Identifying mental models of students for physical and chemical change

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IDENTIFYING MENTAL MODELS OF STUDENTS FOR PHYSICAL AND CHEMICAL CHANGE

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Abstract. *The right and wrong mental models that learners have about the changes in the matter have a great importance in understanding the basis of the chemistry. Therefore, the main purpose of this research was to identify students' misconceptions with regard to physical and chemical change and to come up with models to explain their understanding of this topic. This research was qualitative descriptive with cross-sectional design. The participants were 148 6th graders in Kütahya which is a western city of Turkey. The data were collected through a questionnaire containing five open-ended questions. Additionally, for a more detailed analysis, 28 participants were interviewed to explore the mental models that emerged. Analysis of responses to the questionnaire generated four mental models (Particle Motion Model, Moving Away Particle Model, Particle Motion+Moving Away Particle Model, Macro Model) for physical change and three mental models for chemical change (Changing Particle Model, Moving Away Particle Model and Macro-Micro Change Model). Implications of these results for chemistry education were discussed. Mental models defined in the research can enable teachers of science and researchers to identify difficulties faced by students regarding physical and chemical changes; thus, they can effectively decide which approach to take on to devise scientific models.*
Keywords: *chemical change, chemistry education, mental model, misconceptions, physical change.*

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Introduction

Chemistry is the study of substance, its properties, and its structure, investigating how and why substances interact with one another to form other substances. For this reason, the concept of substance is the essence of chemistry. In other words, in order for students to learn chemistry, it is essential that they have a thorough understanding of substance and its change. Due to its importance, a unit called "Particle structure of matter/ Substance and change" has been put in the 6th grade science curriculum in Turkey. The main purpose of this unit is to enable students to understand that substance consists of moving particles, changes can be classified as physical or chemical, density is important for living things and is calculated considering mass and volume (MoEN, 2013).

It is clear from this purpose that students should understand physical and chemical change and the difference between the two thoroughly. In addition, the topic of physical and chemical changes is linked to other chemistry concepts such as states of substance, atoms, ions, molecules, elements and compounds, and motion of particles (Tarhan, Ayyıldız, Ogunç, & Acar Şeşen, 2013). Hence, without having a good understanding of the topic of substance, the students are likely to experience difficulties in learning subsequent topics of chemistry (Griffiths & Preston, 1992; Okumuş, Öztürk, Doymuş, & Alyar, 2014).

Realizing this, many researchers have conducted studies on students' understandings of physical and chemical change and have made an effort to identify their misconceptions with regard to this topic (Ardaç & Akaygün, 2004; Ayvacı & Şenel Çoruhlu, 2009; Çayan & Karslı, 2014; Demircioğlu, Özmen, & Demircioğlu, 2006; Demircioğlu, Ayas, & Kongur, 2012; Eilks, Moellering, & Valanides, 2007; Gönen & Akgün, 2005; Johnstone, 2000; Khurshid & Iqbal, 2009; Kıngır, Geban, & Günel, 2013; Kıngır & Geban, 2014; Kibar & Ayas, 2010; Lemma, 2013; Mirzalar Kabapınar & Adik, 2005; Ormancı & Balım, 2014; Stavridou & Solomonidou, 1989; Sökmen, Bayram, & Yılmaz, 2000; Tsaparlis, 2003; Uluçınar Sağır, Tekin, & Karamustafaoğlu, 2012). For example, in Ayvacı, Senel and Çoruhlu's study (2009), students have erroneously thought that modifications that occur in pure substances are physical changes and particles do not experience transformation in chemical changes. In another study, while burning of wax have been mistakenly thought as a physical change, ice melting, alcohol evaporation, dissolution of salt in water were thought as chemical changes (Sökmen, Bayram, & Yılmaz, 2000). Demircioğlu, Demircioğlu, Ayas and Kongur (2012) have found that students possessed a number of misconceptions including "sublimation of naphthalene is a chemical change, blackening of silver spoons and getting iron from rusted iron are physical changes". In order to understand how students classify changes occurring in substances into physical or chemical change, Stavridou and Solomonidou (1989) have written 18 events in 18 different cards and asked students to classify these events. Through interviewing them, these researchers have found that they look at physical appearance of substance, whether events are artificial or natural, simple or complex and reversible or non reversible to decide if a given event is physical or chemical.

These studies indicate that many students seem to have difficulties with classifying given changes into categories as physical and chemical. In addition, they hold various misconceptions with regard to this topic. Nevertheless, the researchers have not proposed any meticulous models revealing students' understanding of physical and chemical changes. Thus, the lack of research in the related area was the main motivation for the current research.

One of the most important points in science education is the ability of the student to organize the knowledge in the mind. However, students often have difficulty establishing relationships between concepts. To better clarify the concepts for students, it is necessary to associate the concepts in science subjects with other concepts. For example, there is no chance to observe the particles of the material, where there is an opportunity for students to observe that the voice does not spread in the space. This necessitates the use of models in science education (Treagust, Chittleborough, & Mamila, 2002). Models make it easier for people to understand complex phenomena (Paton, 1996; as cited in Demircioğlu, Özmen, & Demircioğlu, 2013). Grosslight, Unger, Jay and Smith (1991) have emphasized that modeling is an important thinking skill that helps to facilitate understanding of abstract and complex scientific topics. Gödek (2004) has highlighted the importance of the need for developing models since they serve as a bridge for understanding some seemingly difficult scientific events. According to Harrison (2001), a model is a simplified representation of an object or processes or an image. Johnson-Laird (1983) has described models as mental constructions that individuals form in their minds (as cited in Ünal & Ergin, 2006; p.190). Model and modeling are the methods used to explain the concepts of science in an accurate and easy way and to gain scientific thinking and working skills from the past to present (Güneş, Gülçiçek, & Bağcı, 2004).

Models in science education in which different classifications are made can be classified as mental models and conceptual models (Örnek, 2008). Conceptual Models are images that are formed in our minds when we hear the names of concepts or when we think of them, that is, images about concepts (Atasoy, 2004). Mental models are individual mental representations produced by individuals as a result of cognitive processes (Güneş, Gülçiçek, & Bağcı, 2004). Students and scientists use mental models when thinking about or relating to science concepts. It is possible to determine how the students understand a topic with the mental models they have created (Coll & Treagust, 2001). Methods are needed to uncover the mental models of students. It is possible to determine to what extent and in what ways students have understood the related topic by benefitting from mental models of the subject area (Vosniadou & Brewer, 1992; as cited in Karagöz & Sağlam; Arslan, 2012).

