constant, K_c for the reaction equilibrium.
e) Here are some data on different initial concentrations for each component in the $N_2O_{4(g)} \leftrightarrows 2NO_{2(g)}$ reaction which takes place at 25°C.

Experiment	Experiment 1st	Experiment 2nd	Experiment 3rd
$[N_2O_4]$	0.500	0.600	0.000
$[NO_2]$	0.0300	0.0400	0.200

Based on the above data, estimate the value of the equilibrium constant, K_c for the reaction. How is the value of K_c compared to part d, is it "same", "larger" or "smaller". Give a brief explanation of your answer!

f) Based on the value of K_c obtained in section d, calculate the value of K_p at the same temperature. It is known that R = 0.0821 L.atm/K.mol.

Data Analysis

The diagnostic test results are put into groups based on similar responses into categories, calculate percentages for each category, and interpret student percentages in a descriptive format that includes student understanding and mental model categories at each level of chemical expression. They have to be analyzed by doing. Mental model categories follow the Lin and Chiu categories: Scientific Model (SM), Phenomenon Model (PM), Character Symbol Model (CSM), and Inference Model (IM) (Lin & Chiu, 2007; Taber, 2009). The Mental Model category of Student Chemistry Teachers of Chemistry Equilibrium describes how a picture of a general study emerges from the perspective of a student chemistry teacher's understanding of chemistry equilibrium from three levels of chemical expression. The mental model is intended to provide an overview of the contribution of chemical understanding to the three chemical expressions (Jansoon et al., 2009). The insights gained relate to the description of categories of student mental models and the relationship between the levels of chemical representation along with the student mental models category.

RESULTS AND DISCUSSION

Chemistry learning will be better if studied from the multiple representation perspective: macroscopic, sub-microscopic, and symbolic. These multiple representations are interrelated and help students understand the scientific phenomena. Chemical representation plays an important part in studying chemistry. Representation at the macroscopic level focus on what is visible. At this stage, students learn about scientific phenomena occurring. This phenomenon happens at a sub-microscopic stage where all particles interact with each other but it is invisible and can not be observed. This state will lead the abstract chemistry concepts and it is the key to making scientific explanations. The description of phenomena at this level will be put into concepts, theories, and principles that can describe the phenomena at the macroscopic level, using the description of electron flow, and other particle interactions. The representation at the symbolic level involved equations in chemistry, equations in math, graphics, mechanisms of reaction, analogy, and kits to describe the scientific process in the other representations.

Based on the results of diagnostic tests of chemical equilibrium conducted on 22 prospective chemistry teachers, the findings were obtained in the form of their answers that had been categorized according to the categories of their responses. The level of prospective chemistry teachers' understanding of the chemical equilibrium arranged for each learning indicator according to macroscopic, sub-microscopic, and symbolic levels, can generally be seen in Figure 4.

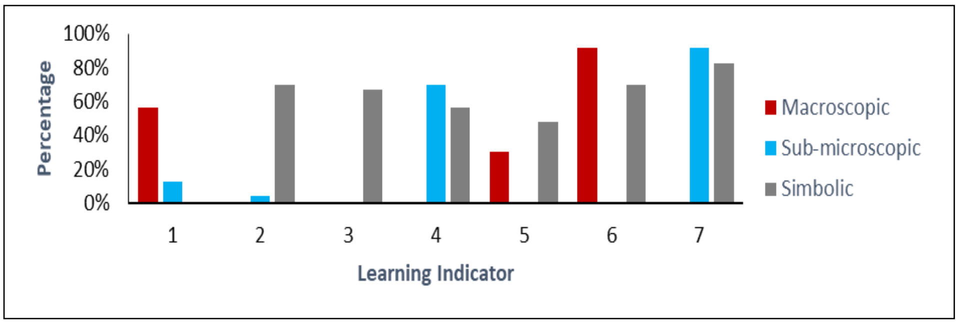


Figure 4. Level of prospective chemistry teachers' understanding every learning indicator for each level of chemical representation.

