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Pre-service Chemistry Teachers' Mental Model of Colligative Properties for Nonelectrolyte Solutions

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Abstract

Mental models are representations that describe the understanding of the three levels of representation in chemistry, that is macroscopic, sub-microscopic, and symbolic. This study aims to obtain a general description of the mental model of pre-service chemistry teachers in the colligative properties of non-electrolyte solutions. The study was a descriptive research with 22 second-year FIP Chemistry Education students from Pelita Harapan University Tangerang. Data collection was carried out with research instruments in the form of diagnostic tests. The results of the study state that the average percentage level of representation is 67 % macroscopic level, 31% sub-microscopic level, and 72 % symbolic level. The results of this study indicate that students' understanding at the macroscopic and sub-microscopic level of the colligative properties of non-electrolyte solutions was low compared to chemical representations at a symbolic level. Meanwhile, the categories of mental models possessed by pre-service chemistry teachers in the topic of non-electrolyte colligative properties vary for each level of chemical representation. Based on the percentage at each level of representation, the mental model of chemistry teacher candidates with a symbolic model category is higher than the scientific model. The low mental model of the scientific model contributed to the understanding of the pre-service chemistry teachers that the concept of chemistry is not intact scientifically.

Keywords: Mental model, chemical representation, colligative properties

Introduction

Chemistry subject matter, like other natural science subject matter, contains complex and abstract concepts. To understand the concept of chemistry, students must understand three levels of representation. (Johnstone, 2009). The macroscopic and symbolic levels usually get more emphasis than the sub-microscopic levels in both the high school and college general chemistry classes. It is challenging for the students to visualize the chemical structure and dynamics of particles; therefore, various visualizations and tools have been used in chemistry education. For science educators, it has been important to understand how students visualize and represent particular phenomena – i.e., their mental models– to design more effective learning environments (Akaygun, 2016). Students' understanding of chemistry learning is seen from their ability to connect the three aspects because, in understanding chemistry deeper, students must be able to balance the relationship between concepts in chemistry with these three levels, this can help students overcome difficulties in visualizing the structure of the material (Andriani et al., 2017). The mental model is a term that appears to represent an understanding of the three levels of representation.

A set of ideas in a person's mind to describe and explain a phenomenon can be represented by a mental model (Jansoon et al., 2009). This means that misconceptions are mental models that are incompatible with scientific truth (Aini et al., 2019)). The mental model used by novices and experts in chemistry for simulating and reasoning about sub-microscopic processes (Bongers et al., 2019).

The mental model is a theory about the organization of knowledge. For this reason, a mental model can be defined as the representation of individual knowledge (Seel, 2006)). Mental models are knowledge structures consisting of coherent elements to explain phenomena (Didiş et al., 2014). The mental function of the model is similar to computer simulation because it allows simulations in the minds of learners by processing input to predict outcomes (Taber, 2013). Thus, individual reasoning is possible and facilitates problem-solving, and as a result, they have very important daily reasoning (Gentner, 2002)). Supriadi in his research (Supriadi et al., 2018). Found that mental model also affected by initial knowledge of the students. His research describes findings that the higher the initial knowledge of the students, the mental model will be higher also. Rahmi in her research also find

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the contribution of the mental model to misconception in chemistry. It is clear that a mental model that is not complete will lead to misconceptions in chemistry (Rahmi et al., 2020).

Chemistry is a branch of science that is concerned with the properties and interactions of the matter of a substance (Ridwan et al., 2017). Three levels of knowledge in learning chemistry, the macroscopic level, the particulate/sub-microscopic level, and the symbolic level. At the macroscopic level, the explanation focuses on observable chemical characteristics. This can be done when students observe real phenomena in the laboratory or in everyday life. At the macroscopic level, it includes changes in color, temperature, pH of the solution, gas formation, or precipitate formation that can be observed during chemical reactions. For example, the macroscopic level of water includes a physical description of water at various temperatures. At the particulate/sub-microscopic level, chemistry is represented in terms of the atoms, molecules, and ions that form it using a molecular image or model (Ridwan et al., 2017).

The relationship between the three levels is described by Johnstone (2009) in the triangular shape known as the Johnstone's triangle.
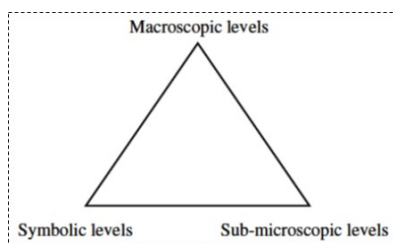

Figure 1. Three levels of representation used in chemistry

In chemistry learning, the use of modeling and deep modeling Chemistry learning can be an easy deep visualization tool that bridge the macroscopic and sub-microscopic domains of students (Gilbert, 2004).

