

# Prospective Primary School Teachers' Understanding on States Of Matter and Their Changes

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**Abstract.** This study investigated Prospective Primary School Teachers (PPST)' conceptual understandings on states of matter and their changes. Data were collected from 37 students Primary School Teacher Education Program. The students were given open-ended questions that explored their understandings on states of matter and their changes divided into macroscopic, submicroscopic and symbolic levels. Their understandings were divided into categories: understand, partial understand, misconception, and do not understand. The results showed that almost all students understood that matters are composed of particles. But most of them did not understand that between the particles exists "particle-free space". Almost all students knew most of phenomena (macroscopic level) related to states of matter and their changes. However, most of them could not explain the phenomena at submicroscopic and symbolic levels. At these levels, their understandings were still largely in the categories of partial understanding, misconception, or do not understand. Given these results it can be concluded that most of the students did not have fully understandings on states of matter and their changes. These results imply the need for improving the teaching and learning quality on states of matter and their changes for PPST in Indonesia.

## 1. Introduction

Learning science subjects is knowing the various natural phenomena that exist in the environment and can explain them scientifically [1],[2]. According to the constructivist view, it is important for teachers to know what students already know or think before they teach their students scientific conception[3]. Students often come to class with a variety of knowledge which is different from scientific conceptions [4]. These misconceptions inhibit students to gain scientific conceptions. Therefore, it is very important for teachers to know what already exists in the student's cognitive structure and eliminate them to make students acquire scientific conception easier [5].



In chemistry subject, according to Taber most of the misconceptions is not the result of interaction between students and the environment outside the school but due to the interaction of students in a formal learning environment, namely due to students' misconceptions from earlier science learning, limitations in science models, errors in model applications and language statements used that are less precise [6]. Misconceptions caused by previous science learning will further affect on how students interpret and construct new concepts [7]. To avoid misconceptions in chemistry it needs good science teaching before they study chemistry specifically in high school, especially learning about the states of matter and their changes that are fundamental to study chemistry at higher levels [8]. The concepts about states of matter and their changes are very important basic concepts in order to understanding other science concepts [1],[9],[10]. Furthermore, the concept of states of matter and the changes are also a key component in science curriculum from primary school to middle school [10],[11],[12].

As known, chemistry subject is study about matter (properties, structure, composition) and its change [13],[14]. Based on chemistry point of view, the topic states of matter and their changes include three levels that need to be studied, namely macroscopic, submicroscopic and symbolic level [15]. Given this, after learning the topic students are expected to know the various phenomena of changes in states of matter (macroscopic level), to explain the phenomena scientifically (submicroscopic level) and symbolizes the phenomena (symbolic level). Good conceptual understandings about matter, substances and particles will be good prerequisite to understand subject matter of chemistry [8]. Without a good understanding of these concepts then most of the next study of chemistry can be as learning a mystery story. If this happens then study of chemistry can only be done by rote memory [3].

In other countries such as in Turkey the above concepts are studied by students ranging from grade 4 to grade 8 (10-14 years) [9]. Ozmen found that primary school students given early introduction of the particle concept had a better particle conception than that of students who are not given the introduction of the particle concept [9]. Research results of Sanmarti and Merino indicated that students aged 9-11 years (equivalent to primary school students ages) introduced about the particle concept have a better ability in describing the arrangement of particles in the process of physical changes as compared to that of students not given the introduction [2].

Previous research results indicated that students of various levels have misconceptions and difficulties in understanding the topic states of matter and changes [9],[10],[16],[17]. Misconceptions that occur in the topic caused by various factors, including, according to Ben-Zvi et al, the concept is too abstract and according to Gabel et al, the poor visualization capabilities of students [10]. In addition, students' misconceptions is also due to the learning process in schools, "school-made misconceptions" [18]. The students' difficulties to learn about the states of matter and the changes did not apart from the teachers' difficulties to understand particulate nature of matter composing all matter. Research results found by Håland in Norway showed that at least 80% of prospective teachers have problems to understand the concepts associated with matter, substances and particles [3]. Tatar in Turkey found that PPST have a number of misconceptions [19].