The level of prospective Chemistry teachers' understanding of the dynamic equilibrium and equilibrium constant is higher at the macroscopic level than at the sub-microscopic. It shows that the prospective chemistry teacher had a low understanding and could not explain the basic concept of dynamic equilibrium. On the other hand, their understanding of equilibrium shifting at the sub-microscopic level is higher than the concept of dynamic equilibrium itself. They could explain better how the equilibrium will react when there are changes applied. The low understanding of the concept of dynamic equilibrium at the sub-microscopic level shows that the students have difficulty understanding how the process of reaching the equilibrium and what kind of conditions happen during the equilibrium. Whereas the sub-microscopic level connects the explanation of phenomena at the macroscopic level to the symbolic level which will lead to solidifying the students' understanding

The gap in understanding in this sub-microscopic stage can also be analyzed from the results of student interviews conducted. Many students preferred to memorize chemical concepts at the symbolic level without understanding the meaning of the symbols used. This situation leads to creating difficulty for students to experience construct explanations at the submicroscopic level related to the macroscopic level phenomena (Suja & Nurlita, 2016). Moreover, they failed to make the connection between the observation data at the macroscopic level with the symbolic level (Rahmi et al., 2018). It was found that in learning chemistry equilibrium, the mathematical concept of chemical equilibrium is more emphasized compared to other concepts. Students assume that their mathematical mastery is very important. Students want to prepare themselves to be competent in examinations. In learning chemistry equilibrium, they more often practice the concept of counting (counting chemistry equilibrium). Students' ability in solving numerical chemistry problems by using the mathematical equations but missed the understanding of chemical concepts or the foundational concept. Thus, it becomes crystal clear that students' understanding of chemistry equilibrium at the symbolic level dominates more than any other level.

This result indicates that the learning should be with multiple representations since it is significant to improve students' learning of chemistry concepts, especially the role of visualization representations to explain the phenomenon of sub-micro (Yakmaci-Guzel & Adadan, 2013). Report from previous studies shows that molecular animations could stimulate students' imagination and enhance their understanding at the sub-microscopic level tus could build a bridge to macroscopic phenomena and changes in matter (Akaygun, 2016; Al-Balushi & Al-Hajri, 2014; Ryoo & Linn, 2014). However, there is a lack of students' capacity to transfer these visualization mental models to reasoning (Bongers et al., 2020). In more detail, the level of prospective chemistry teachers' understanding of the chemistry equilibrium subject in terms of each level of chemical representation for the two learning indicators can be seen based on each indicator item. These details are summarized in Table 2.

Table 2. Level of prospective chemistry teacher's understanding of the chemistry equilibrium subject in terms of each level of chemical representation

Chemical Representation	Problem	Percentage	Percentage Average
Macroscopic	1 (a)	56,52%	59.42%
	4 (a)	30,43%	
	6 (a)	91,30%	
Sub-microscopic	1 (b)	13,04%	51.34%
	1 (e)	4,55%	
	3 (b)	65,22%	
	3 (c)	73,91%	
	5 (a)	100,00%	
Symbolic	1 (c)	91,30%	66,18%
	1 (d)	47,83%	
	1 (f)	69,57%	
	2 (a)	60,87%	
	2 (b)	69,57%	
	3 (a)	56,52%	
	4 (b)	47,83%	
	5 (b)	69,57%	
	6 (b)	82,61%	

The results of students' answers to the chemistry equilibrium diagnostic test questions were analyzed further to find the description of their mental models. The students' answers are then groupings into the macroscopic, sub-microscopic, and symbolic levels based on their responses, along with that the data is further analyzed to give the type of students' mental models, whether including Scientific Models (SM), Phenomenon Models (PM), Character-Symbol Models (CSM), or Inference Model (IM). According to the mental model category description by Lin and Chiu (2007), the data has been drawn to find the connection between mental model types that match their description for each level representation in chemistry. Generally, the level of student mental model categories for the macroscopic, sub-microscopic, and symbolic levels of the chemistry equilibrium material is based on learning indicators, as shown in Figure 5.

