

Research Article

Evaluation of mental models of prospective science teachers on chemical reactions

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The aim of this study is to examine prospective science teachers' (PSTs) mental models and meanings for the concept of chemical reaction. For this purpose, this study adopted a phenomenological research design including 48 PSTs. To determine the mental modeling about chemical reactions, PSTs were given an interview card showing the reaction between magnesium and oxygen gas, and were asked to draw and visualize this reaction and a semi-structured interview was held about the specified reaction. The results revealed that the majority of the PSTs used the particle atom model to model for the chemical reactions, and as their education level increased, the models they used shifted from the particle model to the atomic model. In addition, the explanations showed that all the PSTs explained the reaction of magnesium with oxygen gas at the macroscopic level in the first stage and when asked the evocative interview question, most of them explained the reaction at the microscopic level, but some PSTs continued to make explanations at the macroscopic level despite the hinted interview problem. It was also found that the transition from the macroscopic level to the microscopic level of the PSTs' explanations with the evocative interview question was influenced by the education level and their mental models regarding the reaction. In chemistry teaching starting from the high school senior year, it is recommended to use visual materials related to reactions based on atomic models instead of particle-based materials.

Keywords: Science teacher education; Chemical reactions; Chemical reaction models

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1. Introduction

Chemistry is a science that studies the structure and properties of matter. It explores how and why substances interact with each other while forming other items. The changes that occur as a result of the interaction of substances with each other are examined under two main headings as physical and chemical changes. Since learning chemical changes is the most fundamental component of chemistry teaching, researchers attach great importance to students' learning about chemical changes (Cheng, 2018). Chemical changes are related to other chemistry concepts such as atoms, ions, molecules, elements, compounds and movement of particles (Tarhan et al., 2013). Atoms, ions, molecules, elements, compounds and particles seem abstract to students because they are microscopic structures. This abstract structure of chemistry causes students to have difficulties in learning chemistry (Carter & Brickhouse, 1989; Nakhleh, 1992). In order for students to learn

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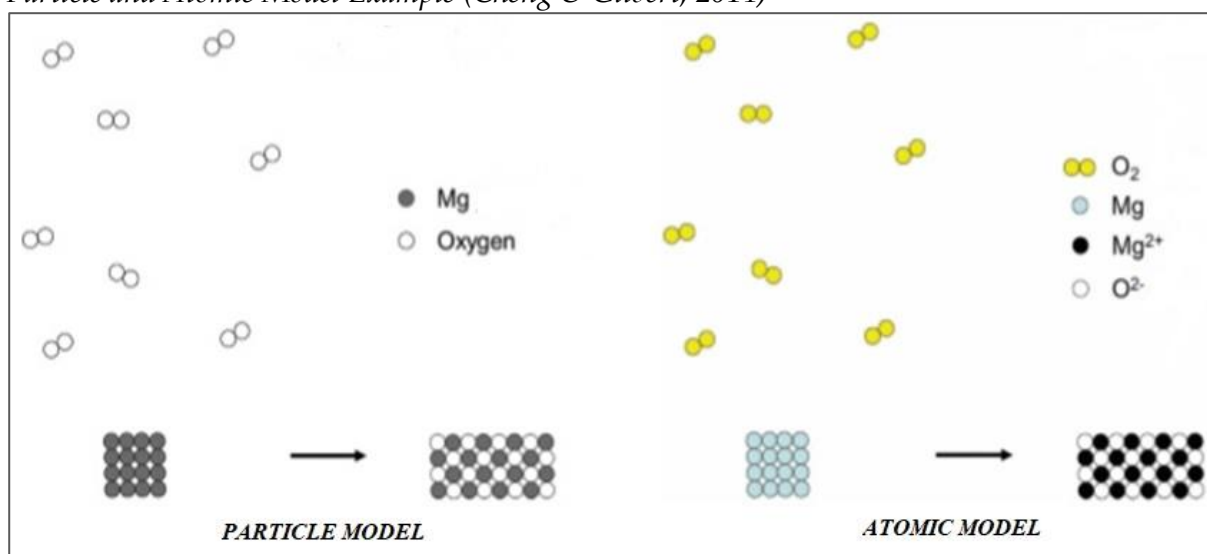
chemistry, they need to make associations between the macroscopic, microscopic and symbolic nature of chemistry. While students have no difficulty understanding macroscopic and symbolic nature, in order to understand microscopic nature students need to create mental images about things they cannot see, which is very difficult (Taber & Coll, 2002). Many studies have been conducted by researchers on students' misunderstanding of chemical changes, the reasons for these misunderstandings and therefore the level of understanding of chemical changes.

In this context, the researchers conducted researches on chemical changes and chemical reactions to examine how students' understanding developed over time and how their knowledge structures were reconstructed. As a result of these studies, it was concluded that individuals' cognitive levels improved and that they restructured knowledge, but some of their misconceptions continued (Boo & Watson, 2001; Liu & Lesniak, 2006; Solsona et al., 2003; Øyehaug & Holt, 2013; Weinrich & Talanquer, 2015). In some studies, it has been investigated how it can be facilitated for individuals to learn chemical changes (Ardac & Akaygun, 2004; Hadenfeldt et al., 2016; Johnson & Tymms, 2011; Kelly et al., 2017; Smith et al., 2006; Williamson & Abraham, 1995; Zhang & Linn, 2011). In a study conducted with undergraduate and graduate chemistry students, the strategies used by students in classifying different chemical reactions were investigated and it was concluded that the level of expertise in chemical classification did not develop linearly and continuously with academic education (Stains & Talanquer, 2008).