Research Focus

When studies on mental models in chemistry are examined, it is seen that studies on chemical bonding (Taber, 1998; Taylor & Coll, 2002), atomic structure (Adbo & Taber, 2009; Akaygün, 2016; Çökelez & Dumon, 2005; Çökelez & Yalçın, 2012; Harrison & Treagust, 1996; Kıray, 2016; Polat, 2012; Zarkadis, Papageorgiou, & Stamovlasis, 2017), acids, acid strength and bases (McClary & Talanquer, 2011; Çelikler & Harman, 2015), particle nature of matter (Demircioğlu, Vural, & Demircioğlu, 2013) and vapor pressure (Tümay, 2014) are common. Taber (1998) has found that the mental model students prefer for covalent compounds is simple octet rule. Similarly, Harrison and Treagust (1996) have conducted interviews with 48 students in the 8th, 9th and 10th classes about the atomic structure. As a result of the research, they have found that students mostly prefer solar system model in terms of atomic mental structures and simple realistic models in the field-fill type of molecular models. Coll and Treagust (2001) have conducted interviews with six students, including two at the 12th grade, university and doctorate levels, each, to determine their mental models of chemical bonding. Researchers have determined that all students have more mental models of chemical bonding than a simple, realistic model of octet rule, only the doctoral students have more detailed information than others. Coll and Treagust (2003) have investigated the mental models of

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high school, undergraduate and postgraduate education related to metallic bonding. They have determined that students prefer a realistic view of the unconventional properties of the metallic materials and the structure of the bond, and that they generally use the electron sea model in their explanations. In mental model studies associated with structure of the atom, Bohr atom model has been identified as the dominant mental model among students. Kıray (2016) has stated that Bohr atom model hinders students' learning of quantum structure of the atom. It has been established that students visualized the atom as round, ball or sphere, and as hard or solid. In addition, in his vapor pressure study, Tümay (2014) has identified three models generated by pre-service chemistry teachers as "vapor pressure of a liquid is dependent on the total number of vapor particles", "the number of vapor particles is stable and non-changeable as soon as a liquid-vapor balance is established", and "vapor pressure only collides with the surface of the liquid".

Research Questions

In this research, it was aimed to identify students' misconceptions with regard to physical and chemical change and to come up with models to explain their understanding of this topic. In accordance with this aim, the main question of this research was "how are students' mental models of physical and chemical change?" On the basis of this main question, the following questions were attempted to be answered;

1. To what extent do students understand the difference between physical and chemical change?
2. What misconceptions do students hold with regard to physical and chemical change?
3. Can students' understanding of physical and chemical change be modeled?

Although many researchers made an effort to address the first two research questions, it was not possible to identify any study which addressed the third research question. Thus, the research enabled readers to examine if our answers to the first two research question align the results of other studies. More importantly, the research attempted to identify mental models of students, which helped visualize their understanding of physical and chemical change. By doing so, it was anticipated to explain students' difficulties with understanding and misconceptions regarding this topic.

Methodology of Research

General Background

This research was qualitative descriptive with cross-sectional design. In this research, researchers collected the data through survey at one time so that it can provide information in a short time about certain attitudes or practices (Creswell, 1994). The research aimed at identifying students' misconceptions and mental models regarding physical and chemical change. In this sense, the research attempted to reveal the misconceptions caused by students' wrong mental models related to the subject. These models were described, explained and evaluated in detail without any interference on the current situation in the research. This research was conducted in the spring semester of the 2015-2016 academic year.

Sample of Research

The current research took place in eight secondary schools in Kütahya which is a western city of Turkey. The participants were 148 6^{th} grade students (64 female, 84 male) who voluntarily agreed to participate. The participants'ages were 11 or 12. Data for this research were collected when these students were studying the unit called "Particle structure of matter/substance and change" in a science class. In terms of socio-economical backgrounds, students were mostly the children of low-income or middle-income families. Students of two schools lived in towns while students from other six schools resided in villages, coming to schools in town by means of transportation. To ensure ethical considerations, before students were invited to participate in the research, permission to conduct the research was obtained from the school administration. Students were informed that the results of the research would be used for research purposes only and they were also assured of the confidentiality of their identity.

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Description of Course Content

To achieve the learning objectives of this unit, students received instruction for 6 hours. First, the teacher talked about alchemist trying to convert elements to gold and asked students to compare this with changes they see in their environment. Then, the students were told to make "the same matter different appearance" and "which feature of substance has changed" experiments and conduct the "physical and chemical change" activity. The teaching process ended with a text called "recycle" which emphasized that substance did not lose its properties in a physical change.

Data Collection Tools

Physical and Chemical Changes Questionnaire (PCCQ): Based on previous research studies and learning objectives set by Turkish Ministry of Education in science program for 6th graders, an 8-item questionnaire to examine their knowledge and mental models in physical and chemical change was developed. All of the questionnaire items were open-ended. Two faculty members and one science teacher examined the questionnaire to establish its content validity. In addition, 26 students were administered the questionnaire and asked if they had difficulty understanding the items. Based on the opinions of experts and students, the number of items was reduced to 5 and some of them were combined into one item.

> *Interviews:* 28 students were interviewed about the responses they gave to the questionnaire items. Semi-structured interviews were conducted one-to-one by one of the researchers. The interviews lasted 30-35 minutes on average, and were recorded with a voice recorder. In the selection of these students, their answers given to the questionnaire were taken into consideration.

Data Analysis

It is necessary to identify consistent patterns in students' answers to deduce mental models; that is why, many researchers employ analytical inductive analysis methods. To achieve this, in data analysis, questionnaires that were answered by students were numbered to prepare and organize the data for analysis. Subsequently, the answers were presented by researchers in frequency patterns by placing them in categories formed with the considerations of main ideas and common features between statements and drawings. The data were supported with direct quotations extracted from student interviews in accordance with categories. The findings were then explained, correlated, and interpreted.

With the aim of ensuring data reliability, the analysis was conducted by the researchers and then the results of the analysis were compared, which indicated a 90.00% consistency. Points upon which there was no consensus were resolved by means of discussions with researchers. If one idea was mentioned under different concepts, that idea was included in more than one concept. Thus, frequency and percentage values might be more than the number of participants in the tables presented in the method section. Based on students' drawings, we tried to come up with a number of models explaining their understanding of physical and chemical change. In the research, the determined mental models are limited with the answers given to the questions asked.

In addition, to assess their performance in questionnaire, 5-level determination scale (Karagöz & Sağlam Arslan, 2012) was utilized (Table 1). Table 2 shows with examples how the questions which students answer by drawing in the questionnaire were analysed according to 5-level determination scale. The data obtained from the interviews were transcribed. Interview records were documented on paper and listened by the one of the researchers three times to ensure its accuracy. The researchers made an effort to identify the misconceptions of students regarding subject based on the questionnaire and interview results. Moreover, direct quotations were made use of so as to reflect students' mental models more efficiently.

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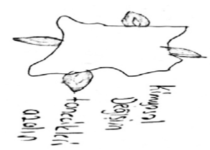
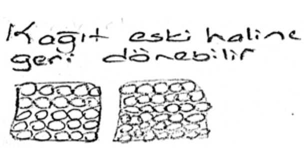
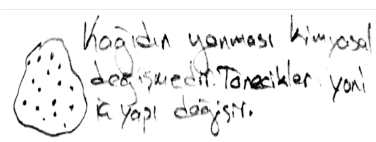
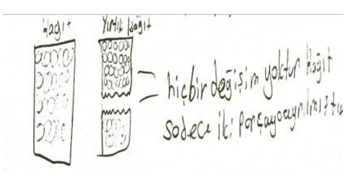
Table 1. 5-level determination scale.

Level	Definition of analysis
Level [0]	No answer
Level [1]	Answers contradicting with scientific knowledge
Level [2]	Answers consistent with scientific knowledge but contain wrong knowledge or parts
Level [3]	Answers consistent with scientific knowledge but are not complete.
Level [4]	Full answers are consistent with scientific knowledge.

Table 2. Analyzes and examples of drawing questions in the questionnaire.

Level	Definition of analysis	Examples of Drawing	
		Physical Change	Chemical Change
Level [0]	There is no drawing or explanation.	-	-
Level [1]	Drawing and explanation of students is contradicting with scientific knowledge		 Chemical change, the particles are reduced.
Level [2]	One of the students' drawing or explanations contain wrong knowledge	 Paper can return to its original state.	 Paper burning is chemical change. Particles, internal structure changes.
Level [3]	Students'drawings and explation is consistent with scientific knowledge but are not complete		When the paper is burned, it becomes ash and a new substance emerges. Chemical change occurs in this case (No drawing).
Level[4]	Student's drawing and explanation is completely correct.	 There is no change, the paper divided into only two parts.	 The structure of the paper changes. When the paper is burned, gas emerges. Heat and light spreads.