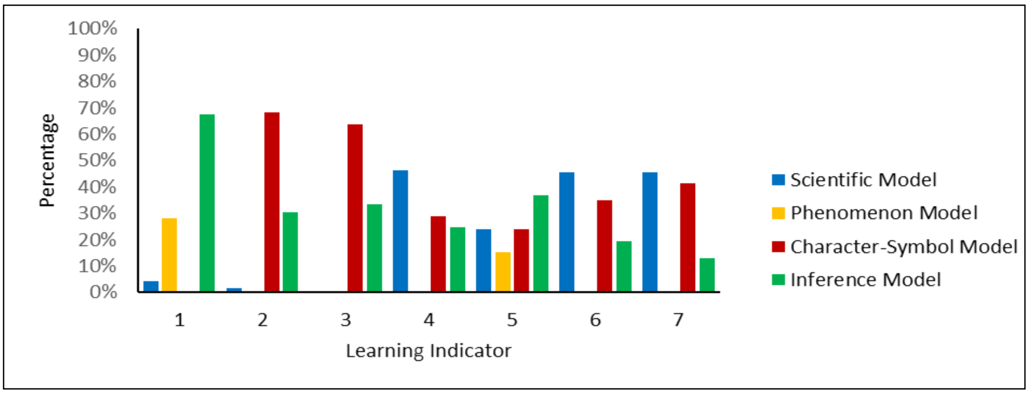


Figure 5. Levels of model mental category prospective chemistry teacher in chemical equilibrium for each learning indicator.

Figure 5 shows that almost all students have Character-Symbol Model (CSM) in every problem that represents symbolic level representation. Nearly half are in the Phenomenon Model (PM) and Inference Model (IM) categories, and only a small proportion is included in the Scientific Model (SM) category. Understanding the symbolic level is the best for almost all students based on the Character-Symbol Model (CSM) percentage. The scientific Model (SM) category is only gained by a few because they only can describe, interpret, and predict phenomena that occur based on facts, laws, principles, or certain scientific principles. Some of the data also shows inaccurate conclusions because only gives incomplete explanations or generalizations of some separate scientific concepts, put into the Inference Model (IM) category. Furthermore, the Phenomenon Model (PM) category is owned by almost half of the students because their understanding is more at the macroscopic level, as well as when explaining at the sub-microscopic level they still use an explanation of what they can observe.

Based on the data obtained, then for items representing macroscopic representations, it is obtained that the understanding of prospective teacher-students is generally quite good on the Phenomenon Model (PM) mental model. For problems in the sub-microscopic category, it was found that students generally still had difficulty explaining scientifically their understanding of the concept of dynamic equilibrium. From the results of interviews with students, it was found that they still had difficulty understanding molecularly the chemical processes that occur in equilibrium reactions that take place back and forth. And almost all the questions that represent the symbolic level show that students tend to use the concept of mathematical calculations on chemical equilibrium.

The number of students who fall into this category of mental models by their understanding in terms of the macroscopic level for this learning indicator. Furthermore, the Scientific Model (SM) category is owned by most students, and the Inference Model (IM) by almost half the students. Meanwhile, some learning indicator is not included in the Character-Symbol Model (CSM) category. This is because in this indicator no questions are made that measure student understanding in terms of the symbolic level so no students are included in the category of CSM mental models. The chemical representations are macroscopic, sub-microscopic, and symbolic levels as their properties tat unique and different between them. Based on a comparison of mental model categories by Lin and Chiu (2007) combined with properties of chemical representations and the type of mental models they have, the connections between the two concepts are shown in Table 3.

Table 3. Relationship of mental model categories and chemical representations.

Model Mental Category	Chemistry Representation		
	Macroscopic Level	Sub-microscopic Level	Symbolic Level
Scientific Model (SM)	√	√	√
Phenomenon Model (PM)	√		
Character-Symbol Model (CSM)			√
Inference Model (IM)	√	√ (build the wrong conclusion)	√

Table 3 shows the connections show that the mental model category of the scientific model (SM) is made from all three levels of chemical representation, with correct answer alternative for sub-microscopic. Indeed, interpreting the sub-microscopic level needs knowledge at the macroscopic and symbolic levels. Measuring understanding at the macroscopic level connects to the mental model phenomenological model (PM). And for measuring understanding at the symbolic level, the appropriate type of mental model is the Character Symbolic Model (CSM). Mental Model Type Inferential Modeling (IM) is an alternative response for each item at the macro, micro, and symbolic levels that form the wrong conclusion. At this stage, misconceptions can be formed when students have incomplete mental models at the micro-level (Rahmi et al., 2020).