In order to better understand chemistry concepts, visualization is very important (Mcintosh, 1986; Noh & Scharmann, 1987). The ability of students to visualize particles such as atoms, molecules, and ions in their minds enables them to explain chemical events better in line with scientific views (White, 1988). It helps students to think creatively and develop their imaginations in order to present the concepts of abstract chemistry in a concrete and clear way by visualizing them with teaching materials (Düzakaya, 2004). Models are one of the materials that can be used to visualize abstract chemistry concepts such as atom, molecule and ion in students' minds (Gilbert & Treagust, 2009; Johnstone, 1991). Visualizing micro-scale chemistry concepts, which are difficult to visualize in students' minds, by using models enables students to understand the concepts accurately and fully, as well as providing permanent learning (Adadan, 2014; Eyceyurt-Türk & Tüzün, 2018; Halloun, 2007; Mendonça & Justi, 2011; Oliva et al., 2015; Wei et al., 2013).

Figure 1

Particle and Atomic Model Example (Cheng & Gilbert, 2014)



Erduran and Duschl (2004) and Gilbert and Justi (2016) stated that model-based reasoning will play an important role in learning and exploring chemistry. Cheng and Gilbert (2017) suggested that two different models can be used to teach chemical reactions to students, such as;

1. *Particle reaction model*: In the particle model that students use to explain chemical reactions, chemical reactions are likened to rearrangement of Lego blocks and explained as simple rearrangement of particles. The core assets in the particle model are treated as intact and undivided entities. In short, as a simple rearrangement of these model particles, subatomic particles are not considered in a reaction.

2. *Atomic reaction model*: This model includes more specific structural entities such as atoms, ions, molecules, electrons, and protons. These structural entities participate in chemical reactions and eventually transform into other chemical species. This model goes beyond the spatial rearrangement of unidentified chemical species (Cheng & Gilbert, 2017). Taber (2003) suggested that chemical reactions can be regarded as rearrangement of electrons. This idea is consistent with the atomic reaction model.

Table 1

Comparison of two chemical reaction models (Cheng & Gilbert, 2017)

	<i>Particle reaction model</i>	<i>Atomic reaction model</i>
Structural assets	Particles or atoms are not composed of unitary and subatomic particles in nature.	Includes atoms, ions, molecules and electrons and protons as subatomic particles.
Process (Chemical Reaction)	Spatial rearrangement of particles and atoms.	Rearrangement of chemical species. Submicroscopic changes occur in some reactions, for example, the conversion of atoms to ions and ions to atoms.

In their study with high school students, Cheng and Gilbert (2017) asked students to visualize the reaction between magnesium and oxygen gas, and based on student drawings, they found that students used two models in their drawings, and these were particle and atomic models. In their drawings, they first used the particle model, and when they saw advanced chemical reactions such as redox, they reached the conclusion that the models they used shifted towards the atomic model (Cheng & Gilbert, 2017). Similarly, Cheng (2018), who employed a different chemical reaction, asked students to draw the reaction that occurred between magnesium and hydrochloride in a study he conducted with high school students. As a result of the research, he reached similar results with Cheng and Gilbert (2017), and it was concluded that while the students first used the particle model, the models they used shifted towards the atomic model when they saw advanced chemical reactions such as redox. He then asked the students to explain the drawings and revealed that the high school students who learned advanced chemical concepts used concepts such as energy and redox in their explanations while explaining their drawings. In another study conducted in this field, Bilir and Digilli-Baran (2018) examined chemical reaction models used in visuals in high school chemistry textbooks. As a result of the research, it was determined that "Particle Reaction Model" was used mainly in the figures and visuals used in chemistry textbooks. In addition, it was concluded that while the particle reaction model was included in the visuals in the 9th, 10th, and 11th grade chemistry textbooks, this particle reaction model was left in the senior year of high school and the atomic reaction model became the only one used.

When the findings of the studies in the literature above are examined, it is noteworthy that the models are of great importance in the teaching of chemical reactions. However, it is obvious that studies examining the mental models of individuals for chemical reactions are limited. It is seen that these studies are generally applied on high school students and there are no studies in which the mental models of PSTs for chemical reactions were studied. In this respect, this study will focus on the mental modeling that PSTs have for the concept of chemical reaction (magnesium and oxygen reaction). The theoretical basis of the research is the study of Cheng and Gilbert (2017) and

Cheng (2018). In the study, the reaction of magnesium and oxygen as a chemical reaction, like Cheng and Gilbert (2017), was discussed, and particle and atomic reaction models presented by the researchers were used in the analysis. The most important difference from Cheng's (2018) study of this study is that the education level of the participants in the study is different, PSTs are asked to explain the reaction of magnesium and oxygen gas, and they try to determine the level (macroscopic or microscopic) they use while explaining this reaction.

In teaching of chemical reactions, it is important to determine the relationship between the models that PSTs have about chemical reactions and the explanations of these models and chemical reactions considering that models hold an important place in teaching the subject of chemical reactions and that teachers will create these models within the framework of the images they might have. Especially, the finding that indicates the change of mental models possessed by PSTs according to grade level and the relationship between the levels of explanation of chemical reactions and their mental modeling is expected to shed light on the efficiency of the science undergraduate program in teaching the subject of chemical reactions.