In addition, the dependence of the three levels above which are associated with concrete and abstract knowledge (Devetak et al., 2004).
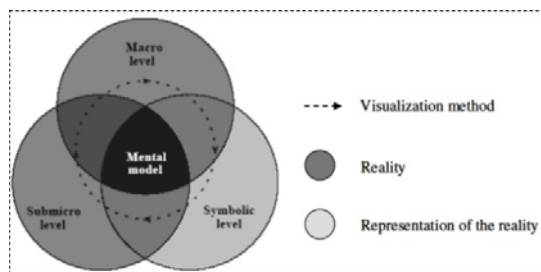

Figure 2. The interdependence of the three levels of science concepts model

In every area of chemistry, the strategies for teaching should consolidate overall the macroscopic, sub-microscopic, and symbolic level of chemical concepts so it can facilitate understanding. Thus, observing a chemical process in daily life or in laboratory work (macroscopic) is not enough and describes the data measured in plots and diagrams (symbolic). There must be explanation observations and symbols on the particle level (sub-microscopic) and can make a connection for all three levels appropriately. In Johnstone's eyes, meaningful learning in chemistry requires exploring the "interior of the triangle" which most learners are so very unfamiliar with (Schwedler & Kaldewey 2020). The capacity to explain the relationship between the three levels above is also possible to acquire knowledge of students' long-term memory. An understanding of the macroscopic level that occurs can be explained by mental models. This shows that mental models have an important role (Coll, 2008). A fully understanding of chemistry can be achieved by representing chemistry concepts in three levels of representation to describe the phenomena (Albaiti et al., 2016)). Linking the sub-microscopic and symbolic level in chemistry can be done through dynamic simulation with a cognitively engaging, comparably enjoyable learning process, which strengthens conceptual understanding (Schwedler & Kaldewey, 2020). Alternative conceptions can be suppressed by increasing understanding of the three levels of chemical representation (Jansoon et al., 2009). However, chemistry studies currently place more emphasis on the symbolic level (Bunce et al., 1991). As a result, chemical material is studied by memorizing that is not meaningful.

On the other hand, learning chemistry which includes three levels of representation, will make understanding of chemistry intact and bring students to understand how the world works. Students build mental models based on students' understanding and experiences that are influenced by the surrounding environment (Darmiyanti et al., 2017). This means that when a student is trying to explain a phenomenon, some of the relevant pieces of knowledge that we call prior knowledge are activated in order to form *in situ* a particular mental model. Thus, based on the phenomenon, a different group of prior knowledge could be used, and a different mental model could be formed in order to reach an explanation (Zarkadis et al., 2017). The incomplete understanding of students in learning chemical concepts will continue to be carried over to the next levels. If this is not addressed, it will be difficult for students to understand chemistry lessons in the future, and their mental chemical models tend to be incomplete. This can also hinder the teaching and learning process of chemistry so that knowing students' mental models of chemistry at the previous level is needed for teachers to be able to provide appropriate learning strategies for students to improve students' incomplete understanding (Yoni et al., 2019).

Mental model research on many chemical concepts has been carried out such as chemical bonding, dilution, matter particles, acid-base, molecular geometry, and polarization, which are generally considered abstract and difficult concepts (Coll, 2008; Jansoon et al., 2009; Lin & Chiu, 2010; McClary & Talanquer, 2011; Wiji & Mulyani, 2018). The research was carried out from the level of basic education to higher education, both for low, medium, and high competence groups. The results of the research obtained also vary depending on the level of education and the category of their respective abilities. The higher the level of education, the mental model at the microscopic level increases and is consistent with scientific concepts (Handayanti et al., 2015). The researchers found that building mental models, especially on the sub-microscopic level concepts, students' understanding of macroscopic and symbolic representations was very important because the understanding of phenomena and the representations should be fully in order to open the limit students' development of knowledge organization (Körhasan & Wang, 2016). Wright and Oliver-Hoyo, in their research, describe that the findings of this mental study model have important implications for teaching (Wright & Oliver-Hoyo 2020).

One of the concepts studied in chemistry is the colligative properties of solutions. The results of the research show that there are still many high school students who have misconceptions about the concept of the colligative properties of solutions. Some of the misconceptions that were found among others were that students thought that a solution with a higher density caused a high boiling point, that the presence of salt in the solution could increase the boiling point because the salt prevented evaporation(Wiji & Mulyani, 2018). This is also in line with the results of research, which found that students thought that the presence of salt would prevent evaporation and increase the boiling point of the solution. Another finding showed that the students considered the bonds in the salt molecule strong enough and that it needed a lot of energy to break it so that the boiling point of the salt solution was higher than the boiling point of water (Wiji & Mulyani, 2018).

Research on pre-service teacher misconceptions on the colligative properties of solutions is important to do because they will teach later. If the mastery of the concept is not good, even accompanied by misconceptions, then these misconceptions will be transmitted to their students, even though the misconceptions can prevent them from being able to understand the concepts well. Pre-service chemistry teachers as the students need to fully understand the chemistry before they can deliver it to their students in the future (Albaiti et al., 2016).

This paper intends to present the analysis of students' mental model profiles in the topic colligative properties of nonelectrolyte solutions.

Methods

This research was conducted using descriptive methods. (Sukmadinata, 2007) states that descriptive research does not provide treatment, manipulation, or alteration of independent variables but describes a condition as it is. Descriptive research is intended to describe a situation or phenomenon as it is. In this study, the descriptive research method is aimed at looking at the mental model profiles of pre-service chemistry teachers on the topic of the colligative properties of nonelectrolyte solutions.