Another incorrect conclusion could come from associative thinking. Associative thinking arises when students think that a concept same as another concept. Associating one concept with another concept will lead to misconceptions. However, it couldn't be avoided because of the degree of similarity between the terms and errors in understanding the connection between concepts. Students' wrong generalizations from the result of their experience, misinformation from teacher carelessness, teacher misconceptions, and reflection of misleading information in textbooks will make incorrect or incomplete concepts (Zajkov et al., 2017), and give impact student's conceptual learning (Chazbeck & Ayoubi, 2018; Develi & Namdar, 2019).

The results of this study were vary based on the data. Based on this, it can be concluded that the types of mental models of prospective chemistry teachers for understanding test questions at the macro level are scientific models (SM), phenomena (PM), and inference models (IM). From the three categories of mental models owned by students, it can be seen that the PM mental model category is more numerous, followed by the IM category and finally the SM category. This shows that the type of mental model of students generally agrees with the characteristics of the problem at the macro level, namely the Phenomenal Model (PM). On the other side, for categories of IM and SM mental models depends on the students' mental models based on their knowledge before, together with the conditions when answering the questions. This showed mental models are always dynamic when interacting with questions or problems or with certain conditions.

The mental model categories for the concept at the sub-microscopic level are the Scientific Model (SM), the Phenomenon Model (PM), and the Inference Model (IM). Students who have SM mental model categories are more than IM and PM categories. This is by the prediction that has been determined previously, that the category of mental model of SM is most appropriate for students to have on this sub-microscopic problem. A scientific Model (SM) is a model that is by generally accepted scientific principles. That is, students' explanations of a sub-microscopic phenomenon require understanding at the macroscopic and symbolic levels, to produce generalizations that are generally accepted and by certain scientific principles. The CSM mental model category dominates more than IM. This is aligned with the symbolic level problem type and indicators from the category of the CSM mental model. The interrelation between chemical representations at each representation to the mental model category of prospective chemistry teachers in the topic of chemical equilibrium is shown in Figure 6.

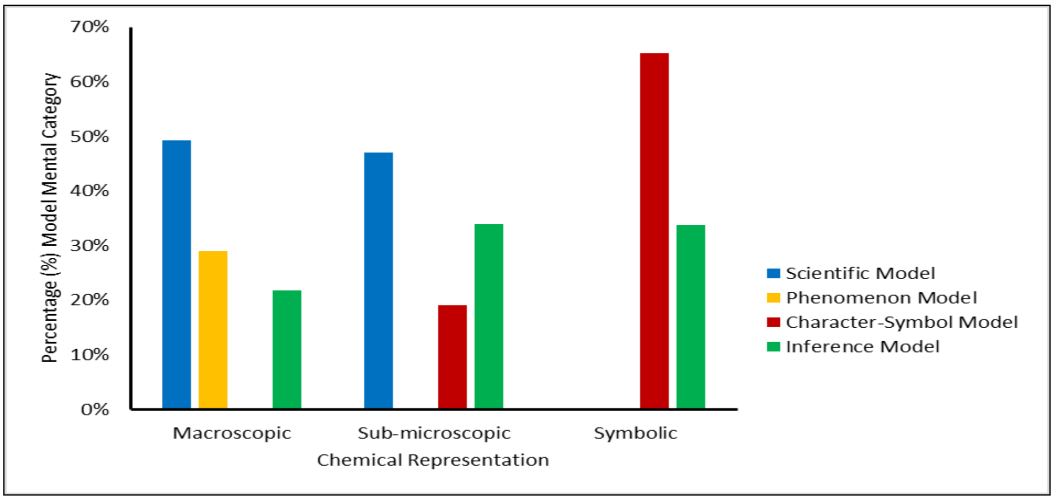


Figure 6. Level mental model categories of prospective chemistry teacher in the chemistry equilibrium material at each level of chemical representation

Developing mental models will be very meaningful for students to enhance their skills. This study will further continue to find the model that can be used to bolster students' mental models to describe interactions of molecules and particles that are very dynamic. Educators could explore students' natural tendencies that could guide the deeper explanations (Galloway et al., 2017) by implementing the value of deeper and causal explanations in learning and evaluation, lest students will change to less scientifically meaningful methods of answers to simply get to the answer (Bodé et al., 2019; Crandell et al., 2019).