1.1. Research Question

The aim of this study is to investigate which of the particle model and atomic model used by the PSTs in their visualization of the chemical reaction between magnesium and oxygen gas, and how this changes according to their education level. In addition, it is also aimed to investigate the level of (macroscopic or microscopic) explanations for chemical reactions while explaining the reaction that occurs between magnesium and oxygen gas, and to reveal the relationship between mental modeling and explanations.

In line with the purposes given above, the following questions were sought in this research;

1. On the basis of which reaction model do PSTs model the reaction of magnesium and oxygen gas in their minds?
2. Do the PSTs model the reaction of magnesium with oxygen gas on the basis of particle or atomic model in their minds different according to the level of education?
3. At what level (macroscopic or microscopic) do the PSTs explain the reaction of magnesium and oxygen gas mostly?
 - a. At what level are the PSTs' explanations before giving the evocative hint?
 - b. At what level are their explanations after giving the evoking hint?
4. Does the level of education affect the PSTs' explanations on the macroscopic or microscopic level of the reaction of magnesium with oxygen gas?
 - a. Do the PSTs' explanations before giving any hint differ according to the level of education?
 - b. Do the PSTs' explanations after giving a reminder hint differ according to the level of education?
5. Is there a relationship between the PSTs' macroscopic or microscopic explanations of the reaction of magnesium with oxygen gas and their mental models regarding this reaction?

2. Method

Phenomenology method, one of the qualitative research techniques, was used in this study, which aims to determine the level (microscopic or macroscopic) that PST use to explain their mental models for chemical reactions and chemical reactions (Creswell, 2013). According to Creswell (2013), this method is used in social sciences to reveal the common meanings that a group of people attribute to an event, object or phenomenon. In this study, within the framework of the perspective put forward by Creswell, the chemical reaction modeling (particle and atomic model) used by PSTs in their drawings and the levels of meanings (macroscopic and microscopic level) they attribute to chemical reactions in their explanations were determined as phenomena and it is aimed to describe the meanings that PSTs attribute to this phenomenon.

2.1. Study Group

The study was carried out with students of department of science teaching of faculty of education of a state university in Turkey during the spring semester of the 2017-2018 academic year. While determining the research group, the maximum diversity sampling method, which is a type of purposeful sampling, was used. In maximum diversity sampling, it is possible to reveal the same situation with various distributions and reach more comprehensive results (Flick, 2002). Within the framework of this approach, the academic averages of PSTs were taken into account in the selection of the research group. Four PSTs at each grade level labeled as low, mediate and high academic averages voluntarily participated in the research group. As a result of this selection, the data collection part of the research was concluded with a total of 48 participants, 12 of whom were students from each grade level.

2.2. Data Collection Process

PSTs who participated in the study were given an interview card containing the "equation of magnesium and oxygen gas reaction" and asked to draw the shape or shapes that come to life in front of their eyes regarding this reaction equation. Cronin-Jones (2005) revealed that the use of drawings in educational research is used to determine models in the minds of participants. After the PSTs drew the reaction, firstly, the question "Can you explain what this equation represents and what it describes?" was asked and it was decided which one of the students' explanations had macroscopic and microscopic levels. With this question, it is expected that the PSTs' answers will be at the microscopic level because regardless of the fact that the drawings of them in a particle model or an atomic model, these models are microscopic level drawings. The interview of the PSTs who did not give the answer of "microscopic level" was carried out with the question of "While you learn chemistry, you learn concepts such as atom, molecule and ion. We call this the microscopic world. How would you explain this chemical reaction about the microscopic world?". Since this interview question contains hints about the microscopic level, it is aimed to enable the students to reveal the concepts related to the microscopic world of chemical reactions in their minds and to make them explain in this way. The answers of PSTs were analyzed in this way. Content validity, which is defined as how much the questions contained in the data collection tool represent the content, is an important issue (Creswell, 2002). The data collection tool was evaluated in terms of content validity by three chemistry education experts at undergraduate and graduate levels. It was decided that the data collection tool was capable of displaying the concepts targeted in the study. Also, three PSTs who were not included in the study were asked to test the comprehensibility of the questions. In this pilot application, it was concluded that the questions were understandable.

The interviews were recorded. There was no time limit for the drawings of the PSTs and the interviews, however, the drawings and interviews were completed in an average of 15-20 minutes.

2.3. Data Analysis

The data obtained from the drawings of PSTs were classified according to the determining features of the particle and atomic model (according to Table 1). Classification criteria are as follows.

(a) Drawings showing only the spatial rearrangement of particles during reaction are classified as particle model.

(b) Drawings representing different particles such as magnesium atoms, magnesium ions, oxygen molecules, oxidation and reduction products before and after the reaction or drawings showing electron transfers are classified as atomic models.

In the macroscopic and microscopic classification of the data obtained from the interviews with PSTs, while the events that can be directly observed are mentioned, it is classified at the macroscopic level; and at the microscopic level when the explanations are made using atoms, molecules or subatomic particles such as ions, etc (Ebenezer, 2001; Johnstone, 1982; Özmen & Ayas, 2003; Treagust et al., 2003).

In this study, the use of a model consists the main focal point instead of the misconceptions that PSTs have about the concept of chemical reaction. Therefore, evaluations were not made by taking the scientific quality of student drawings into consideration. In coding the data collection tools given to PSTs, the data collection tool of each participant was expressed with a number and their class was written at the bottom left. For example, a second grade PST was given a number first and expressed as "2S14".

For the reliability of the data analysis, the data were coded independently by an author, who is an expert in chemistry education and a colleague. A high level of consistency was observed between the codes given: 95.83% (46 of 48 PSTs).