Results of Research

Table 3 presents the results of qualitative analysis for question 1 ("*Explain what you understand from substance change?*"). 13 students did not answer this question. Other students' responses fell into 8 categories. The highest number of responses (56), were coded in the "change of state" category. Students in this category seemed to explain substance change in terms of state of change and did not consider chemical change. The second highest number of responses (34) were coded in the "physical and chemical change" category. Students in this group seemed to divide substance change as physical and chemical change and gave real-life examples. The lowest number of responses (1) were coded in the "returns- does not return" category. The student in this category wrote "substance goes through a physical and chemical change. If a new substance emerges, it is a physical change. If not, it is a chemical change". The interview conducted with one of the students seemed to support the results emerged from qualitative analysis of Question 1:

Researcher: What do you understand from substance change?

Student: It is like changing from solid to gas or from gas to liquid.

Researcher: Do you mean that substance change depends only on state of change?

Student: These are physical changes. There are chemical changes, too. For example, one substance might convert to another substance.

Researcher: Can you explain more?

Student: I just gave you an example for physical change. Fermentation of yogurt and frying of potatoes are examples for chemical changes.

Table 3. Results of frequency analysis for question 1.

Change in Matter	Category	*N*	%
Physical Change	Change of state	56	37.84
	Change in appearance	5	3.38
	Number of particles / Distance	4	2.70
	Particle Movement	3	2.03
	Total	**68**	**45.95**
Physical Change + Chemical Change	Physical and chemical change	34	22.97
	Misconception	4	2.70
	Returns- does not return	1	0.68
	Total	**39**	**26.35**
Chemical Change	Change in substance identity/internal structure	8	5.41
	Total	**115**	**77.71**

Table 4 presents the results of qualitative analysis for question 2a (*If ice is completely melted and converted into water, what will you expect to see in the balance scale?)*. 10 students did not answer this question. As presented in Table 3, correct responses to Question 2a fell into three main categories: (1) There is no emergence of new substance, (2) scale will still be in balance, (3) There is a change of state. The highest number of responses (45) were coded in the "There is no emergence of new substance" category. False responses fell into two main categories: (1) Scale will not be in balance, (2) There is emergence of new substance. The highest number of responses (63) were coded in the "Scale will not be in balance" category. 35 or 23.65 percent were coded in the "There is an emergence of new substance". The below interview is an example of student understanding of ice melting.

Researcher: Piece of ice located in a closed container on balance scale is melting after a while. Do you think that balance is broken?

Student: The balance is broken. Because ice melted, its mass decreased.

Researcher: Why does its mass decrease when ice melts?

Student: Because temperature is high, ice is melting and converted into liquid. Particles are separate in liquid. Because particles are separate, mass of ice decreased.

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Table 4. Results of frequency analysis for question 2a.

Change in Matter	Category	*N*	%
Physical Change	There is no emergence of a new substance	45	30.41
	Scale will still be in balance	35	23.65
	There is a change of state	34	22.97
	Distance among particles change	1	0.68
	The number of particles does not change	1	0.68
Chemical Change	Scale will not be in balance	63	42.57
	There is an emergence of a new substance	35	23.65
	The number of particles does not change	2	1.35
	Volume of substance does not change	1	0.68
	It is a chemical change	1	0.68
	The density of substance decreases	1	0.68
	Total	**219**	**148**

Question 2b asked students to explain the event of ice-water conversion at the particle level by drawing. The analysis resulted in four models: (1) Particle Motion Model, (2) Moving Away Particle Model, (3) Particle Motion+Moving Away Particle Model, (4) Macro Model. When naming these models, students' drawings and its associated explanations were grouped under specific headings. Students' drawings which imply that particles of substance do not change as a result of a physical change, and only distance among particles changes were coded under "moving away model". Responses which implied that movement of particles changes as a result of physical change were included the "particle motion model". Students in this model seemed to think that if a substance is solid, its particles make vibration motion; if it is liquid or gas, its particles are more mobile and make vibration, translational and rotational motions. "The particle motion + moving away particle model" included student drawings which implied that as a consequence of a physical change, particles of a substance mobilize and distance among the particles changes. Students in "the macro model" made drawings which implied changes only in appearance of substance. As Table 5 shows, the vast majority of responses (108) were included in the moving away particle model. One of the students' understanding from ice-water conversion is shown below.

Researcher: Can you explain what is happening in the ice-water conversion?

Student: Ice particles are closer but water particles are more far from each other. Water particles are more mobile but ice particles are less mobile.

Researcher: I got you. You made this drawing.

Student: Yes.

Researcher: Why did you draw ice with more particles than water?

Student: Because, water moves, its particles move as well. Because ice is solid, it has more particles and vibrates more.

Researcher: Can you explain more? Because it has more particles, it vibrates more?

Student: Because it has more particles, it cannot move. Thus, it only vibrates.

Researcher: Do you think that water has always fewer particles than ice?

Student: Yes.

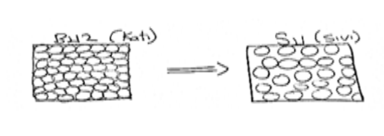
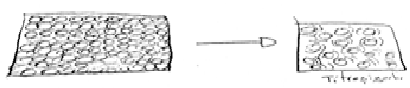
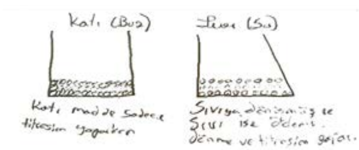
Researcher: Why do you think so?

Student: Because liquid are mobile, its particles are less.

Researcher: During state of change, the number of its particles decreased. Correct?

Student: Yes

Table 5. Results of frequency analysis for question 2b.

Change in Matter	Mental Model	Example Drawings for Mental Model	*N*	%
	Moving Away Particle Model		108	72.97
	Macro Model		12	8.11
Physical Change	Particle Motion Model		3	2.03
	Particle Motion+ Moving Away Particle Model		2	2.03
	Total		**125**	**85.14**

Question 3a asked students to write the differences between paper burning and cutting paper in half. While four students left Question 3a unanswered, eleven of them wrote down the question again for the answer, and five students gave irrelevant responses such as "it's a paper so it can burn", and "it can be divided". Other students' responses fell into 5 categories. Approximately half of the total responses were about physical and chemical change (Table 6). 51 responses were about emergence of new substance, identity change and returning to original state. In these categories, students' responses to burning the paper as chemical and to tearing it into pieces as physical change were placed under the group of "physical/chemical change". In addition, their responses stating that the structure of paper does not change after tearing it into pieces and that paper structurally changes after burning it were placed into the category of "a new substance is formed/not formed". Similarly, answers claiming that identity of the substance does not change when the paper has been torn into pieces and that identity of the substance changes after burning it were categorized as "identity changes/does not change". 17 of the participants identified the phenomenon of burning the paper as irreversible while they considered tearing the paper into pieces to be a reversible phenomenon. That is why; these responses were included in the category of "reversible/non-reversible". Even though classifying phenomena in terms of being irreversible or not is a misconception, such responses were not included in the category of misconception since students' responses were within the boundaries of the specific situation presented in the questions. However, some participants claimed that burning of paper is a physical change and that dividing the paper causes a chemical change on the ground that when the paper burns, particles are destroyed with it and that when it is divided, particles also get divided with the process. Considering this, such responses were included in the category of misconception.