Teachers can be a source of the misconceptions for students in understanding science contents due to several things, including a lack of knowledge about the concepts to be taught [20], educational background specialization and teaching experience of teachers [21]. Actually teachers should be more than just mastery in subject matter but they should also be able to diagnose misconceptions and designing learning strategies to help students confront misconceptions and turn them into scientifically conceptions [22]. Based on the review of the literature, Ozmen conclude that there are three main reasons why chemistry is considered difficult by students [9]. The first is chemistry topics are abstract. Secondly many everyday terms used have different meanings from everyday meanings. The third is students' cognitive development stages who have not reached the formal operational stage and their low capacity of visualization. In addition to those three things, according to Johnstone chemistry also includes three levels

of representation, macroscopic, submicroscopic and symbolic [18]. According to Hinton and Nakhleh students fully understanding of a phenomenon can be demonstrated by their ability to present and interpret such phenomena in the three levels [23].

Although several researches on the states of matter and the changes have been reported, but researches on the understanding of the topic categorized into macroscopic, submicroscopic and symbolic level has not been done. Given all above, the purpose of this study is to investigate on “how PPST in Indonesia understand about the states of matter and their changes at macroscopic, submicroscopic and symbolic level”.

## 2. Research methodology

This descriptive study aimed to describe the conception of primary school teachers about the states of matter and their changes. The research was conducted for six months, from September 2015 until February 2016. The study involved 37 student teachers in a Primary School Teacher Education Program in West Java taking science as their major. They have already completed Basic Concepts of Chemistry, Biology, and Physics courses. The research instrument used is a multiple-choice test combined with essay, questionnaire about students' confidence level of their answer. This test is used to measure students' understanding levels about states of matter and their changes classified into macroscopic, submicroscopic and symbolic level. Students' answers in each level were then classified following the simplified categorization from Abraham [24], as follows:

- Understand: Respondents answer questions correctly includes all components in accordance with the scientific conception and the respondents were convinced by the answer.
- Partly Understand: Respondents answer questions correctly, but does not include all the components in accordance with the scientific concept and respondents undecided or are not sure of the answer.
- Misconception: Respondents answer questions with answers that are not logical with the wrong information.
- Do not understand: Respondents answer questions with the wrong answer or no answer at all.

## 3. Results and discussions

### 3.1. PPST' understanding on the discontinuous nature of matter

Table 1 below shows that the majority of PPST already understand and believe that any substance, whether in the form of solid, liquid and gas are composed by particles.

**Table 1.** PPST' understanding on the existence of particles of matter.

Levels of Understanding	The Concept on the Existence of Particle of Matter		
	Solid	Liquid	Gas
Understand	86.48%	97.29%	97.29%
Partly Understand	13.52%	2.71%	2.71%
Misconception	0%	0%	0%
Do not Understand	0%	0%	0%

In Table 2 below shows that PPST who already understand that there is a particle-free space between the particles composed solid, liquid and gas is still low (around 30%). Most of them have misconceptions, such as between particles of solids is air or other substances that fill it; between the particles of liquids is air, empty spaces and other liquids; between particles of gases is air and empty space. These results are

consistent with previous researches which found that students/college students have misconceptions in understanding the existence of particle-free space, mostly referred to it as an empty space [1],[25],[26].

**Table 2.** PPST' understanding on the existence of "particle-free space" between particles of matter.

Levels of Understanding	The Concept on the Existence of "Particle-Free Space" between Particles of Matter		
	Solid	Liquid	Gas
Understand	24.32%	27.03%	24.32%
Partly Understand	18.92%	18.92%	16.22%
Misconception	37.84%	43.24%	40.54%
Do not Understand	18.92%	10.81%	18.92%

From the above findings, it seems that PPST have difficulty to accept the concept that between the particles of matter (solid, liquid or gas) is particles-free space. In the science history was known that earlier times scientific community needed up to 2,000 years to accept the discontinuous nature of matter or the concept that all matter are composed by the particles separated by particle-free spaces [27]. Only after discovery of vacuum, the concept of the discontinuous nature of the matter can be accepted by the scientific community. Based on the literature, the lack of time to introduce the concept causes many misconceptions related to particle concepts [9],[28],[29].

### 3.2. PPST' understanding on states of matter and their changes at macroscopic level

In Table 3 below shows that some PPST still have misconceptions regarding expansion, sublimation, and deposition phenomena. Misconceptions related to expansion such as solids, liquids and gases do not change the volume when heat is given. Misconception related to sublimation such as shrinking of mothballs involve evaporation process. And misconception related to deposition such as the formation of icebergs at the poles as the process of freezing and sublimate.