3. Findings

In order to find an answer to the first of the research questions, PSTs were asked to visualize the chemical reaction presented with the interview card given and the drawings they made were classified. The distribution of the drawings of the PSTs participating in the study regarding the reaction of magnesium with oxygen gas according to the particle and atomic model is given in Table 2.

Table 2

Distribution of PSTs' drawings of the reaction of magnesium with oxygen gas by particle and atomic model

<i>Models Used</i>	<i>Particle model (f)</i>	<i>Atomic model (f)</i>
Number of PSTs	31	17

When Table 2 is examined, it is seen that while 31 PSTs visualize the reaction of magnesium with oxygen gas with a drawing of particle model, 17 of them used the atomic model. In this respect, it can be stated that the PSTs participating in the study mostly made drawings on the basis of the particle model while visualizing the chemical reaction of magnesium and oxygen gas. Examples of particle and atomic model drawings of PSTs are presented in Table 4.

Findings regarding the second research question of the study, "Do the PSTs model the reaction of magnesium with oxygen gas on the basis of particle or atomic model differentiate according to the level of education?" are given in Table 3.

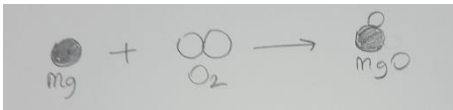
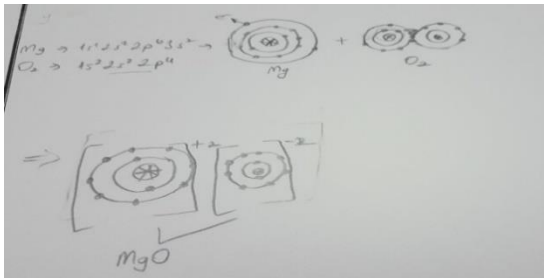
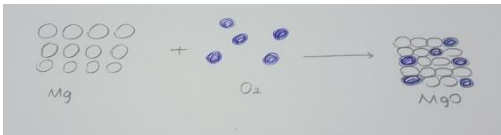
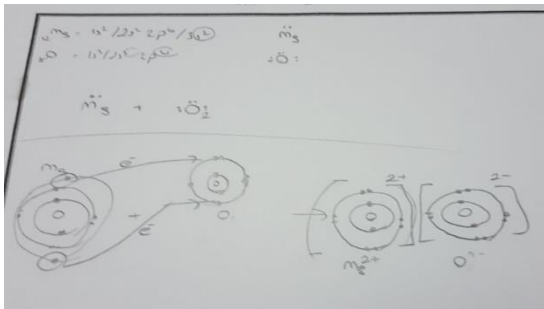
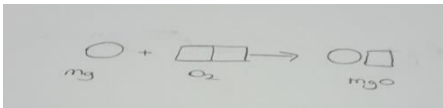
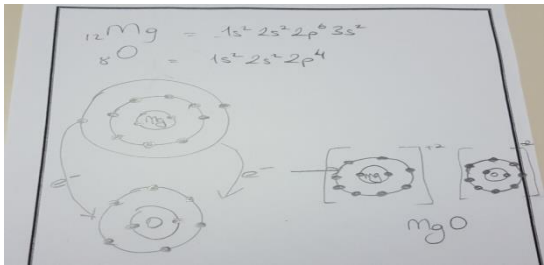
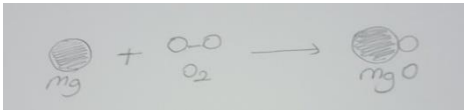
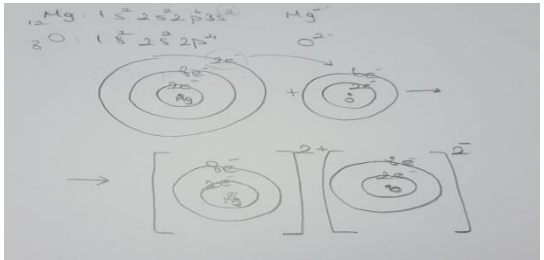
Table 3

Distribution of the particle and atomic model-based drawings of the PSTs' reaction of magnesium with oxygen according to their education

<i>Education Level</i>	<i>Particle Model</i>	<i>Atomic Model</i>
1st Grade	9	3
2nd Grade	8	4
3rd Grade	8	4
4th Grade	6	6
Total	31	17

When Table 3 is examined, it is see that while nine of the first-year PSTs visualized the chemical reaction of magnesium with oxygen gas with the particle model, three used the atomic model; eight of the second grade PSTs used the particle model while four of them used the atomic model, also, in the third grade, while eight students preferred the particle model went for the atomic model and six of the fourth grade students used the particle model and the other six, the atomic based drawing. In this context, it can be claimed that as the education level of PSTs increases, there is a transition from particle model to atomic model in the modeling of the reaction of magnesium with oxygen gas. In the table below (Table 4), examples of PSTs' levels of education and the models they use are presented.

Table 4
Drawing examples of PSTs' reaction of magnesium with oxygen gas

Education Level	Drawing Made by the PST	
	Particle Model	Atomic Model
1st Grade		
2nd Grade		
3rd Grade		
4th Grade		

After the PSTs completed their drawings, they were asked the question of "Can you explain what this equation represents and describes?" and their answers were analyzed. Due to the fact that all PSTs gave the answer of "macroscopic level" the interview was carried on with the evocative interview question of "While learning chemistry, you learn concepts such as atom, molecule, and ion. We call this the microscopic world. How would you explain this chemical reaction about the microscopic world?" and by analyzing the students' answers, the findings regarding the data before and after the evocative interview question are presented in the table below.