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Table 6. Results of frequency analysis for question 3a.

Category	*N*	%
Physical / Chemical change	78	52.70
New substance emerges / does not emerge	17	11.49
Its identity changes /does not change	17	11.49
Can /cannot return to its original state	17	11.49
Misconception	12	8.11
Total	**141**	**95.28**

Question 3b asked students to visualize their answer for the following question by drawing: "*If we have a chance o look at the events of paper burning and cutting paper in half with a magnifying glass, what can we expect to see?*". Regarding cutting the paper, it was revealed that 72 students made accurate drawings for the physical change occurring as the consequence. In the other drawings (Table 7), a model emerged for physical change and three models for chemical change. Responses with regard to paper burning, which implied that, the shape of particles change as a result of the chemical change, were grouped under the "moving away particle model". Responses which implied that chemical change is only in the appearance of the substance were grouped under macro model. Students did not make a drawing showing what is happening to particles in this model. Responses which implied (1) if a substance burns, its particles burn as well, (2) if a paper burns completely, its particles remove, (3) events which take place in the appearance of substance also take place in the internal structure, were included in the macro-micro change model. The students' drawings which indicate that particles do not change; only distance among them changes in the event of paper burning were included in the moving away particle model. Below interviews show an understanding of a student with regard to the difference between paper burning and cutting of a paper.

Researcher: What are the differences between paper burning and cutting of a paper? Can you draw?

Student: When paper burns, its appearance changes. Thus, a chemical change happened. When cutting a paper, its appearance changes. Thus, a physical change happened.

Researcher: Can you explain more? What are the differences between the two?

Student: When cutting a paper, we had two papers. When paper burns, it darkens.

Researcher: Can you draw?

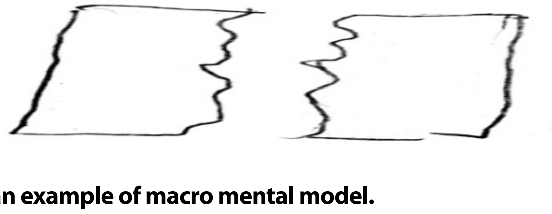


Figure 1: Cutting in half as an example of macro mental model.

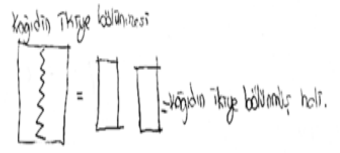
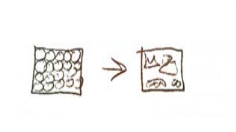
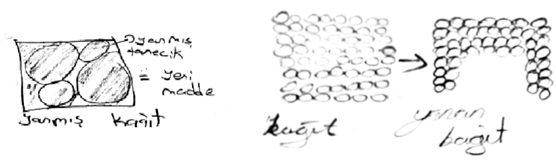
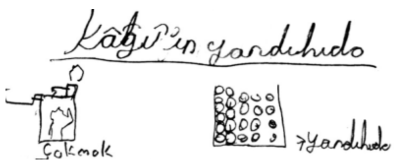
Researcher: Can you draw paper burning?

Student: If paper burns, it darkens. But I cannot draw.

Researcher: What's happening to its particles?

Student: I have no idea.

Table 7. Results of frequency analysis for question 3b.

Change in Matter	Mental Model	Example Drawings for Mental Model	*N*	%
Physical Change	Macro Model		25	16.89
Chemical Change	Changing Particle Model		38	25.67
	Macro Model		27	18.24
	Macro-Micro Change Model		16	10.81
	Moving Away Particle Model		7	4.73

Question 4 asked students to define physical and chemical change and to explain what is happening to particles in the process of physical and chemical change. 9 of the participants left the question unanswered whereas 14 of them responded with statements such as "physical change is physical" or "chemical change is chemical", which were placed under the category of uncodable. Additionally, it was revealed that 10 students had misconceptions in their responses to changes in the substances. It was deduced that these students associated physical change with matter's internal structure and chemical change with its appearance. When the answers of the other students are examined, as Table 8 illustrates, students seemed to define physical and chemical change based mainly on whether particles and identity change or not. While change in appearance seemed to be the second important criterion for defining physical change, emergence of a new substance and change in internal structure were the second important criterion for defining chemical change. One student indicated his understanding from physical and chemical change in the following way:

Researcher: What do you understand from physical and chemical change?

Student: When iron rusts, it is a chemical change. Slicing a tomato is a physical change. Tomato rot is a chemical change.

Researcher: When you slice a tomato, what is happening to its particles?

Student: They become separated.

Researcher: When a tomato is rotten, what is happening to its particles?

Student: Its particles stale.

Researcher: Since its particles stale, do you think that they are alive?

Student: They are alive. But when they stale, they may not be alive.

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Researcher: When they stale, they become lifeless?

Student: Yes.

Researcher: Why do you think so?

Student: I do not know.

Table 8. Results of frequency analysis for question 4.

Change	Defining Criteria	*N*	%
Physical Change	Particles and identity remain the same	29	19.59
	Appearance changes	25	16.89
	New substance does not emerge	16	10.81
	Can return to its original state	13	8.78
	Its color, taste and smell does not change	12	8.10
Chemical Change	Particles and identity change	27	18.24
	A new substance emerges	18	12.16
	Internal structure changes	18	12.16
	Does not return to its original state	13	8.78
	Its color, taste and smell change	13	8.78
	Giving examples	35	23.64
	Total	**219**	**147.93**

Question 5 asked students to indicate whether given events was a physical or chemical change and to give a rationale for their answer. 10 students left the question blank while 83 of them responded with statements repeating the question, and 40 students' responses could not be coded due to their lack of meaning. When the other answers are examined, as Table 9 shows, 80 responses were about appearance change (40), or not emergence of new substance (40) to explain the event of cutting of bread as a physical change. Almost the same number of responses were about "change of state" to explain the event of water cycle (39) and water frost (42). The majority of students seemed to explain the event of molding of bread based on changes in its color, taste and smell. Emergence of new substance was the most given response by students to explain the event of fermentation of yogurt and rusting of iron. Below interview shows an understanding of a student regarding rusting of an iron and molding of a bread.

Researcher: When iron rusts, do its particles rust or only its surface rusts?

Student: Its particles rust as well.

Researcher: When bread molds, does its particles take the color of mold?

Student: Yes

Researcher: Why?

Student: For example, when bread molds, it has green spots. This breaks its shape. Thus, I thought that its particles became green.

Table 9. Results of frequency analysis for question 5.

Answers	Events					
	CB (n)	WF(n)	WC(n)	MB(n)	FY (n)	RI (n)
Its appearance changes	40	10	7	5	2	5
Change of state	-	39	42	-	-	-

Answers	Events					
	CB (n)	WF(n)	WC(n)	MB(n)	FY (n)	RI (n)
New substance does not emerge	40	14	9	-	-	-
A new substance emerges	-	-	-	23	37	31
Its color, taste and smell does not change	18	4	2	-	-	-
Its color, taste and smell changes	-	-	-	38	23	20
Its identity does not change	10	14	9	-	-	-
Identity/Particle structure change	-	-	-	26	22	27
Its particles do not change.	5	-	-	-	-	-
Can return to its original state	5	21	21	-	-	-
Does not return to its original state.	-	-	-	11	7	15
Particles vanish	2	-	-	-	-	-
Mold mushroom serves	-	-	-	8	-	-
Bacteria multiply	-	-	-	-	5	-
Becomes unusable	-	-	-	-	-	8
Chemical change	4	28	43	-	-	-
Physical change	-	-	-	8	28	19
Total	**124**	**130**	**133**	**119**	**124**	**125**

**CB: Cut of Bread, WF: Water Frost, WC: Water Cycle, MB: Molding of bread, FY: Fermentation of Yogurt, RI: Rusting of Iron*

Table 10 shows the level of students for each question in the questionnaire. About half of the students were in level 1 for question 2a and 3b, which indicated that they had difficulty answering these two questions. On the other hand, more than half of the students were in level 3 for question 1 and 2b, which suggested that they answered these questions fairly well. Almost 40% of students were in level 3 for question 3a and 4. For question 5, the highest number of students was in level 2. When students in level 3 and 4 were aggregated for each question separately, students were most successful in answering question 2b with 70% and 3a with 65%. On the other hand, when students in level 0, 1 and 2 were aggregated, they were least successful in answering questions 2a and 3b with 69%.