**Table 3.** PPST' understanding on states of matter and their changes at macroscopic level.

Levels of Understanding	Concept Labels						
	Expansion	Evaporation	Condensation	Melting	Freezing	Sublimation	Deposition
Understand	32.43%	100%	100%	100%	100%	97.3%	29.73%
Partly Understand	8.11%	0%	0%	0%	0%	0%	21.62%
Misconception	35.13%	0%	0%	0%	0%	2.7%	40.54%
Do not Understand	24.33%	0%	0%	0%	0%	0%	8.108%

### 3.3. PPST' understanding on states of matter and their changes at submicroscopic level

As known, representation at submicroscopic level is based on the particle theory used to explain real phenomena in the form of the motion of a particle such as electrons, ions, atoms and molecules [30]. In line with that, this study investigated PPST' understanding in verbally explaining the process of expansion (where the states of matter does not change but it changes size) and changes of states of matter such as evaporation, condensation, melting, freezing, sublimation, and deposition.

Based on Table 4 below shows that PPST who are able to explain all concepts at the submicroscopic level verbally are below 50%. Most of the students can be categorized as partly understand, misconception or do not understand.

**Table 4.** PPST' Understanding on states of matter and their changes at submicroscopic level verbally.

Levels of Understanding	Concept Labels						
	Expansion	Evaporation	Condensation	Melting	Freezing	Sublimation	Deposition
<b>Understand</b>	45.95%	46.85%	32.43%	40.54%	43.24%	33.33%	39.64%
<b>Partly Understand</b>	18.92%	13.51%	18.02%	18.02%	18.02%	15.32%	18.92%
<b>Misconception</b>	8.11%	19.82%	24.32%	17.12%	21.62%	17.12%	18.02%
<b>Do not Understand</b>	27.03%	19.82%	25.23%	24.32%	17.12%	34.23%	25.23%

Some misconceptions that arise are as follows:

**Table 5.** PPST' misconceptionson states of matter and their changes.

Expansion/ Changes in states of matter	PPST' Misconceptions
<b>Expansion</b>	Particles of solids, liquids, and gases enlarged when experiencing expansion
<b>Evaporation</b>	Water particles disappear when water evaporate Water particles swell when water turns into water vapor
<b>Condensation</b>	Water particles swell when it turns into dew Water particles do not have movement when water vapor condenses to water
<b>Melting</b>	Water particles are smaller when ice melts Water particles disappear when ice melts Water particles do not have movement when ice melts
<b>Freezing</b>	Water particles do not move in frozen ice
<b>Sublimation</b>	Particle of mothballs shrink and disappear
<b>Deposition</b>	Water particles do not move when vapor turns into solid

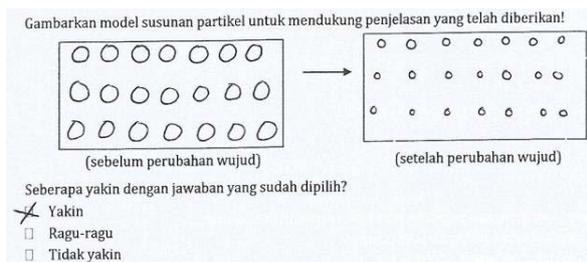
Those above misconceptions of PPST in explaining the phenomenon at the submicroscopic level are in line with previous research findings [9],[10],[16],[26]. According to Nussabaum and Novick, misconceptions that occur in the submicroscopic level is due to various factors, including everyday experience<sup>1</sup> and learning processes which present events and assumptions but those are not in accordance with the phenomenon known in everyday life [31].

PPST' understanding to explain the phenomena visually by using drawing were also investigated. Table 6 below shows that PPST who are able to draw particle model for all the labels concept is below 50%. Many of them still have misconceptions.

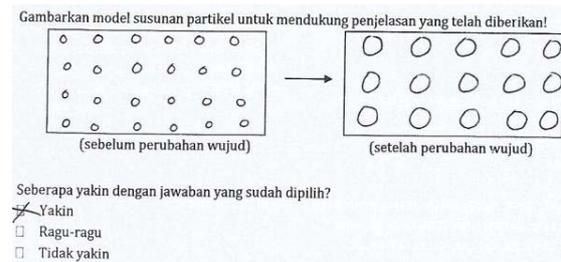
**Table 6.** PPST' understanding on states of matter and their changes at submicroscopic level visually.