This research was conducted in the Chemistry Education Study Program of the University of Pelita Harapan, with the subjects involved being students of second-level chemistry teacher candidates. Students who are the subject of this research have also studied the colligative properties of the solution. The instrument used is a diagnostic test.

The test used is in the form of a diagnostic test that aims to see the mental model profile of chemistry teacher candidate students on the sub-material of the colligative properties of nonelectrolyte solutions.

Diagnostic tests are defined as tests that are used to determine student weaknesses so that based on these weaknesses, appropriate treatment can be given (Arikunto, 2009).

The diagnostic test in this mental model research is in the form of open-ended questions (with pictures and descriptions). The diagnostic test in the form of open questions was chosen in the hope that it could represent the abilities of the

students' at macroscopic, sub-microscopic, and symbolic levels as well as the categories of mental models they had because students were given the freedom to express their opinions.

As for the description of the understanding of student chemistry teacher candidates on the topic of colligative properties of nonelectrolyte solutions in terms of macroscopic, sub-microscopic, and symbolic levels, this is limited to predetermined learning indicators.

The learning indicators are lowered back into 6 item indicators, each of which has been designed to see the understanding of student chemistry teacher candidates on the topic of the colligative properties for nonelectrolyte solutions in terms of

macroscopic, sub-microscopic, and symbolic levels. The suitability of the learning indicators with the item indicators and their chemical representations is as shown in **Tables 1** and **2**.

The results of the diagnostic test were analyzed by grouping similar answers into one category, calculating the percentage of each category, and interpreting the percentage value of students in descriptive form, including students' understanding at each level of chemical representation and mental model categories had. The mental model category follows the categories that are scientific model (SM), phenomenon model (PM), character-symbol model (CSM), and inference model (IM) (Lin & Chiu, 2007).

Table 1. Compatibility of learning indicators with indicators of diagnostic test question items and its representation (part 1)

Learning Indicator	Indicator Item Problem	Representation
1. Describe the process of forming a solution	▪ Observing the process of mixing sugar solids and NaCl in liquid as the basis for determining the formation of a solution	Macroscopic
	▪ Describe the differences in the end results of mixing two types of solids in water	Sub-microscopic
	▪ Describe the process of forming ionic solutions through an overview of the process of dissolving NaCl in water	Sub-microscopic
2. Explain how to calculate the concentration of a solution in various concentration units of a solution	▪ Observing two different colored $Cu(OH)_2$ solutions as the basis for the difference in solution concentration	Macroscopic
	▪ Describe the difference in solution concentration based on the amount of solvent and dissolved in two solutions	Sub-microscopic
	▪ Calculate the concentration of the solution in molarity and molality	Symbolic
3. Explaining the effect of solutes that are difficult to evaporate on the vapor pressure of the solvent	▪ Explain the definition of solution vapor pressure	Sub-microscopic
	▪ Estimating the difference in vapor pressure between pure solvent and solution	Sub-microscopic
	▪ Calculating Solution Vapor Pressure	Symbolic
4. Describe the boiling point of the solution	▪ Observing the heating process of water as a basis for explaining the concept of the boiling point	Macroscopic
	▪ Describe the process of boiling water through graphs and molecular structures of liquids at boiling	Sub-microscopic
	▪ Describe the difference between the boiling points of a pure solvent and a solution through graphs and the molecular structure of boiling liquids	Sub-microscopic
	▪ Calculate the increase in the boiling point of the solution and the boiling point of the solution after a number of solutes have been added	Symbolic

Table 2. Compatibility of learning indicators with indicators of diagnostic test question items and its representation (part 2)

Learning Indicator	Indicator Item Problem	Representation
1. Describe the freezing point of the solution	▪ Observing the process of freezing water as the basis for the freezing point	Macroscopic
	▪ Describe the process of water freezing through graphs and molecular structures of liquids when frozen	Sub-microscopic
	▪ Explain the function of salt in making ice cream	Macroscopic
	▪ Describe the difference between the freezing points of a pure solvent and a solution through graphs and the molecular structure of liquids when frozen	Sub-microscopic
	▪ Calculate the decrease in the freezing point of a solution and the freezing point of a solution after a number of solutes are added	Symbolic
2. Describe the osmosis process	▪ Observing the conditions of cucumbers that were left in water and those that were left in a salt solution	Macroscopic
	▪ Describe the process of osmosis through an image of the osmosis process	Sub-microscopic
	▪ Calculating the osmotic pressure of the solution	Symbolic

Results and Discussion

The mental model profile of pre-service chemistry teachers in the topic colligative properties of nonelectrolyte solutions describes pre-service chemistry teacher understanding in the topic colligative properties of non-electrolyte solutions at the three levels of chemical representation. This is because mental models provide an overview understanding chemistry at the three chemical representations (Devetak et al., 2004). The findings obtained are also used to describe the categories of mental models that students have and to explain the relationship between the three levels of chemical representation also the categories of mental models that students have.