Table 10. Students' performance for each question.

Question	Level 0		Level 1		Level 2		Level 3		Level 4		Total
	N	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*	*%*	*N*
1	13	8.78	38	25.67	8	5.41	76	51.35	13	8.78	148
2a	9	6.08	69	46.62	24	16.22	24	16.22	22	14.86	148
2b	2	1.35	33	22.30	9	6.08	95	64.19	9	6.08	148
3a	4	2.70	29	19.59	18	12.16	60	40.54	37	25	148
3b	11	7.43	72	48.65	19	12.84	43	29.05	3	2.02	148
4	9	6.08	34	22.97	35	23.65	57	38.51	13	8.78	148
5	1	0.68	29	19.59	54	36.49	41	27.70	23	15.54	148
Total	**49**	**33.1**	**326**	**205.4**	**201**	**112.8**	**449**	**267.6**	**159**	**81.1**	**100**

As Table 11 reveals, students' misconceptions emerging from the questionnaire and interviews were grouped into three main categories: Physical and Chemical Change, Particle and Mass-Weight. A total of 177 misconceptions were identified in the three categories. Physical and chemical change category (157) had the highest number of misconceptions. "If ice is converted into water, a new substance emerges" was the most common misconception.

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There were 12 misconceptions in the particle category. "Solid substances have always a higher number of particles than the liquid substances" was the most common misconception. Mass-weight category had 8 misconceptions. While 7 students had the misconception of "If distance becomes longer between particles, mass of substance increases", 1 student had the misconception of "As ice particles move little, they are heavier".

Table 11. Misconceptions of students.

Category	Misconceptions	*N*	%
Physical and Chemical Change	If ice is converted into water, a new substance emerges.	35	19.77
	If a substance changes but returns to its original state, it is a physical change. If not, it is a chemical change.	25	14.12
	If we burn a piece of paper it is converted into ash. Ash particles become black.	17	9.61
	If iron rusts, its particles rust, too.	13	7.35
	If paper is burned, its particles disappear.	13	7.35
	If bread becomes moldy, its particles become blue and green.	11	6.22
	The number of particles increases in physical change and decreases in chemical change.	10	5.65
	Particles disappear in chemical change.	7	3.95
	Physical changes take place only in change of state.	5	2.83
	If there is a color change after a certain event, it is definitely a chemical change.	4	2.26
	Particles are alive. If chemical changes occur, they become lifeless.	4	2.26
	If we burn a paper, its particles become smaller.	4	2.26
	If we tear paper, its particles become half.	3	1.70
	If a change occurs itself, it is chemical. If it is done by people, it is physical.	2	1.13
	Ash is not a substance.	2	1.13
	If ice melts, its particles become bigger.	1	0.57
	If we cut bread, its particles disappear.	1	0.57
Particle	Solid substances have always a higher number of particles than the liquid substances.	5	2.83
	Particles can be seen by microscope.	3	1.70
	Magnifying glasses magnify the appearance of particles.	2	1.13
	There are substances between particles.	1	0.57
	Particles are alive because they make translational and rotation movement.	1	0.57
Mass-Weight	If distance becomes longer between particles, mass of substance increases.	7	3.95
	As ice particles move little, they are heavier.	1	0.57

Discussion

In the research, for questions 1, 2b, 3a, and 4 in the questionnaire, it was observed that students mostly responded with "consistent with scientific knowledge but are not complete" answers; that is, they used correct but incomplete descriptions when defining physical and chemical changes. For questions 2a and 3b that are in the questionnaire, it was found that they gave answers "contradicting with scientific knowledge". A great majority of participants failed to illustrate physical and chemical changes occurring within the matter on the particle level. For the 5th question, it was observed that the most frequent responses given were answers that were "consistent with scientific knowledge but contain wrong knowledge or parts". Regarding this outcome, it was inferred that students were successful at classifying phenomena as physical and chemical; however, they either provided inaccurate explanations for the reasons of change in the matter or they were unable to give any type of responses to the situation when they were asked to describe the change. The findings indicated parallelism with the research in the related literature (Atasoy, Genç, Kadayıfçı, & Akkuş, 2007; Demircioğlu, Özmen, & Demircioğlu, 2006; Kıngır

& Geban, 2014; Sökmen, Bayram, & Yılmaz, 2000; Zan Yörük, 2003). Abdo and Taber (2009) explored that students experienced difficulties with learning chemical change. In parallel, Kıngır and Geban (2014) deducted that even though students achieved high scores in test results, it was evident that they lacked competence in describing the terminology related to chemical change. Similarly, Zan Yörük (2003) pinpointed that only a small number of the students comprehended physical and chemical changes. In addition, Taşdemir and Demirbaş (2010) stated that students were unable to associate the terms physical and chemical change with their daily lives since they appointed meanings to the terms other than their scientific meanings. Moreover, in the study, it is observed that students comprehended physical change better than they understood chemical change. In relation, Ormancı and Balım (2014) highlighted that students were able differentiate physical change in general sense yet had problems with particle illustration in physical change, and they were able to neither identify chemical change nor illustrate it on particle level. This result indicates that students substantially explained the reason for the change with classified examples based on prior experiences and knowledge based on memorization; however, they were unable to provide explanation for the change due to the lack of conceptual understanding. Therefore, to enable students to achieve conceptual learning, it can be reasonable for teachers to create learning environments that lead students to thinking, questioning, and discussing the changes occurring on both structural and macroscopic levels by presenting various examples to them.

The most important contribution of our research was to identify mental models of students regarding physical and chemical change. Analysis of responses to the question about ice-water conversion resulted in four models: (1) Particle Motion Model, (2) Moving Away Particle Model, (3) Particle Motion+ Moving Away Particle Model, (4) Macro Model. Among these models, moving away particle model emerged as the most frequent mental model which included students who seemed to think that particles of substance do not change as a result of a physical change, and only distance among particles change. When the mental models appearing connected to physical change are examined, it is revealed that students most frequently visualize physical change as *only the change of distances between matter particles*. This understanding might be the cause of students' association of physical change with the change of state. It was revealed that according to "Macro Model" related with physical change, students comprehended physical change as *only the change occurring in the appearance of the matter*. This outcome indicates that students do not consider the occurrences on micro level. The main reason behind this might be that changes occurring on particle level are not thoroughly mentioned, suitable models are not used in science classrooms, and that some students cannot gain abstract thinking skills completely. Considering the issue, there is a considerable amount of research in the literature suggesting that students have difficulties with understanding the phenomena in matter's internal structure and explaining chemical occurrences on particle level (Demircioğlu, Demircioğlu, Ayas, & Kongur, 2012; Kibar & Ayas, 2010; Okumuş, Öztürk, Doymuş, & Alyar, 2014). On another note, the third most frequently appearing model is "particle motion model". Students employing this mental model stated that *only a change in the movement of particles* occurred, and they drew translational, rotational, and vibrational particle movements. "Particle motion + moving away particle model" was the least appearing model in the context of physical change. It was determined that students equipped with this model both mentioned *particles' vibrational, translational, and rotational movements* and thought that *particles move away from each other* during the physical change.