CONCLUSION

Based on the results of data processing, research findings, and discussion of the profile of prospective chemistry teachers' mental models on the material chemistry equilibrium show varied results. Students' understanding at a sub-microscopic level for chemistry equilibrium material is the lowest when compared to representation at other levels. The mental models of prospective chemistry teachers vary from the Scientific Model (SM), Phenomenon Model (PM), Character-Symbol Model (CSM), and Inference Model (IM). Meanwhile, the connection between chemical representation and the type of mental model of prospective chemistry teachers in chemistry equilibrium material is aligned with analysis, which is based on previous research a comparison between the characteristics of chemical representation and the mental model categories they have. This study showed that the learning of chemical equilibrium to these students emphasizes more at a symbolic level. The students gain more understanding at the symbolic level and less at the macroscopic and even more at the sub-microscopic level. Further study will be needed to develop a learning strategy and learning media that could facilitate the multiple representations in chemistry. Considering also that chemical equilibrium is connected with the other concept in chemistry such as oxidation-reduction, acid, and base, and also rate of reaction thus the correct mental model of this concept becomes important. The next study also should recognize that sub-microscopic level representation is very important as this level help the students understand the scientific concept and give the correct explanation to chemical phenomena and reduce the misconception. This research is limited to the analysis of a mental model based on the diagnostic test. This research is very dependent on the response of the research subjects in the diagnostic test. In this study, no further investigation was carried out regarding the understanding of research participants about the contents of the diagnostic test so there is the potential for errors in interpreting the instructions in the test. To minimize this error, it is necessary to conduct interviews with research participants to confirm their perceptions of more in the diagnostic test.

ACKNOWLEDGEMENTS
The authors would like to thank Pelita Harapan University (UPH) for their support in making this project possible. This work was supported by the Research University Grant (P-025-FIP/VI/2018) initiated by UPH.

REFERENCES

Akaygun, S. (2016). Is the oxygen atom static or dynamic? the effect of generating animations on students' mental models of atomic structure. *Chemistry Education Research and Practice*, *17*(4), 788–807. https://doi.org/10.1039/c6rp00067c

Al-Balushi, S.M., & Al-Hajri, S.H. (2014). Associating animations with concrete models to enhance students' comprehension of different visual representations in organic chemistry. *Chemistry Education Research and Practice*, *15*(1), 47–58. https://doi.org/10.1039/c3rp00074e

Arikunto, S. (2009). *Dasar-dasar evaluasi pendidikan*. Bumi Aksara.

Avargil, S. (2019). Learning chemistry: Self-efficacy, chemical understanding, and graphing skills. *Journal of Science Education and Technology*, *28*(4), 285–298. https://doi.org/10.1007/s10956-018-9765-x

Bodé, N.E., Deng, J.M., & Flynn, A.B. (2019). Getting past the rules and to the why: causal mechanistic arguments when judging the plausibility of organic reaction mechanisms. *Journal of Chemical Education*, *96*(6), 1068–1082. https://doi.org/10.1021/acs.jchemed.8b00719

Bodner, G., & Domin, D. (2000). Mental models: The role of representations in problem solving in chemistry. *University Chemistry Education*, *4*(1), 24–30.

Bongers, A., Beauvoir, B., Streja, N., Northoff, G., & Flynn, A.B. (2020). Building mental models of a reaction mechanism: The influence of static and animated representations, prior knowledge, and spatial ability. *Chemistry Education Research and Practice*, *21*(2), 496–512. https://doi.org/10.1039/c9rp00198k

Cetin, G., Ertepinar, H., & Geban, O. (2015). Effects of conceptual change text based instruction on ecology, attitudes toward biology and environment. *Educational Research and Reviews*, *10*(3), 259–273. https://doi.org/10.5897/err2014.2038

Chazbeck, B., & Ayoubi, Z. (2018). Resources used by lebanese secondary physics teachers' for teaching electricity: Types, objectives and factors affecting their selection. *Journal of Education in Science, Environment and Health*, *4*(2), 118–128. https://doi.org/10.21891/jeseh.409487

Chittleborough, G.D. (2004). *The role of teaching models and chemical representation in developing studdents' mental models of chemical phenomena.* Dissertation. Bentley: Curtin University of Technology.

Coll, R.K. (2008). Chemistry learners' preferred mental models for chemical bonding. *Journal of Turkish Science Education*, *5*(1), 22–47.