Pre-service chemistry teacher understanding in macroscopic, sub-microscopic, and symbolic levels

Chemistry learning can be studied through three levels of representation, that are macroscopic, sub-microscopic, and symbolic levels (Johnstone, 2009). The three levels of representation relate to one another and are used to understand a phenomenon that occurs. Chemical representation plays a vital role in learning chemistry (Chittleborough, 2004).

Representation at the macroscopic level focuses on something that can be seen. At this level, students observe chemical phenomena that occur. The representation at the sub-microscopic level is an abstract level but provides an explanation of the microscopic (particulate) phenomena.

This level is characterized by the concepts, theories, and principles used to explain what is observed at the macroscopic level, using explanations such as the transfer of electrons, molecules, or atoms. Meanwhile, representation at the symbolic level is used to represent chemical phenomena that occur at the macroscopic level through chemical equations, mathematical equations, graphs, reaction mechanisms, analogies, and model kits (Johnstone, 2009).

Based on the results of the diagnostic test for the colligative properties of nonelectrolyte solutions, the findings from the students' answers were grouped according to the category of answers they gave. The group of answers given by the student is then made into a percentage to make it easier to interpret.

The level of understanding of pre-service chemistry teachers in the topic colligative properties of nonelectrolyte solutions arranged per learning indicator for the macroscopic, sub-microscopic, and symbolic levels, in general, can be seen in **Figure 3**.

Based on **Figure 3**, most students have a good understanding of the macroscopic and symbolic levels, where the percentage at the macroscopic level is less than the symbolic level. This means that understanding at the symbolic level is better than at the macroscopic level. Meanwhile, almost all students have a poor understanding at the sub-microscopic level except for the second learning indicator, which explains how to calculate the concentration of a solution in various concentration units of a solution. Almost all students can give a scientific explanation regarding the concentration solution based on the number of solute particles they have inside the solution. At the third learning indicator that explains the effect of solutes that are difficult to evaporate on the vapor pressure of the solvent, the researcher could not provide any problem item to measure the student understanding at the macroscopic level.
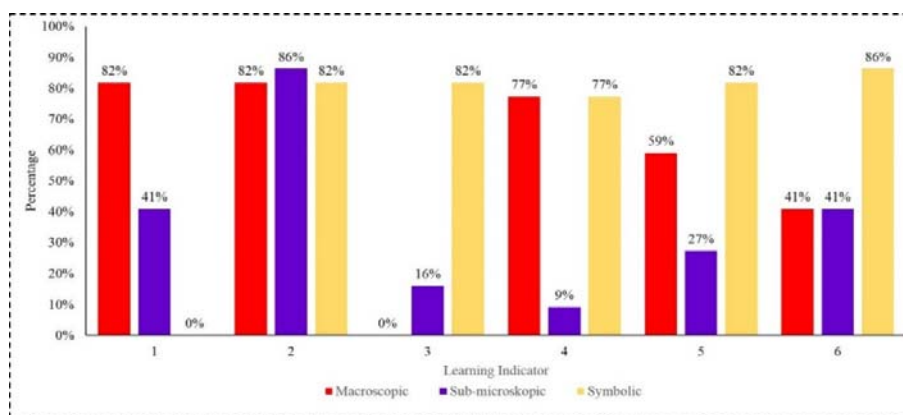
Figure 3. Level of prospective chemistry teachers' understanding of colligative properties of nonelectolyte solutions in every learning indicator for each level of chemical representation

Looking at the interpretation of the chemical representations obtained, then overall from the six learning indicators above, the tendency of students' understanding of the colligative properties of non-electrolyte solutions can be drawn in terms of the lowest submicroscopic level compared to the macroscopic and symbolic levels even though the submicroscopic level is a bridge that can explain phenomena at the macroscopic level with representations at the symbolic level so that students' understanding becomes intact.

In general, the results of interviews with students found that during the colligative nature of learning, the mathematical calculation concept received more emphasis than other concepts. Students more often practice the concept of calculating the concentration of the solution, the increase in boiling point, the decrease in the freezing point, and the osmotic pressure of the solution.

This is the same as that reported by Bunce et al. (1991) that students are often able to solve numerical chemistry problems, use mathematical equations and enter numbers without understanding the concept of chemistry or the underlying science. Thus, it is clear that students' understanding of the colligative properties of nonelectrolyte solutions at the symbolic level is more dominant than other levels.

Several factors that can cause this condition can come from the teachers and students themselves. Generally, because both teachers and students are focused on mastery of the topic, there is an assumption that mastery of the phenomenon related to colligative properties and mathematical concept related is more important, so much learning time is focused on these two levels. Thus, understanding at the macroscopic and symbolic level becomes more dominant than the sub-microscopic level. If students cannot relate the three levels of chemical representation, the concepts they understand will be fragmented and allow students to only memorize because the concepts learned only reach the surface (Eky et al., 2018).

The findings obtained are in line with those expressed by Bunce et al. (1991) in his research where solving chemical problems numerically through mathematical equations can be mastered by students even though they are not accompanied by an understanding of the chemical concepts on which they are based.