Analysis of responses to the question about paper burning and cutting paper resulted in a mental model for physical change (Macro Model) and three mental models for chemical change (Changing Particle Model, Moving Away Particle Model and Macro-Micro Change Model). Changing particle model were the most frequent models for chemical change. Upon consideration of mental models surfacing in accordance with the issue of chemical change, it was revealed that students mostly comprehended chemical change as *the change of matter's particles in shape*. In connection, it was observed that some students initially illustrated particles as round shapes, after the chemical change, demonstrated them as various shapes such as a triangle and a square. Additionally, some students stated that they thought carbon atom transforms into a different atom upon reacting; thus, they emphasized that changes occur in the shapes of atoms. Connected to this, Bozoğlu (2007) has conveyed a similar misconception in his study. According to "Macro model" linked to chemical change, it was revealed that student comprehended chemical change as the *change occurring only in external appearance rather than changes on the micro level*. Macro model served as a mental model generated for both chemical and physical changes. This indicates that students decide both changes based solely on the changes occurring on the external appearance of the matter. However, this decision process can prevent them from differentiating the physical and chemical changes. Such a mental model might lead students to identifying a rusty iron as an outcome of physical change due to its change in color

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and, similarly, a burning steel string as a physical change due to recognizing it as melting and changing in shape (Tsaparlis, 2003). With the macro model employed, it is evident that students fail to take matter's particle structure and changes on particle level into consideration when they face the issue of chemical change. Yıldırır and Demirkol (2018) have found in their study that there was no correlation between chemical change and particle concepts regarding the same students' mental structures in terms of chemical and physical changes. The reason why students cannot comprehend chemical change issue on particles level might be that they are unable to visualize occurrences resulting from reactions on microscopic levels to think about them abstractly (Johnson, 2000). This situation will potentially lead to hindrances in future learning of the chemical reaction concept that basically constitutes the majority of phenomena in nature. This is because the relationship between chemical change, physical change, matter, and particle terms should be established accurately to enable understanding of chemical reaction (Stavridou & Solomonodiou, 1998; Johnson, 2000). Regarding "Macro-micro change model" associated with chemical change, it was revealed that students assumed that *changes occurring on macro level occur on micro level, as well*. Students simply relate macroscopic changes occurring in the matter to the matter's particles (Çökelez, 2009). In a similar report, Çayan and Karslı (2014) revealed that regarding the physical change, students tended to assume it was a physical change when a chalk was crushed because they thought that the particles of the chalk would also be crushed. In addition, Bozoğlu (2007) observed that students thought that atoms of a burning candle would be tensed, atoms would be cut if the matter was cut and that they would be bent with a bending wire. Regarding chemical change, it was extracted that only a small number of students assumed that *particles merely retract from each other in chemical change* according to "Moving away particle model". These findings suggest that students have difficulties with differentiating physical and chemical changes just as it is the case for macro model.

In the research, it was deduced that some students had misconceptions regarding the subject matter. It appeared that concerning physical and chemical changes, they possessed a misconception stating "*If the matter can be reversed into its original state after the change, it is physical change; if not, it is a chemical change*." Similar findings were possible to detect in the literature (Atasoy, Genç, Kadayıfçı, & Akkuş, 2007; Gönen & Akgün, 2005; Kıngır & Geban, 2014; Meşeci, Tekin, & Karamustafaoğlu, 2013; Mirzalar Kabapınar & Adik, 2005; Stavridou & Solomonidou, 1989). Kıngır and Geban (2014) indicated that students identified tarnished silver and rusty iron as an outcome of physical change since a tarnished ring could be polished and a rusty iron could be rid of the rust. According to Palmer and Treagust (1996), the reason for such misconception might be that phenomena of physical and chemical changes are identified as being reversible or irreversible in course books. In addition, the statement "*Particles increase in number in physical change; in chemical change, number of particles decrease*" was identified as another misconception. Especially for burning phenomenon, students stated that particle number of the matter would decrease on the ground that particles would also burn down. Additionally, in the case of dividing the paper into pieces, they assumed that number of particles would increase in number because the number of papers would be more than one after dividing. Similarly, Mitchell and Gunstone (1984) and Bozoğlu (2007) determined that students assumed a decrease in atom number since the atoms would be incinerated in the event of burning the wood and the candle. Another misconception appearing related to the subject is as follows: "*Particles are alive. If the matter goes through a chemical change, they will be inanimate*." A similar finding was detected in the study Bozoğlu (2007) conducted. In students' responses, a misconception stating "*Physical change only occurs with the change of the state*" was extracted. Ayvacı and Şenel Çoruhlu (2009) detected students' assumptions claiming that physical changes are merely changes in the state. These misconceptions generated by students might be a product of their mental models. For instance, their assumption of physical change being a change of the state could be related to their moving away particle mental model on the issue of physical change. Similarly, macro-micro change model belonging to chemical change category could be the source of their misconceptions. In macro-micro change model, students' drawings and explanations revealed that they assumed *a phenomenon occurring on macro level will happen on micro level, as well.* Students employing this mental model made explanations as the following: "if an iron gathers rust, its particles will also get rusty", "particles of a moldy bread are green and blue in color", "when the paper burns, its particles will shrink in size", "when the paper burns, its particles are destroyed", "if the paper burns, it turns to ash, therefore making the particles black", "if the paper is torn into pieces, its particles will be divided in half", and "if ice melts, its particles grow in size". These misconceptions show parallelism to the findings of some studies (Albanese & Vicentini, 1997; Çayan & Karslı, 2014; Çökelez, 2009; Çökelez & Yalçın, 2012). Apart from these, some statements such as "if there is a change in color after a phenomenon, it is definitely a chemical change", "particles are destroyed in chemical change", "when ice turns into water, a new matter is formed", and "ash is not a matter" were reached. A misconception stating "if there is a change in color after a phenomenon, it is definitely a chemical change" might stem from the macro model employed by students. Another misconception is the statement "it is a chemical change if the change occurs by itself; it is a physical change if it is inflicted by humans". In relation, Stavridou and Solomonidou (1989) explored that students decide on the classification of physical and chemical changes based on two criteria. First, they identify the type of change with the consideration of matter's initial and final appearance. Second, they take criteria such as natural change, basic change, and change in substance into consideration when they decide on the change type. Contrary to the finding of this research, it was revealed that students identified the phenomenon as physical change if the change occurred naturally; however, they regarded the change as chemical if the change was inflicted by humans, that is to say, if it was artificial.

In the research, it was detected that students had certain misconceptions towards the concept of particles, and these deductions coincided with the findings of other studies. In the research, some misconceptions were revealed as follows: "Particles can be observed with a microscope" (Harrison & Treagust, 1996; Gökulu, 2013; Meşeci, Tekin, & Karamustafaoğlu, 2013; Nakhleh & Samarapungavan, 1999; Nakhleh, Samarapungavan, & Sağlam, 2005), "Particles are living beings because they perform rotational and translational movements" (Meşeci, Tekin, & Karamustafaoğlu, 2013), "There are matters between particles", and "Magnifying glasses enlarge the appearance of particles to some extent". Some students assumed that just as magnifiers can enlarge the view of the matter; it can similarly make particles look bigger.