Table 5

Distribution of PSTs' statements before and after the evocative interview question about the reaction of magnesium with oxygen gas by macroscopic or microscopic levels

<i>Before the Evocative Interview Question</i>		<i>After the Evocative Interview Question</i>	
Macroscopic Level	Microscopic Level	Macroscopic Level	Microscopic Level
48	-	11	37

When Table 5 is examined, it is seen that before the evocative interview question, forty-eight PSTs explained their drawing to visualize the reaction of magnesium with oxygen gas on a macroscopic level. When the same PSTs were asked about the interviews with evocative questions, it is seen that the explanations of thirty-seven of them regarding their drawings shifted to the microscopic level, but the explanations of eleven still remain at the macroscopic level. Within the framework of these findings, it can be argued that the macroscopic level concepts were activated first to explain the reaction of magnesium with oxygen by PSTs. Especially after the evocative interview question, it can be argued that some PSTs' explanations shifted to microscopic level, even if they made statements at the macroscopic level, it does not mean that the PSTs could not make a microscopic sense of the relevant reaction. Interview examples of $_1S8$ and $_3S32$ coded participants are given below.

- Researcher:* Can you explain what this equation represents and describes?
 $_1S8$: There is a burning reaction here. The magnesium solid and oxygen gas react. It forms the magnesium oxide solid. (Answer before the evocative interview question)
- Researcher:* When you learn chemistry, you learn concepts such as atom, molecule, ion. We call this the microscopic world. How would you explain this chemical reaction regarding the microscopic world? (Evocative interview question)
 $_1S8$: Magnesium atom and oxygen molecule react. This is a redox reaction, magnesium is oxidized by giving electrons, oxygen is reduced by taking these electrons, and the ions formed attract each other to form compounds. (Answer after the evocative interview question)

As seen in the responses of $_1S8$ in the interview, $_1S8$ defined the reaction as the combustion reaction before the evocative interview question and mentioned the physical states of magnesium, oxygen and magnesium oxide. $_1S8$ said that the resulting product was solid. Since $_1S8$ mentioned directly observable events (combustion reaction, physical conditions of reacted and released products) in the explanation before the evocative interview question, the explanation is at the macroscopic level. After the evocative interview question, $_1S8$ defined the reaction as a redox reaction and stated that one substance will be reduced as a result of receiving and giving out electrons and the other will be oxidized. In this respect, the student's explanation before the $_1S8$ evocative interview question showed that she made using subatomic particles such as atoms, molecules and ions, and mentioned high-level chemistry concepts such as redox, reduction, and oxidation at the microscopic level. However some of students' (for example $_3S32$) explanations were not changed after evocative interview questions.

- Researcher:* Can you explain what this equation represents and what it describes?
 $_3S32$: Magnesium solid and oxygen gas combine to form magnesium oxide solid. This is a combustion reaction.
- Researcher:* When you learn chemistry, you learn concepts such as atom, molecule, ion. We call this the microscopic world. How would you explain this chemical reaction regarding the microscopic world? (Evocative interview question)
 $_3S32$: Magnesium is solid, oxygen is gas, and reaction product is solid magnesium oxide. This is a heterogeneous reaction. (Answer after the evocative interview question)

As can be seen in the responses given by $_3S32$ in the interview, $_3S32$ explained the reaction before the evocative interview question, and made an explanation in accordance with the macroscopic level as the directly observable physical state of the reacting and combustion products

and the combustion reaction of the equation. After the evocative interview question, $3S32$ did not use subatomic particles such as atoms, molecules, and ions in the explanations, and explained it as a heterogeneous reaction, which is one of the observable properties, showed that this explanation was at the microscopic level.

The distribution of PSTs' explanations before and after the evocative interview question regarding the reaction of magnesium with oxygen gas by macroscopic and microscopic level and education level is presented in Table 6 for the fourth question of the research.

Table 6

Distribution of PSTs' macroscopic or microscopic explanations before and after the evocative interview questions about the reaction of magnesium with oxygen gas by level of education

	Before the Evocative Interview Question		After the Evocative Interview Question	
	Macroscopic Level	Microscopic Level	Macroscopic Level	Microscopic Level
1st Grade	12	-	4	8
2nd Grade	12	-	4	8
3rd Grade	12	-	2	10
4th Grade	12	-	1	11
Total	48	-	11	37

When Table 6 is examined, it is seen that all the PSTs who participated in the study, regardless of their education level, had macroscopic level explanations about the reaction of magnesium with oxygen gas before the evocative interview question. After the evocative interview question, eight of the first and second-grade PSTs' explanations shifted to microscopic level, four of them were still at the macroscopic level, although the explanation of ten of the PSTs in the third grade shifted to the microscopic level, the explanation of two of the PSTs in the fourth grade remained at the macroscopic level. However, it is seen that the explanations of eleven have shifted to microscopic level and that only one explanation remained at macroscopic level. In the light of these findings, it can be argued that the conceptual framework required for microscopic level explanation can be activated with evocative cues, and that the level of education has a positive effect on this activation process, even though the initial concepts associated with the reaction of magnesium with oxygen gas by all participants are at the macroscopic level.