Based on the results of the study, some of the explanations given by students were also in line with previous findings, which indicated that there were students' misconceptions on the concept of the colligative properties of solutions, especially the boiling point of solutions. For example, the presence of salt in the solution can increase the boiling point because the salt prevents evaporation, that the presence of salt prevents evaporation and increases the boiling point of the solution. (Wiji & Mulyani, 2018). Another finding showed that the students considered the bonds to the salt strong enough and that it needed a lot of energy to break them so that the boiling point of the salt solution was higher than the boiling point of water. There are also students who think that evaporation will be difficult because there is an interaction between salt ions and water molecules so that the boiling point of the solution increases (Wiji & Mulyani, 2018).

The explanation given regarding the effect of the presence of volatile solutes on the vapor pressure of the solution in several textbooks varies. The reasons why a nonvolatile solute lowers the vapor pressure of the solvent are complex. One way to understand it is as follows. For evaporation to occur, molecules on or near the surface must have kinetic energy equal to or greater than the minimum amount required to evaporate. For example, at a certain temperature, 1% of the solvent molecules have this energy. Only these molecules can evaporate and experience dynamic equilibrium with their liquid and vapor. If, for example, there is a 20 % portion of a nonvolatile solute in solution, then only 1% of the molecule has the necessary kinetic energy to evaporate, and only 80 % is the solvent. Therefore only 0.8 % of the solvent molecules in the

solution have sufficient energy to evaporate. The remaining 0.2% of the involatile dissolved molecules are difficult to evaporate. Since the fraction of the solvent molecules that have sufficient energy is reduced in the solution, the rate of evaporation also decreases. Because of this, the vapor concentration required for equilibrium is also lacking. As a result, the vapor pressure above the solution is lower than the vapor pressure above the pure solvent (Wiji & Mulyani, 2018).

Silberberg (2007) provides the following explanation. The vapor pressure of a solution with a nonvolatile solute always lowers the vapor pressure of the pure solvent. At equilibrium, the rate of evaporation (molecules leaving the liquid) is equal to the rate of condensation (molecules entering the liquid). When we add a nonvolatile solute, the number of molecules on the surface also decreases, thereby reducing evaporation per unit time. In order to maintain equilibrium, fewer molecules can enter the liquid, and this only happens when the concentration of the gas, i.e., its vapor pressure, will fall.

In contrast to the two books above, Hill & Petrucci (2002) argues that there are various kinds of "molecular" explanations regarding Raoult's Law. However, what is presented, which is more satisfying, is a thermodynamic explanation. Since the mole fraction of the solvent in the solution is <1, the vapor pressure in an ideal solution is lower than in its pure state. The solution has lower entropy than the pure solvent. Since the forces between molecules in an ideal solution are the same, the ΔH of evaporation is the same, both from the pure solvent and from the solution. The entropy of evaporation must also be the same because ΔS = ΔH/T. However, since the entropy of the ideal solution is higher than that of the pure solvent, the vapor from the solution must have higher entropy than the entropy of the pure solvent vapor. The vapor entropy will increase if the molecules are able to move more freely, that is, at a lower pressure. A number of solutes being dissolved in the solution will lower the vapor pressure of the solvent.

In physical chemistry books such as those written by Levine (1995), the approach is to derive the equation of the chemical potential of a pure solvent and compare it with the chemical potential of the solvent in the solution. The presence of solute decreases the mole fraction of the solvent; as a result, the chemical potential of the solvent in the solution also decreases. These changes result in changes in vapor pressure, boiling point, freezing point and cause the osmosis phenomenon.

Stating that thermodynamic degradation provides the basis for the remarkable observation that colligative properties are not affected by the type of dissolved particles, whether small molecules or large molecules such as polymers, or ionic species such as Na^+ and Cl^-. Only the number of these particles, in a certain amount of solvent, has an effect on the colligative properties of the solution. The direct explanation continues in the direction of deriving the equation for each of the colligative properties through the chemical potential of the solvent due to the addition of the solute. So these books do not explicitly provide an explanation at the sub-microscopic level (Wiji & Mulyani, 2018).

Based on the descriptions of these textbooks, there is no single book that suggests that the reason for the difference in solution vapor pressure is the result of the interaction between the solute-solvent particles or because the solute particles prevent the solvent from evaporating. So, most of the reasons that were put forward by students were not in line with what was described in the textbook.

The results of student understanding at each level of chemical representation for each item indicator are stated in **Tables 3** and **4**.