Furthermore, it was revealed that some students had misconceptions as the following: "The mass of the matter increases when the distance between particles grows" and "Ice is heavier because ice particles move less". The misconception "The mass of the matter increases when the distance between particles grows" was identified by Gönen and Akgün (2005) while Demircioğlu, Demircioğlu and Ayas (2004) encountered a misconception as follows: "Mass of the substance diminishes due to the increasing distance between particles". Gönen and Akgün (2005) tied this misconception to students' assumption that changes in the matter's mass affect the change in molecular size during the change of state. Kenan, Özmen and Güney (2007) stated that some students assumed that from gas to solid state, particle size would increase while some explained that particle size would increase from solid to gas state. Similar to macro-micro change model, researchers emphasized that these misconceptions were generated since students attempted to explain changes occurring on micro level with the mindset of observable changes occurring on macro level. Particle structure of the matter is the milestone of science and chemistry classes (Ergün & Sarıkaya, 2014), and the failure to comprehend micro and macro dimensions on relational grounds accurately will result with hardships in understanding the subject matter, causing other misconceptions among students. As can be seen in this research, false mental models on physical and chemical changes employed by students brought about misconceptions regarding several fundamental concepts.

Conclusions

This research served three objectives: (1) to examine the degree to which students understand physical and chemical change, (2) to identify their misconceptions, (3) to come up with mental models of students for explaining their understanding of physical and chemical change. Results revealed that students did not perform well in the questionnaire, held many misconceptions about physical and chemical change and student drawings enabled to produce mental models. The most important contribution of our research was to identify mental models of students regarding physical and chemical change. Analysis of responses to the question about ice-water conversion resulted in four models: particle motion model, moving away particle model, particle motion+ moving away particle model, macro model. Analysis of responses to the question about paper burning and cutting paper resulted in a mental model for physical change (Macro Model) and three mental models for chemical change (Changing Particle Model, Moving Away Particle Model and Macro-Micro Change Model). Changing particle model were the most frequent models for chemical change.

Considering the research on physical and chemical changes and mindsets of students, it is evident that student misconceptions towards related subjects have not recently changed, and students still have aforementioned misconceptions. These findings underline the vitality for teachers to make changes regarding the teaching of these concepts. Through the mental models identified in this research, science educators, researchers and teachers can understand students' difficulties in learning about physical and chemical changes and they can design more effective instructional approaches to construct the scientific models.Readers are reminded that data for this research were collected from particular schools in a western city of Turkey. Hence, it would be difficult to generalize findings to other settings. Future researchers might conduct studies employing our questionnaire to examine if they identify

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similar misconceptions and mental models. Mental models may vary depending on the new knowledge gained by the individuals. Therefore, students' development of mental models regarding physical and chemical changes can be examined with a longitudinal research.

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References

Albanese, A., & Vicentini, M. (1997). Why do we believe that an atom is colourless? Reflections about the teaching of the particle model. *Science & Education*, *6* (3), 251-261.
Adbo, K., & Taber, K. S. (2009). Learners' mental models of the particle nature of matter: A study of 16-year-old Swedish science students. *International Journal of Science Education*, *31* (6), 757-786.
Akaygun, S. (2016). Is the oxygen atom static or dynamic? The effect of generating animations on students' mental models of atomic structure. *Chemistry Education Research and Practice, 17* (4), 788-807.
Ardaç, D., & Akaygün, S. (2004). Effectiveness of multimedia-based instruction that emphasizes molecular representations on students'understanding of chemical change. *Journal of Research in Science Teaching*, *41*, 317-337.
Atasoy, B. (2004). *Science learning and teaching* (2nd ed.). Ankara: Asil Yayın.
Atasoy, B., Genç, E., Kadayıfçı, H., & Akkuş, H. (2007). The effect of cooperative learning to grade 7 students' understanding of physical and chemical changes topic. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 32*, 12-21.
Ayvacı, H. Ş., & Şenel Çoruhlu, T. (2009). Effects of explanatory stories on elimination of students'misconceptions about physical and chemical change. *Ondokuz Mayıs Üniversitesi Eğitim Fakültesi Dergisi, 28*, 93-104.
Bozoğlu, M. (2007). *The effect of role-play method on formation of image about atom concept in 7th grade student* (Unpublished master's thesis). Ankara. Gazi University.
Coll, R. K., & Treagust, D.F. (2001). Learners' mental models of chemical bonding. *Research in Science Education, 31*, 357–382.
Coll, R. K., & Treagust, D. F. (2003). Learners' mental models of metallic bonding: A cross-age study. *Science Education*, *87*, 685-707.
Creswell, J. W. (1994). *Research design qualitative and quantitative approaches*. Thousand Oaks: Sage Publications.
Çayan, Y., & Karslı, F. (2014). The effects of the problem based teaching learning approach to overcome students' misconceptions on physical and chemical change. *Kastamonu Üniversitesi Kastamonu Eğitim Dergisi, 23* (4), 1437-1452.
Çelikler, D., & Harman, G. (2015). An analysis of science students' mental models of acids and bases. *Mustafa Kemal Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, *12* (32), 433-449.
Çökelez, A. (2009). Students' (Grade 7-9) ideas on particle concept: Didactical transposition. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi*, *36*, 64-75.
Çökelez, A., & Dumon, A. (2005). Atom and molecule: Upper secondary school french students' representations in long-term memory. *Chemistry Education Research and Practice*, *6* (3), 119-135.
Çökelez, A., & Yalçın, S. (2012). The analysis of the mental models of students in grade-7 regarding atom concept. *Elementary Education Online, 11*, 452-471.
Demircioğlu, G., Özmen, H., & Demircioğlu, H. (2006). Primary student teachers' understanding levels and misconceptions about physical and chemical change. *Milli Eğitim Dergisi, 170*, 260 - 273.
Demircioğlu, H., Demircioğlu, G., Ayas, A., & Kongur, S. (2012). A comparison of 10th grade students' theoretical and applied knowledge about the concepts of physical and chemical change. *Türk Fen Eğitimi Dergisi*, *9,* 162-181.
Demircioğlu, H., Vural, S., & Demircioğlu, G. (2013). Gifted students' mental models: The particulate nature of matter. *Eğitim Bilimleri Dergisi*, *38*, 65-84.
Eilks, I., Moellering, J., & Valanides, N., (2007). Seventh-grade students' understanding of chemical reactions: Reflections from an action research interview study. *Eurasia Journal of Mathematics, Science & Technology Education*, *3* (4), 271-286.
Ergün, A., & Sarıkaya, M. (2014). The effects of the model based activities on overcoming the misconceptions regarding the particulate natured structure of the matter. *NWSA-Education Sciences, 9* (3), 248-275.
Gödek, Y. (2004). *Opinions about the concept of dissolution of science teacher candidates*. Presented VI. National Science and Mathematics Education Congress, (9–11 September 2004, İstanbul, Turkey).
Gökulu, A. (2013). To investigate effects of computer based learning and to determine students' misconceptions on nature of the matter concept. *The Journal of Academic Social Science Studies, 6* (5), 571-585.
Gönen, S., & Akgün, A. (2005). An investigaton of the applicability of worksheet and class discussions on determining and remedying lack of knowledge and misconceptions. *Elektronik Sosyal Bilimler Dergisi, 4* (13), 99-111.
Griffiths, K. A., & Preston R. K., (1992). Grade-12 students misconceptions relating to fundamental characteristics of atoms and molecules. *Journal of Research in Science Teaching*, *29*, 611-628
Grosslight, L., Unger, C., Jay, E., & Smith, J. L. (1991). Understanding models and their use in science: Conceptions of middle and high school students and experts. *Journal of Research in Science Teaching*, *28* (9), 799-822.
Güneş, B., Gülçiçek, Ç., & Bağcı, N. (2004). Analysis of science educators' views about model and modelling. *Türk Fen Eğitimi Dergisi, 1* (1), 35-48.