Levels of Understanding	Concept Labels						
	Expansion	Evaporation	Condensation	Melting	Freezing	Sublimation	Deposition
Understand	15.32%	24.32%	24.32%	32.43%	32.43%	29.73%	8.11%
Partly Understand	33.33%	10.81%	8.11%	13.51%	10.81%	18.92%	16.22%
Misconception	17.12%	24.32%	21.62%	16.22%	16.22%	10.81%	10.81%
Do not Understand	34.23%	40.54%	45.95%	37.84%	40.54%	40.54%	64.86%

Misconceptions that occur include drawings of particle models that are changing the size (shrink and swell) as shown below:



**Figure 1.** PPST' answer on condensation at submicroscopic level visually.



**Figure 2.** PPST' Answer on Evaporation at Submicroscopic Level Visually.

Figures 1 and 2 above belong to misconceptions because the drawings of particle size change (become smaller / become larger), particle size of solids, liquids, and gases should scientifically remain unchanging during the changing. These research results are consistent with previous studies which found that students/ college students assumed that particle size increases when there is a change from solid to liquid and to gas [26],[32],[33]. Another misconception found in Figures 1 and 2 is that drawings of the distance between the particles before and after the changes are the same. The distance between the particles should be different before and after the change. In general, the distance between particles in solids is dense, in liquids is distant and in gases is very distant. Besides the changes of the distance between particles, drawings should also show the change in the arrangement of the particle when states of matter change. The difficulties of PPST in Indonesia to explain the phenomena at submicroscopic level is in line with several studies conducted in other countries which found that students of all levels, college students and even prospective student teachers have difficulty to explain the states of matter and their changes at the submicroscopic level [34],[35],[36],[37].

#### 3.4. PPST' Understanding on States of Matter and Their Changes at Symbolic Level

Symbolic level is representation in the form of chemical symbols, formulas and reaction equation [30]. In this study, PPST' understanding level was measured by asking them to write symbols of states of matter such as solid (s), liquid (l) and gas (g) at different changes states of matter. PPST' understanding about changes states of matter at symbolic level shown in Table 7 below:

**Table 7.** PPST' understanding on changes states of matter at symbolic level.

Levels of Understanding	Concept Labels					
	Evaporation	Condensation	Melting	Freezing	Sublimation	Deposition
<b>Understand</b>	37.84%	35.14%	43.24%	45.95%	21.62%	5.41%
<b>Partly Understand</b>	27.03%	24.32%	43.24%	29.73%	16.22%	18.92%
<b>Misconception</b>	13.51%	10.81%	0.00%	0.00%	0.00%	0.00%
<b>Do not Understand</b>	21.62%	29.73%	13.51%	24.32%	62.16%	75.68%

Table 7 shows that the percentage of PPST who can write the symbolic level for all changes states of matter is still below 50%. On the concept evaporation and condensation there are still PPST who have misconceptions. Following is a misconception that occurs in writing the symbol of the evaporation.



**Figure 3.** PPST' answer in writing symbols of evaporation.

This above symbolic representation shows a misconception in which the evaporation process is regarded as the decomposition of H<sub>2</sub>O into H<sub>2</sub> and O<sub>2</sub>. Results were consistent with previous researches found that students of all levels, college students and prospective teachers assume that when the process of evaporation, the water molecules will break down into oxygen and hydrogen [38],[39]. As known, in the evaporation, water molecules are not changes, they exist before and after the evaporation.

#### 4. Conclusion

The results of this study indicate that the Primary School Teacher Education Program has not provided its PPST with a full understanding related to the topic of states of matter and their changes. They did not have a full understanding about the discontinuous nature of matter. They already understood that matter is composed by particles, however, they did not understand the existence of the particle-free space that exists between the particles. Eventhough they already understood phenomena regarding to states of matter and their changes at macroscopic level, however, they still had difficulties to explain the phenomena at submicroscopic level both verbally and visually. And they also had difficulties to represent the phenomena at symbolic level. The results suggest the need for improving the quality of teaching and learning processes on states of matter and their changes at Primary School Teacher Education Program.

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