When we look at the example of the interview with $3Ö40$ below, the PSTs explained the reaction before the evocative interview question, while the macroscopic level was directly observed because the student mentioned the known combustion reaction and the physical state of the reacted and released product, and after the evocative interview, the PST mentioned the ions, electrons and the bond formed. It was observed that the explanation of the fourth grade PST was at the microscopic level because of the subatomic particles. While $4S40$'s explanation before the evocative interview question was at a macroscopic level, the student's explanation shifted to microscopic level after the evocative interview question.

Researcher: Can you explain what this equation represents and describes?

$4S40$: Looks like a burning reaction. Magnesium formed magnesium oxide with oxygen. The solid and gas reacted, resulting in a solid. Combustion reaction is a chemical reaction.

Researcher: When you learn chemistry, you learn concepts such as atom, molecule and ion. We call this the microscopic world. How would you explain this chemical reaction regarding the microscopic world?

$4S40$: Here, the magnesium atom gives two electrons to form a $2+$ charged magnesium ion. It takes these two electrons in oxygen and forms the $2-$ charged oxygen ion. These ions attract each other and form ionic ally bonded magnesium oxide compound.

When we look at the example of the interview with $2S15$ below, the evocative interview question is macroscopic because it directly explains the reaction before the interview question, as it directly mentions the number of products that react and exit, and the type of reaction. After the

evocative interview question, $_2S15$ continued to explain the distinctive features such as color, odor, and taste of the reacted and extracted products, namely, the properties known to be directly observed, at the macroscopic level.

Researcher: Can you explain what this equation represents and describes?

$_2S15$: There is oxygen, but there will be no burning, probably because carbon dioxide and water did not form. One of the two events must have occurred, like a formation.

Researcher: When you learn chemistry, you learn concepts such as atom, molecule, ion, etc. We call this the microscopic world. How would you explain this chemical reaction regarding the microscopic world?

$_2S15$: In other words, the substance before reacting and the substances formed after entering are different from each other. Distinctive properties of the substance such as color, odor and taste change. The mass of those entering is equal to the sum of the mass of the products.

Findings regarding the research question "Is there a relationship between the PSTs' explanation of the reaction of magnesium with oxygen gas at macroscopic or microscopic level and their mental modeling about this reaction?" are presented below.

Table 7

Distribution of particle and atomic based drawings of PSTs for the reaction of magnesium with oxygen gas according to their macroscopic or microscopic descriptions before and after the evocative interview question

<i>Mental Modelling</i>	<i>Before the Evocative Interview Question</i>		<i>After the Evocative Interview Question</i>	
	Macroscopic Level	Microscopic Level	Macroscopic Level	Microscopic Level
Particle Model	31	-	11	20
Atomic Model	17	-	-	17

When Table 7 is examined, it is seen that 31 PSTs who visualized the reaction of magnesium with oxygen gas based on a particle model and 17 PSTs who visualized the atomic model-based visualization before the evocative interview question explained the reaction on a macroscopic level. After the evocative interview question, it is seen that 11 PSTs who visualized the reaction of magnesium with oxygen gas based on a particle model, explained the reaction at the macroscopic level, and 21 PSTs who drew on the basis of microscopic and atomic models, and at the microscopic level. In this respect, it can be argued that the first associations of all the PSTs at the macroscopic level, whether the mental model of the reaction of magnesium with oxygen gas is based on particle or atomic model. However, after an evocative hint is given, it can be argued that the PSTs who have a mental model based on atomic model can more easily activate the conceptual framework required for microscopic level explanation, making explanations at microscopic level after all the evocative hint. In short, it can be thought that particle-atomic s-mental modeling has an effect on PSTs' activation of the conceptual framework for the relevant reaction at the microscopic level. In Table 8 below, some PSTs' drawings based on the atomic and particle model to visualize the reaction of magnesium with oxygen gas and examples of macroscopic and microscopic explanations of these drawings before and after the associative interview question are presented.

Table 8

Education levels, mental modeling and macroscopic explanation level examples of PSTs about the reaction of magnesium with oxygen gas before and after the evocative interview question