Crandell, O.M., Kouyoumdjian, H., Underwood, S.M., & Cooper, M.M. (2019). Reasoning about Reactions in organic chemistry: Starting it in general chemistry. *Journal of Chemical Education*, *96*(2), 213–226. https://doi.org/10.1021/acs.jchemed.8b00784

Develi, F., & Namdar, B. (2019). Defining friction force: A proposed solution to a textbook problem. *Journal of Education in Science Environtment and Health*, *5*(1), 91–101. https://doi.org/10.21891/jeseh.487399

Devetak, I. (2005). *Explaining the latent structure of understanding submicropresentations in science*. Slovenia: University of Ljubljana.

Farida, I., Liliasari, & Sopandi, W. (2011). Pembelajaran berbasis web untuk meningkatkan kemampuan interkoneksi multiple level representasi mahasiswa calon guru pada topik kesetimbangan larutan asam-basa. *Jurnal Chemica*, *12*(1), 14–24. https://doi.org/10.35580/chemica.v12i1.131

Fernández-González, M. (2013). Idealization in chemistry: Pure substance and laboratory product. *Science and Education*, *22*(7), 1723–1740. https://doi.org/10.1007/s11191-011-9428-2

Galloway, K.R., Stoyanovich, C., & Flynn, A.B. (2017). Students' interpretations of mechanistic language in organic chemistry before learning reactions. *Chemistry Education Research and Practice*, *18*(2), 353–374. https://doi.org/10.1039/c6rp00231e

Halim, N.D.A., Ali, M.B., Yahaya, N., & Said, M.N.H.M. (2013). Mental model in learning chemical bonding: A preliminary study. *Procedia - Social and Behavioral Sciences*, *97*, 224–228. https://doi.org/10.1016/j.sbspro.2013.10.226

Hono, A.S., Yuanita, L., & Suyono, S. (2017). Penerapan model learning cycle 7e untuk memprevensi terjadinya miskonsepsi siswa pada konsep reaksi redoks. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *3*(2), 354. https://doi.org/10.26740/jpps.v3n2.p354-360

Ibrahim, B., & Rebello, N.S. (2013). Role of mental representations in problem solving: Students' approaches to nondirected tasks. *Physical Review Special Topics - Physics Education Research*, *9*(2). https://doi.org/10.1103/PhysRevSTPER.9.020106

Irawati, R.K. (2019). Pengaruh pemahaman konsep asam basa terhadap konsep hidrolisis garam mata pelajaran kimia SMA kelas XI. *Thabiea: Journal of Natural Science Teaching*, *02*(1), 1–6. https://doi.org/10.21043/thabiea.v2i1.4090

Jansoon, N., Cool, R. K., & Somsook, E. (2009). Understanding mental models of dilution in thai students. *International Journal of Environmental and Science Education*, *4*(2), 147–168.

Johnson-Laird, P. (1983). *Mental models: Towards a cognitive science of language, inference and consciousness.* Cambridge: Harvard University Press.

Johnstone, A.H. (1991). Why is science difficult to learn? Things are seldom what they seem. *Journal of Computer Assisted Learning*, *7*(2), 75–83. https://doi.org/10.1111/j.1365-2729.1991.tb00230.x

Johnstone, A.H. (2009). *Foreword, in gilbert j. k. and treagust d. f. (ed.), multiple representations in chemical education*. Berlin: Springer.

Landa, I., Westbroek, H., Janssen, F., van Muijlwijk, J., & Meeter, M. (2020). Scientific perspectivism in secondary-school chemistry education: Integrating concepts and skills in chemical thinking. *Science and Education*, *29*(5), 1361–1388. https://doi.org/10.1007/s11191-020-00145-3

Latipah, J., Jamilah, S.N., Sari, S.T., & Almubarak. (2021). Analysis of student's mental model through representation chemistry textbooks based on augmented reality.