Table 3. Level of prospective chemistry teacher's understanding of the colligative properties for nonelectrolyte solutions for a macroscopic level of chemical representation

Chemical Representation	Indicator Item Problem	No	Percentage (%)	Percentage Average (%)
Macroscopic	▪ Observing the process of mixing sugar solids and NaCl in liquid as the basis for determining the formation of a solution	1(a)	82	
	▪ Observing two different colored $Cu(OH)_2$ solutions as the basis for the difference in solution concentration	2(a)	82	
	▪ Observing the heating process of water as a basis for explaining the concept of the boiling point	4(a)	77	67
	▪ Observing the process of freezing water as the basis for the freezing point	5(a)	50	
	▪ Explain the function of salt in making ice cream	5(c)	68	
	▪ Observing the conditions of cucumbers that were left in water and those that were left in a salt solution	6(a)	41	

Table 4. Level of prospective chemistry teacher's understanding of the colligative properties for nonelectrolyte solutions for a sub-microscopic and symbolic level of chemical representation

Chemical Representation	Indicator Item Problem	No	Percentage (%)	Percentage Average (%)
Sub-microscopic	▪ Describe the differences in the end results of mixing two types of solids in water	1(b)	36	31
	▪ Describe the process of forming ionic solutions through an overview of the process of dissolving NaCl in water	2(b)	45	
	▪ Describe the difference in solution concentration based on the amount of solvent and dissolved in two solutions	1(c)	86	
	▪ Explain the definition of solution vapor pressure	3(a)	14	
	▪ Estimating the difference in vapor pressure between pure solvent and solution	3(b)	18	
	▪ Describe the process of boiling water through graphs and molecular structures of liquids at boiling	4(b)	5	
	▪ Describe the difference between the boiling points of a pure solvent and a solution through graphs and the molecular structure of boiling liquids	4(c)	14	
	▪ Describe the process of water freezing through graphs and molecular structures of liquids when frozen	5(b)	23	
	▪ Describe the difference between the freezing points of a pure solvent and a solution through graphs and the molecular structure of liquids when frozen	5(d)	32	
	▪ Describe the process of osmosis through an image of the osmosis process	6(b)	41	
Symbolic	▪ Calculate the concentration of the solution in molarity and molality	2(c)	82	72
	▪ Calculating Solution Vapor Pressure	3(c)	82	
	▪ Calculate the increase in the boiling point of the solution and the boiling point of the solution after a number of solutes have been added	4 (d)	77	
	▪ Calculate the decrease in the freezing point of a solution and the freezing point of a solution after a number of solutes are added	5(e)	32	
	▪ Calculating the osmotic pressure of the solution	6(c)	86	

Model mental of prospective chemistry teacher in colligative properties for nonelectrolyte solutions

The results of students' answers to the non-electrolyte solution colligative properties diagnostic test questions given were further analyzed to see their mental model profile. The grouping that has been carried out on the students 'answers is to see students' understanding in terms of macroscopic, submicroscopic, and symbolic levels and is also used to describe the categories of student mental models, whether they include scientific model (SM), phenomenon model (PM), character-symbol model (CSM), or the inference model (IM) (Lin & Chiu 2007).

In accordance with the descriptions and indicators of mental model categories, according to Lin & Chiu (2007), the researchers have drawn a relationship between mental model categories based on their suitability with descriptions of each level of chemical representation.

In general, the category level of students' mental models for the macroscopic, sub-microscopic, and symbolic levels on the nonelectrolyte colligative properties topics which is arranged per learning indicator, can be seen in **Figure 4**.

The mental model category in all learning indicators shows that the character-symbol model (CSM) category is owned by almost all students. After that, followed by the mental model of the phenomenon model (PM), which on average students have almost more than half of it. A small proportion of students have a mental model of the inference model (IM) and scientific model (SM).

This condition is in accordance with the results obtained for each learning indicator with the findings and analysis of students' understanding at each level of chemical representation. Almost all students have a good understanding in terms of macroscopic and symbolic levels, according to their mental model categories, that is, phenomenon model (PM) and character-symbol model (CSM).
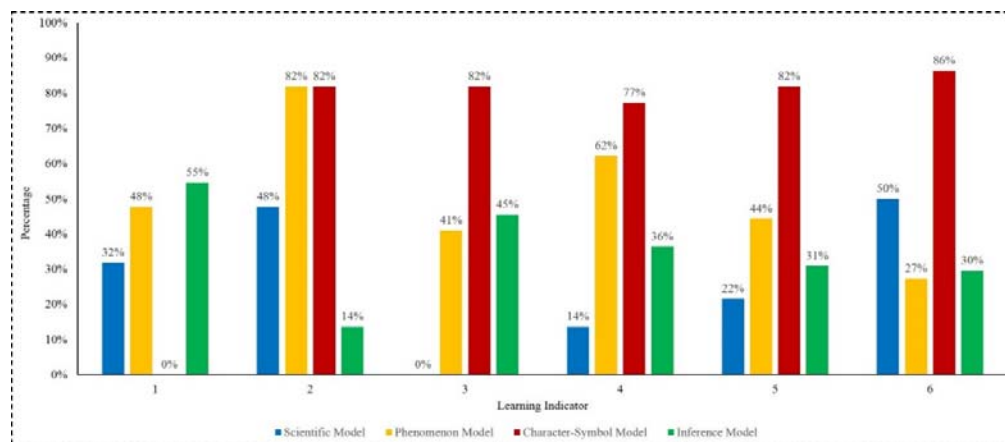

Figure 4. levels of pre-service chemistry teachers' mental model for colligative properties of nonelectolyte solutions in every learning indicator for each level of chemical representation

As for those who have the scientific model (SM) category, there are only a few students who explain the phenomena that occur by describing, interpreting, and predicting based on facts, laws, principles, or according to certain scientific principles. There are also those who provide explanations or generalizations of several separate scientific concepts, but form incorrect conclusions, thus making them into the inference model (IM) category.