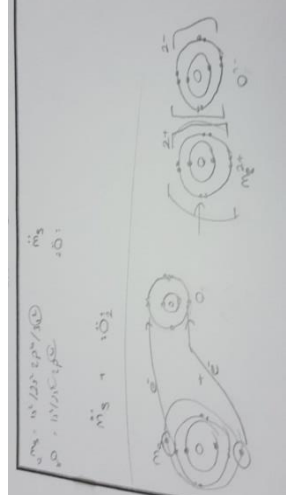
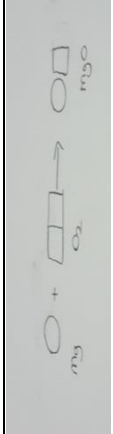
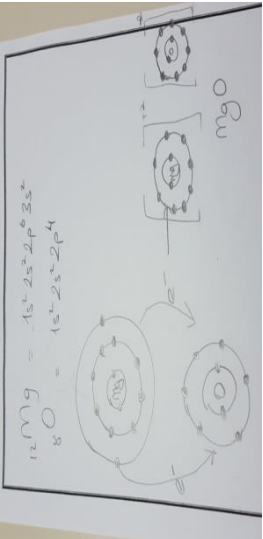
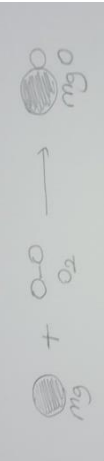
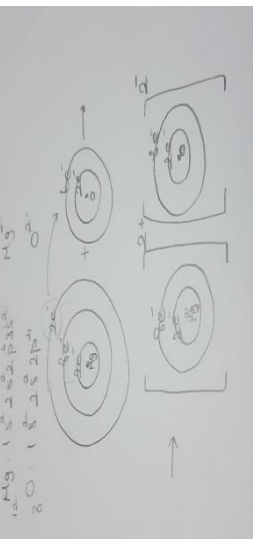
Education Level	Mental Modelling	Explanation Before the Evocative Interview Question	Explanation After the Evocative Interview Question
1st Grade	 <p>(Particle Model)</p>	<p>Now the magnesium solid is burned with oxygen gas and the magnesium oxide solid is released. (Macroscopic Level)</p> <p>There is a combustion reaction here. The magnesium solid and oxygen gas react. It forms the magnesium oxide solid. (Macroscopic Level)</p>	<p>But if this solid was burned, gas should be formed, it was not burned. This was burned by reacting with oxygen. This is a combustion reaction. (Macroscopic Level)</p> <p>The magnesium atom reacts with the oxygen molecule. This is a redox reaction, magnesium is oxidized by giving electrons, oxygen is reduced by taking these electrons, the ions formed attract each other to form compounds. (Microscopic Level)</p>
2nd Grade	 <p>(Atomic Model)</p>	<p>There is oxygen, but there will be no burning, probably because carbon dioxide and water did not form. One of the two events must have occurred, like a formation. (Macroscopic Level)</p>	<p>The substance before reacting and the substances formed after entering are different from each other. Distinctive properties of the substance such as color, odor and taste change. The mass of those entering is equal to the sum of the mass of the products. (Macroscopic Level)</p>
2nd Grade	 <p>(Atomic Model)</p>	<p>It is a combustion reaction. It is formed as a result of the combination of magnesium metal and oxygen nonmetal. (Macroscopic Level)</p>	<p>Magnesium was oxidized by giving electrons to oxygen, and oxygen was reduced by taking electrons, resulting in an ionic bonded crystalline solid product. (Microscopic Level)</p>

Table 8 continued

3rd Grade	 <p>(Particle Model)</p>	<p>Magnesium solid and oxygen gas combine to form magnesium oxide solid. This is a combustion reaction. (Macroscopic Level)</p>	<p>Magnesium is solid, oxygen is gas, and the product released in the reaction is solid magnesium oxide. This is a heterogeneous reaction. (Macroscopic Level)</p>
3rd Grade	 <p>(Atomic Model)</p>	<p>Magnesium and oxygen combined to form a magnesium oxide solid. Reaction means chemistry to me. The lessons come to my mind. (Macroscopic Level)</p>	<p>In the elemental state there is a total of two oxygen atoms and one magnesium atom. Magnesium is 2+ and oxygen 2- charged, and a reaction occurs between them, forming an ionic bonded compound. (Microscopic Level)</p>
4th Grade	 <p>(Particle Model)</p>	<p>It looks like a burning reaction. Magnesium formed magnesium oxide with oxygen. The solid and gas reacted, resulting in a solid. Combustion reaction, that is, a chemical reaction. (Macroscopic Level)</p>	<p>Here, the magnesium atom donates two electrons to form a 2+ charged magnesium ion. Oxygen takes these two electrons and forms a 2- charged oxygen ion. These ions attract each other and form ionically bonded magnesium oxide compound. (Microscopic Level)</p>
4th Grade	 <p>(Atomic Model)</p>	<p>When I look at the entrants and products, I see that this reaction is a combustion reaction. Magnesium oxide formed as a result of the combustion reaction. Solid and gas combined, but solid appeared in products. (Macroscopic Level)</p>	<p>Magnesium and oxygen represent metals and nonmetals. Here, metal solid and nonmetal gas reacted to form a solid product. (Macroscopic Level)</p>

4. Discussion and Conclusion

In this study, the mental models that PSTs used while visualizing chemical reactions were determined. When the data obtained from the drawings of PSTs were analyzed, it was concluded that 31 (64.58%) PSTs visualized chemical reactions in accordance with the "particle reaction model", whereas 17 (35.42%) PSTs visualized the "atomic reaction model". When the mental models of PSTs were compared according to their education level, it was found that as the education level of PSTs increased, the models used in drawings shifted from particle model to atomic model. Similar results were reached in the studies of Cheng and Gilbert (2017) and Cheng (2018). It is expected that most of the PSTs' mental models for chemical reactions are particle model-based, because the particle model is a more superficial and less detailed model than the atomic model. In this respect, it is easier to understand and remember, and provides a simple and quick way to show chemical reactions. Because of these properties, it can be thought that PSTs made more particle model-based drawings while visualizing the reaction of magnesium with oxygen gas. One of the reasons why the particle model is dominant in the drawings according to the atomic model may be that the PSTs first met with the particle model-based visuals in the middle school science course and even exposed to the particle model-based visuals in the chemical reactions subjects until the senior school chemistry classes. Within the scope of chemistry course, individuals encounter atomic based demonstrations for the first time in the senior year of high school on redox. Similarly, in the study evaluating the modeling of the visuals in high school chemistry books, it was concluded that as the high school education level increased, the models used in the visuals used in chemistry books shifted from the particle model to the atomic model (Bilir & Digilli-Baran, 2018). In the university, PSTs attend only General Chemistry courses in two semesters of the first year, Analytical Chemistry and Organic Chemistry in the second year, Special Topics in Chemistry in the third year, and Nuclear Chemistry in the fourth year. As the class level increases, the specialization of the course contents while taking courses in different fields within the field of chemistry and learning more advanced concepts of chemistry in these areas may explain the shift of the models used in students' drawings towards the atomic reaction model. In addition, they encounter different reaction types related to chemistry during their education process and in this case, it can be concluded that they may cause more reasoning about chemical reactions and differences in their visuals.