Harrison, A. G., & Treagust, D. F. (1996). Secondary students' mental models of atoms and molecules: Implications for teaching chemistry. *Science Education*, *80*(5), 509-534.

Harrison, A. G., & Treagust, D. F. (2000). A typology of school science models. *International Journal of Science Education*, *22* (9),1011-1026.

Harrison, A. G. (2001). How do teachers and textbook writers model scientific ideas for students? *Research in Science Education*, *31* (3), 401-435.

Johnson, P. (2000). Childrens'understanding of substances, part 1: Recognizing chemical change, *International Journal of Science Education, 22* (7), 719-737.

Johnstone, A. H. (2000). Teaching of chemistry – logical or psychological? *Chemistry Education and Research Practice, 1*, 9–15.

Karagöz, Ö., & Sağlam Arslan A. (2012). Analysis of primary school students' mental models relating to the structure of atom. *Türk Fen Eğitimi Dergisi, 9* (1), 132- 142.

Kenan, O., Özmen, H., & Güney, K. K. (2007). Ideas of students at different levels of primary education about matter and particle structure. Presented at 16th National Congress of Educational Sciences (5-7 September 2007, Tokat, Turkey).

Khurshid, M., & Iqbal, M. Z. (2009). Children's misconceptions about units on changes, acids and laboratory preparation of CO_2. *Bulletin of Education and Research*, *31*, 61-74.

Kıngır, S., Geban, Ö., & Günel, M. (2013). Using the science writing heuristic approach to enhance student understanding in chemical change and mixture. *Research in Science Education,43*,1645-1663.

Kıngır, S., & Geban, Ö. (2014). 10th grade students' conceptions about chemical change. *Türk Fen Eğitimi Dergisi, 11* (1), 43-62.

Kıray, S.A. (2016). The pre-service science teachers' mental models for concept of atoms and learning difficulties. *International Journal of Education in Mathematics, Science and Technology*, *4* (2), 147-162.

Kibar, Z., B., & Ayas. A. (2010). Implementing of a worksheet related to physical and chemical change concepts. *Procedia-Social and Behavioral Sciences*, *2*, 733-738.

Lemma, A. (2013). A diagnostic assessment of eighth grade students' and their teachers' misconceptions about basic chemical concepts, *African Journal of Chemical Education, 3* (1), 39-59.

McClary, L., & Talanquer, V. (2011). College chemistry students' mental models of acids and acid strength, *Journal of Research in Science Teaching*, *48* (4), 396-413.

Meşeci, B., Tekin, S., & Karamustafaoğlu, S. (2013). Determination of misconceptions about the particle structure of matter. *Dicle Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 5* (9), 20-40.

Ministry of National Education [MoEN]. (2013). *The curriculum of elementary science course*. Ankara.

Mirzalar Kabapınar, F. M., & Adik, B. (2005). Secondary students' understanding of the relationship between physical change and chemical bonding. *Ankara Üniversitesi Eğitim Bilimleri Fakültesi Dergisi, 38* (1), 123-147.

Mitchell, I., & Gunstone, R. (1984). Some student conceptions brought to the study of stoichiometry. *Research in Science Education*, *14,* 78-88.

Nakhleh, M. B., & Samarapungavan, A. (1999). Elementary school children's beliefs about matter. *Journal of Research in Science Teaching, 36* (7), 777-805.

Nakhleh, M. B., Samarapungavan, A., & Sağlam, Y. (2005). Middle school students' beliefs about matter. *Journal of Research in Science Teaching, 42* (5), 581-612.

Ormancı, Ü., & Balım, A. G. (2014). Secondary school students'ideas related to the subject of matter: Drawing methods, *Elementary Education Online*, *13* (3), 827-846.

Okumuş, S., Öztürk, B., Doymuş, K., & Alyar, M. (2014). Aiding comprehension of the particulate of matter at the micro and macro levels. *Eğitim Bilimleri Araştırmaları Dergisi*, *4* (1), 349-368.

Örnek, F. (2008). Models in science education: Applications of models in learning and teaching science, *International Journal of Environmental & Science Education*, *3* (2), 35 – 45.

Polat, Z. (2012). *A comparison between students' mental models of structure and visualizations in textbooks for the concept of atom* (Unpublished master's thesis). İstanbul. Boğaziçi University.

Sökmen, N., Bayram, H., & Yılmaz, A. (2000). Levels of understanding physical change and chemical change concepts of 5th, 8th and 9th grade students. *Marmara Üniversitesi Atatürk Eğitim Fakültesi Eğitim Bilimleri Dergisi, 12,* 261-266.

Stavridou, H., & Solomonidou, C. (1989). Physical phenomena-chemical phenomena: Do pupil make the distinction?. *International Journal of Science Education*, *11* (1), 83-92.

Taber, K. S. (1998). An alternative conceptual framework from chemistry education. *International Journal of Science Education*, *20* (5), 597-608.

Tarhan L., Ayyıldız Y., Öğünç A., & Acar Şeşen B. (2013). A jigsaw cooperative learning application in elementary science and technology lessons: Physical and chemical changes, *Research in Science & Technological Education*, *2,* 184-203.

Taşdemir, A., & Demirbaş, M. (2010). The level of correlation of concepts that primary students seen topics in science and technology class with daily life. *Uluslararası İnsan Bilimleri Dergisi*, *7* (1), 124-148.

Taylor, N., & Coll, R. K. (2002). Pre-service primary teachers'models of kinetic theory: an examination of three different cultural groups, *Chemistry Education: Research and Practice in Europe*, *3* (3), 293-315.

Tsaparlis, G., (2003). Chemical phenomena versus chemical reactions: Do students make the connection? *Chemistry Education: Research and Practice*, *4*, 31-43.

Treagust, F. D., Chittleborough, G. D., & Mamiala, L. T. (2002). Students'understanding of the role of scientific models in learning science. *International Journal of Science Education*, *24* (4), 357-368.

Tümay, H. (2014). Prospective chemistry teachers' mental models of vapor pressure. *Chemistry Education Research and Practice*, *15* (3), 366-379.

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Uluçınar Sağır, Ş., Tekin S., & Karamustafaoğlu, S. (2012). The levels of prospective elementary school teachers' understanding of some chemistry concepts. *Dicle Üniversitesi Ziya Gökalp Eğitim Fakültesi Dergisi, 19,* 112-135.

Ünal, G., & Ergin, Ö. (2006). Science education and models. *Milli Eğitim Dergisi*, *171,* 188-196.

Yıldırım, A., & Şimşek, H. (2013). *Qualitative research methods in social sciences*. Ankara: Seçkin Publishing.

Yıldırır, H. E., & Demirkol, H. (2018). Revealing students'cognitive structure about physical and chemical change: use of a word association test. *European Journal of Education Studies*, *4* (1), 134-154.

Zan Yörük, N. (2003). *A cross age (between 11-14 years old) study regarding the comprehension of mixture, matter's change of state, density, physical-chemical change and pressure subjects in chemistry* (Unpublished master's thesis). Ankara. Hacettepe University.

Zarkadis, N., Papageorgiou, G., & Stamovlasis, D. (2017). Studying the consistency between and within the student mental models for atomic structure, *Chemistry Education: Research and Practice in Europe*, *18*, 893-902.

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