Relationship of chemistry representations with mental model categories of prospective chemistry teacher in chemistry equilibrium

As has been known before, that chemical representation consists of macroscopic, sub-microscopic, and symbolic levels where each level has its own unique characteristics. This is in accordance with the mental model category by Lin & Chiu (2007) which has a description and indicators typical for each category. By comparing the characteristics of chemical representations and the categories of mental models they have, the researcher connects the two, as shown in **Table 5**.

In summary, the relationship shows that although the scientific model (SM) mental model category includes all three levels of chemical representation, this category is a correct alternative answer for sub-microscopic level items. This is because the explanation of the sub-microscopic level also requires an understanding of the macroscopic and symbolic levels. At the same time, the mental model category that is suitable for questions that measure understanding at the macroscopic level is the phenomenon model (PM). Meanwhile, for questions that measure understanding at the symbolic level, the appropriate category of mental models is the character-symbol model (CSM). The mental model category inference model (IM) is an alternative answer to each item at the macroscopic, sub-microscopic, and symbolic levels that form incorrect conclusions.

Table 5. 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 wrong conclusion)			

The variety of mental model students have in each question that measures understanding at each level of chemical representation is obtained from the results of this study. The following is **Tables 6**, 7, and **8** which show the various categories of mental models that students have on each item indicator.

Based on that, it can be concluded that the mental model categories of pre-service chemistry teachers for questions that see understanding at the macroscopic level are the scientific model (SM), the phenomenon model (PM), and the inference model (IM). Of the three mental model categories that these students have, it showed that the category of PM mental models is more, followed by the SM category and finally the IM category. Meanwhile, there are categories of IM and SM mental models because the students' mental models adjust to the knowledge they already know before and the conditions when answering the questions. This proves again the statement that mental models are dynamic structures that are formed when answering questions or solving problems or when dealing with certain situations.

Meanwhile, the categories of mental models that students have for questions that see understanding at the symbolic level are the character-symbol model (CSM) and inference model (IM). The CSM mental model category dominates more than IM. This is in accordance with the characters in the symbolic level problem with indicators from the CSM mental model category itself.

Thus, the relationship between chemical representations at the macroscopic, sub-microscopic, and symbolic levels with the mental model category of prospective chemistry teachers in the topic of chemical equilibrium can be summarized in graphical form in **Figure 5**.

Table 6. Pre-service chemistry teacher's mental model category on macrocscopic question

Chemical Representation	Indicator Item Problem	No	Model Mental	Percentage (%)
Macroscopic	▪ Observing the process of mixing sugar solids and NaCl in liquid as the basis for determining the formation of a solution	1(a)	Scientific Model	18
			Phenomenon Model	82
			Character-Symbolic Model	0
			Inference Model	0
	▪ Observing two different colored $Cu(OH)_2$ solutions as the basis for the difference in solution concentratio	2(a)	Scientific Model	9
			Phenomenon Model	82
			Character-Symbolic Model	0
			Inference Model	9
	▪ Observing the heating process of water as a basis for explaining the concept of the boiling point	4(a)	Scientific Model	23
			Phenomenon Model	77
			Character-Symbolic Model	0
			Inference Model	0
	▪ Observing the process of freezing water as the basis for the freezing point	5(a)	Scientific Model	45
			Phenomenon Model	50
			Character-Symbolic Model	0
			Inference Model	5
	▪ Explain the function of salt in making ice cream	5(c)	Scientific Model	9
			Phenomenon Model	68
			Character-Symbolic Model	0
			Inference Model	23
	▪ Observing the conditions of cucumbers that were left in water and those that were left in a salt solution	6(a)	Scientific Model	59
			Phenomenon Model	41
			Character-Symbolic Model	0
			Inference Model	0

Table 7. Pre-service chemistry teacher's mental model category on a symbolic question