Journal of Physics: Conference Series, *1760*(1). https://doi.org/10.1088/1742-6596/1760/1/012050

Lin, J.W., & Chiu, M.H. (2007). Exploring the characteristics and diverse sources of students' mental models of acids and bases. *International Journal of Science Education*, *29*(6), 771–803. https://doi.org/10.1080/09500690600855559

Liu, C.J., Hou, I.L., Chiu, H.L., & Treagust, D.F. (2014). An exploration of secondary students' mental states when learning about acids and bases. *Research in Science Education*, *44*(1), 133–154. https://doi.org/10.1007/s11165-013-9373-y

Mensah, A., & Morabe, O.N. (2018). Strategies used by grade 12 physical sciences students in solving chemical equilibrium problems. *African Journal of Research in Mathematics, Science and Technology Education*, *22*(2), 174–185. https://doi.org/10.1080/18117295.2018.1475908

Nahum, T., Hofstein, A., Mamlok-Naaman, R., & BAR-DOV, Z. (2004). Can final examinations amplify students' misconceptions in chemistry. *Chemistry Education Research and Practice*, *5*, 301–325. https://doi.org/10.1039/B4RP90029D

Rahmi, C., Wiji, W., & Mulyani, S. (2020). Model mental miskonsepsi pada konsep kesetimbangan kelarutan. *Lantanida Journal*, *8*(1), 64. https://doi.org/10.22373/lj.v8i1.7108

Ryoo, K., & Linn, M. (2014). Designing guidance for interpreting dynamic visualizations: generating versus reading explanations. *Journal of Research in Science Teaching*, *51*(2), 147–174.

Suja, I.W., Sudiana, I.K., Redhana, I.W., & Sudria, I.B.N. (2021). Mental model of prospective chemistry teachers on electrolyte and nonelectrolyte solutions. *IOP Conference Series: Materials Science and Engineering*, *1115*(1), 012064. https://doi.org/10.1088/1757-899x/1115/1/012064

Supasorn, S. (2015). Grade 12 students' conceptual understanding and mental models of galvanic cells before and after learning by using small-scale experiments in conjunction with a model kit. *Chemistry Education Research and Practice*, *16*(2), 393–407. https://doi.org/10.1039/c4rp00247d

Taber, K.S. (2009). Learning at the symbolic level. *International Journal of Science Education*, *14*(2), 75–105. https://doi.org/10.1007/978-1-4020-8872-8_5

Taber, K.S. (2013). Three levels of chemistry educational research. In *Chemistry Education Research and Practice*, *14*(2), 151–155. https://doi.org/10.1039/c3rp90003g

Ulinnaja, H. (2019). High school students' mental models on chemical equilibrium. *Jurnal Pendidikan Sains*, *7*(2), 58–64. http://dx.doi.org/10.17977/jps.v7i2.13324

Vosniadou, S. (1994). Capturing and modeling the process of conceptual change. *Learning and Instruction, 4*(1), 45–69. https://doi.org/10.1016/0959-4752(94)90018-3

Wright, L.C., & Oliver-Hoyo, M.T. (2020). Student assumptions and mental models encountered in IR spectroscopy instruction. *Chemistry Education Research and Practice*, *21*(1), 426–437. https://doi.org/10.1039/c9rp00113a

Wu, S.-H., Lai, C.-L., Hwang, G.-J., & Tsai, C.-C. (2021). Research trends in technology-enhanced chemistry learning: a review of comparative research from 2010 to 2019. *Journal of Science Education and Technology*, *30*(4), 496–510. https://doi.org/10.1007/s10956-020-09894-w

Yakmaci-Guzel, B., & Adadan, E. (2013). Use of multiple representations in developing preservice chemistry teachers' understanding of the structure of matter. *International Journal of Environmental & Science Education*, *8*(1), 109-130.

Zajkov, O., Gegovska-Zajkova, S., & Mitrevski, B. (2017). Textbook-caused misconceptions, inconsistencies, and experimental safety risks of a grade 8 physics textbook. *International Journal of Science and Mathematics Education*, *15*(5), 837–852. https://doi.org/10.1007/s10763-016-9715-0

Zarkadis, N., Papageorgiou, G., & Stamovlasis, D. (2017). Studying the consistency between and within the student mental models for atomic structure. *Chemistry Education Research and Practice*, *18*(4), 893–902. https://doi.org/10.1039/c7rp00135e

***Kelly Sinaga, S.Tp., M.P.Kim. (Corresponding Author)**
Chemistry Education Study Program,
Pelita Harapan University,
Jl. M. Thamrin Boulevard 1100 Lippo Village/ Tangerang 15811, Indonesia
Email: kelly.sinaga@uph.edu