As a result of the analysis of the interview data made with the PSTs to get their opinions about the chemical reaction of magnesium and oxygen gas; It was determined that all of the PSTs explained the chemical reaction of magnesium with oxygen gas on a macroscopic level, and needed evocative hints to make them explain at the microscopic level. It was determined that some PSTs could not explain at microscopic level even if the evocative hint was given. The reason why all of the PSTs explained the chemical reaction of magnesium with oxygen gas at the macroscopic level without giving any evocative at first may be due to the macroscopic level being more concrete and easier to visualize than the microscopic level. Similarly, Rappoport and Ashkenazi (2008) found that the macroscopic level is more concrete than the microscopic level, and Johnstone (1993) found that students grasp the macroscopic level more easily than the microscopic level. Another reason may be that the macroscopic level and the concepts required by this level are closer to the events in daily life and the terms used. For example; PSTs explained the reaction by using concepts such as burning and oxidation, which they use in daily life and which we accept as indicators of macroscopic level. Similarly, Talanquer (2011) argued that students explain what they observed while learning chemistry in terms of daily life.

Although all of the PSTs explained the reaction of magnesium with oxygen gas on a macroscopic level before giving the evocative hint, the majority of them made explanations at microscopic level after the question containing the evocative hint. This can be interpreted as an indication that the PSTs have the conceptual framework for the concept of chemical reaction required to explain at both levels. However, in the conceptual framework of PSTs, the necessary concepts for explaining the chemical reaction concept at macroscopic level are in closer nodes, and

the concepts necessary for explaining at microscopic level are in more distant nodes. For this reason, the concepts necessary to explain at the macroscopic level may have been more easily evoked, remembered, activated and first reflected, but on the contrary, evocative hint may have been given to activate the concepts necessary for explanation at the microscopic level. Similarly, Fu et al. (2010) stated that concepts are structured in memory by associating them with each other, and when a visual of any concept is seen, the related concept and therefore the closest concepts associated with this concept are activated. However, in the study, it was found that some PSTs responded at the macroscopic level despite giving evocative hints. This is an unexpected result. The reasons for achieving such a result may be the education level of PSTs and their mental models for the reaction of magnesium with oxygen gas. Discussion of these variables is made in the following section.

Considering that the drawings of the PSTs represent the microscopic level in both drawings, whether they are particle models or atomic models, and these drawings are very important in terms of revealing the understanding of the microscopic dimension of chemistry (Gilbert & Treagust, 2009). The explanation levels of the PSTs were expected to be at microscopic level while explaining the reaction of magnesium with oxygen gas. As all the PSTs made their explanations at macroscopic level, the results obtained by asking the evocative interview question of "When you learn chemistry, you learn concepts such as atom, molecule, ion. We call this the microscopic world. How do you explain this chemical reaction about the microscopic world?" showed that the explanations of them shifted from the macroscopic level to the microscopic level (Table 4), and according to the education level, this change was observed especially in the third and fourth grade (Table 6). This situation has been demonstrated again with the results of the research. In this case, the fact that concepts such as atom, molecule, ion, electron, energy are difficult to explain on a microscopic level and these concepts are abstract for students may have caused them to be unable to explain at the beginning. When an association is made about these concepts to PSTs, the result that their explanations shifted to the microscopic level supports this. The change in the level of explanation, especially in the third and fourth grade, may be an important factor for PSTs to increase the variety of courses they take in the field of chemistry with the increase in their education level, and as a result, to learn high-level chemistry concepts.

It was concluded that the level was macroscopic after the first interview question in the explanations of the PSTs' drawings with atomic and particle models, that is, microscopic. The reason for this difference between student drawings and explanations is explained by the fact that concrete concepts are a stronger resource in explaining the concepts in students' minds and in these way students can express the concepts in their minds more easily (Türkoğuz et al., 2014). However, after asking the associative interview question in the interview with the PSTs, the fact that the PSTs responded more at the microscopic level (Table 7), has revealed that the microscopic reaction modeling's and concepts such as atom, molecule, ion, electron, energy, which we deem to be difficult are already in the minds of the PST and can be uncovered with a hinted question.

As a result, in this study, it was concluded that PSTs used the particle atom model more in their mental modeling of chemical reactions, and as their level of education increased, their modeling shifted from particle model to atomic model. When looking at the level of these modeling, it was seen that the models of the students were at the microscopic level, whether it is a particle model or an atomic model. Although PSTs used the microscopic level in their drawings, it was found that the explanation level was at the macroscopic level when the PSTs were asked to explain the chemical reaction. This situation revealed that the participants had information about microscopic level in their minds, but they did not use it in explanation. For this reason, when we asked PSTs to explain the reaction with an evocative question, it was concluded that the tendency of them to use microscopic level in their explanations increased, and this tendency was higher from the second grade. Considering all these results, in order to increase student success in science, the concretization of abstract concepts in science education-teaching starting from the preschool education-teaching period, taking into account this in the teaching process, focusing on model-

based teaching in concretizing these abstract concepts, using simulations in teaching and abstract concepts in teaching materials and use of materials in which abstract concepts are concretized are suggested to be paid attention. It can be argued that, instead of particle-based materials in chemical reaction teaching, especially from the last year of high school, visual materials related to reactions based on atomic models should be prepared and used in chemistry teaching.

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