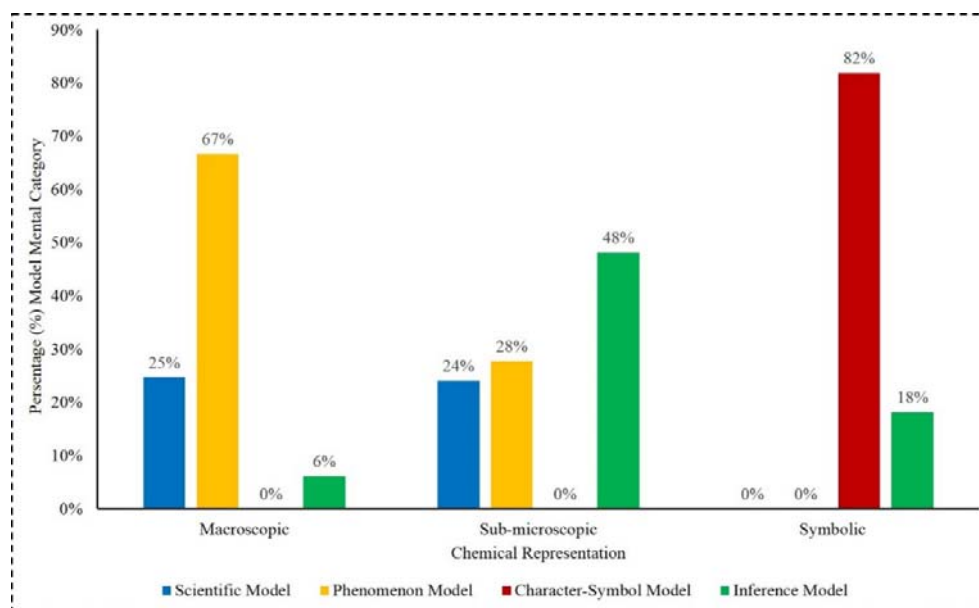| Chemical Representation	Indicator Item Problem	No	Model Mental	Percentage (%)
	▪ Calculate the concentration of the solution in molarity and molality	2(c)	Scientific Model	0
			Phenomenon Model	0
			Character-Symbolic Model	82
			Inference Model	18
	▪ Calculate the increase in the boiling point of the solution and the boiling point of the solution after a number of solutes have been added	3(c)	Scientific Model	0
			Phenomenon Model	0
			Character-Symbolic Model	82
			Inference Model	18
Symbolic	▪ Calculating Solution Vapor Pressure	4(d)	Scientific Model	0
			Phenomenon Model	0
			Character-Symbolic Model	77
			Inference Model	23
	▪ Calculate the decrease in the freezing point of a solution and the freezing point of a solution after a number of solutes are added	5(e)	Scientific Model	0
			Phenomenon Model	0
			Character-Symbolic Model	82
			Inference Model	18
	▪ Calculating the osmotic pressure of the solution	6(c)	Scientific Model	0
			Phenomenon Model	0
			Character-Symbolic Model	86
			Inference Model	14

Figure 5. Levels of pre-service chemistry teachers' mental model for colligative properties of nonelectolyte solutions in every learning indicator for each level of chemical representation

Table 8. Pre-service chemistry teacher's mental model category on a sub-microscopic question

Chemical Representation	Indicator Item Problem	No	Model Mental	Percentage (%)
Sub-microscopic	▪ Describe the differences in the end results of mixing two types of solids in water	1(b)	Scientific Model	36
			Phenomenon Model	0
			Character-Symbolic Model	0
			Inference Model	64
	▪ Describe the process of forming ionic solutions through an overview of the process of dissolving NaCl in water	1(c)	Scientific Model	41
			Phenomenon Model	14
			Character-Symbolic Model	0
			Inference Model	45
	▪ Describe the difference in solution concentration based on the amount of solvent and dissolved in two solutions	2(b)	Scientific Model	86
			Phenomenon Model	0
			Character-Symbolic Model	0
			Inference Model	14
	▪ Explain the definition of solution vapor pressure	3(a)	Scientific Model	0
			Phenomenon Model	55
			Character-Symbolic Model	0
			Inference Model	45
	▪ Estimating the difference in vapor pressure between pure solvent and solution	3(b)	Scientific Model	0
			Phenomenon Model	27
			Character-Symbolic Model	0
			Inference Model	73
	▪ Describe the process of boiling water through graphs and molecular structures of liquids at boiling	4(b)	Scientific Model	0
			Phenomenon Model	55
			Character-Symbolic Model	0
			Inference Model	45
	▪ Describe the difference between the boiling points of a pure solvent and a solution through graphs and the molecular structure of boiling liquids	4(c)	Scientific Model	5
			Phenomenon Model	55
			Character-Symbolic Model	0
			Inference Model	41
	▪ Describe the process of water freezing through graphs and molecular structures of liquids when frozen	5(b)	Scientific Model	9
			Phenomenon Model	27
			Character-Symbolic Model	0
			Inference Model	64
	▪ Describe the difference between the freezing points of a pure solvent and a solution through graphs and the molecular structure of liquids when frozen	5(d)	Scientific Model	23
			Phenomenon Model	32
			Character-Symbolic Model	0
			Inference Model	45
	▪ Describe the process of osmosis through an image of the osmosis process	6(b)	Scientific Model	41
			Phenomenon Model	14
			Character-Symbolic Model	0
			Inference Model	45

Conclusions

The mental model profiles of chemistry teacher candidate students on the sub-material of the colligative properties of nonelectrolyte solutions showed varying results. Students' understanding at the sub-microscopic level for the sub-material colligative properties of this non-electrolyte solution was the lowest when compared to representations at other levels. The mental model categories of students also vary from the scientific model (SM), the phenomenon model (PM), the character-symbol model (CSM), and the inference model (IM). Meanwhile, the relationship between the chemical representation and the category of students' mental models in the sub-material of the colligative properties of non-electrolyte solutions is almost in accordance with the previous analysis, which is based on the comparison between the characteristics of the chemical representation and the categories of mental models it has.

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