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Mental Models of the Students From Different Levels of Education About The Structure Of Atom*

Farklı Eğitim Düzeyindeki Öğrencilerin Atomun Yapısına İlişkin Zihinsel Modelleri

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Abstract. The current study it was attempted to determine the ability of middle school students, pre-service science teachers and physics and chemistry graduates enrolled in a pedagogical formation program for questioning well-established scientific facts related to the structure of atom by investigating the models they have constructed in their minds about the structure of atom. The participating students were asked to draw the atom models in their minds, to illustrate their knowledge about the attraction and repulsion of electric forces and to indicate what would happen if the reverse of what they know where the truth through drawings. The study employed the phenomenological design. The qualitative data collected from the students were first grouped through coding. Then, categories and themes were created from the codes and frequency and percentage values related to the categories and themes were calculated. The results of the study have revealed that adequate success for these research group has not been accomplished in teaching of abstract concepts in each level of education.
***Keywords**:* Science education, Chemistry education, Chemistry philosophy, Mental models.

Öz. Çalışmada; ortaokul öğrencileri, eğitim fakültesi fen bilgisi öğretmenliği öğrencileri ile pedagojik formasyon kursuna katılan fizik ve kimya bölümü mezunlarının atomun yapısı konusunda zihinlerinde oluşturdukları modeller ile genel geçer olarak kabul edilen bilimsel gerçekleri sorgulayabilme düzeyleri belirlenmeye çalışılmıştır. Bu amaçla katılımcılara zihinlerindeki atom modellerini çizmeleri, elektriksel yüklerin birbirlerini çekip itmeleri hakkında var olan bilgilerini aktarmaları ve katılımcılarda bulunan bu bilginin tam tersi olsaydı olacaklarla ilgili görüşlerini şekil çizerek belirtmeleri istenmiştir. Çalışmada fenomolojik desen kullanılmıştır. Araştırma örneklemini Muğla merkez ve köylerindeki ortaokul dördüncü sınıf öğrencileri, Muğla Sıtkı Koçman Üniversitesi Eğitim Fakültesi Fen Bilgisi Öğretmenliği bölümünde öğrenim görmekte olan öğrenciler ile yine aynı fakültenin pedagojik formasyon kursuna katılan öğrenciler oluşturmaktadır. Elde edilen veriler, öncelikle kodlanarak gruplandırılmıştır. Daha sonra kodlardan kategoriler ve temalar oluşturularak bu kategori ve temalara ilişkin frekans ve yüzde değerleri hesaplanmıştır. Araştırmanın sonuçları, incelenen araştırma grubu için her eğitim kademesinde soyut kavramların öğretiminde yeterli başarının sağlanamadığını göstermektedir.
Anahtar kelimeler: Fen eğitimi, Kimya eğitimi, Kimya felsefesi, Zihinsel modeller.

SUMMARY

Introduction. Education is the activity and the process of making changes in the desired direction in the behaviors of the individual so that he/she can adapt to the society and improve his/her skills in order to adapt to the collective living. In addition, education should enable students to think more seriously in their professional, social and personal lives. In this regard, curriculums are being updated in order to adapt to the developing and changing social life. Science education requires three basic levels of understanding about symbols, equations and calculations. These are micro level, symbolic level and macro level. Yet, as revealed by various studies, transition from one level to another is not easy for students. In Bloom's taxonomy, it has been illustrated that learning occurs in cognitive, emotional, and psychomotor domains and these domains are divided into subheadings by addressing learning levels. Models are effective in teaching, especially in teaching science. Models are of great importance in scientific research. Model-based learning is important in both individual and group learning in terms of learning activities and application of the learned information into the real life.

Method. The current study employed both quantitative and qualitative research designs. From among the qualitative research designs, the phenomenological design was used. In the phenomenological design, focus is on the phenomena which we are aware of but we do not have deep and elaborate understanding about. We can encounter phenomena in various forms as events, experiences, perceptions, tendencies, concepts and states. In phenomenological research, data sources are the individuals or groups who have experienced and can express the phenomenon under investigation. Problem Statements of this research:

1. What are the mental atom models of the students from different levels of education?
2. What are the opinions of students from different levels of education about the identical and opposite charges in atom?

The sampling of the current study is comprised of 19 middle school fourth grade middle school students from the central province of the city of Muğla and 8 middle school fourth grade students from a village of the city of Muğla, 42 first-year and 32 fourth-year pre-service science teachers from the Education Faculty of Muğla Sıtkı Koçman University and 15 physics graduates and five chemistry graduates enrolled in the pedagogical formation program offered in the same faculty. In the selection of the sampling, the random sampling method was used. Of the participating middle school student, 33.3% (*n*=9) are females, 66.7% (*n*=18) are males; of the undergraduate students, 68.1% (*n*=64) are females and 31.9% (*n*=30) are males. A data collection tool including some demographics (age, grade level, field of study, preferred type of movies, preferred type of books) and three open ended questions to elicit the participants' mental models about the structure of atom and the extent to which they can use their knowledge in practice was developed. The data collection tool was prepared by reviewing the literature and the alternative concepts reported in this literature and considering how students perceive events. In order to establish the reliability and validity of the data collection tool, it was subjected to review of the experts in the field and then in light of their feedbacks, some corrections were made and the final form of the data collection tool was given. The data collected in the study were analyzed by using the content analysis method. In such analysis, the main objective is to arrive at concepts and relationships that can explain the collected data. In the content analysis of data, coding is performed by assigning names to the meaningful sections between new data. From the codes, categories and themes are created. Categories and themes are more general and abstract than the concepts obtained in the content analysis. Moreover, frequencies and percentages for the created categories and themes were calculated. In the quantitative data analysis, SPSS 20.0 statistical program package was used.

Results. Within the context of the study aiming to elicit the mental models of the middle school students, pre-service science teachers and physics and chemistry graduates enrolled in a pedagogical formation program about the structure of atom, the participants' responses to three open ended

questions were examined. The data collected in the study revealed that the middle school students do not know the basic elements constituting atom or explain them erroneously to a great extent. The mental atom models elicited in the first question were divided into three themes through coding. While the middle school students from the city produced these three models in their drawings though in varying ratios, the middle school students from the village only depicted the *Mediatic model (Rutherford atom model)* in their drawings. Nearly 53% of the students from the city also drew the *Mediatic model (Rutherford atom model)*.

Discussion and Conclusion. The models of atom produced by the university students were gathered under five different groups. A high majority of the pre-service science teachers were found to have *Electron cloud model*. Similar to them, majority of the physics and chemistry graduate pedagogical formation program students have the *Electron cloud model* as their mental model. The university students depicted their mental models of atom in the form of the *Electron cloud model* resembling more to the solar system model rather than the modern model. Thus, it seems that the effect of the historical models on the formation of mental models used to question scientific facts is great. This is believed to be because they cannot make a successful transition between scientific events.

Introduction

Education is the activity and the process of making changes in the desired direction in the behaviors of the individual so that he/she can adapt to the society and improve his/her skills in order to adapt to the collective living (Aycan and Aycan, 2011). In addition, education should enable students to think more seriously in their professional, social and personal lives. In this regard, curriculums are being updated in order to adapt to the developing and changing social life. The aim of the updated curriculums is to educate individuals who are questioning, critically thinking, developing problem solving skills and willingness to research and to create learning environments where learners are active and can individually participate in learning [Ministry of Education (MEB), 2018]. Questioning is of great importance in science teaching. In classrooms where traditional methods are used, students see their teachers as experts who provide correct answers. In contrast, in an inquiry-based teaching environment, students learn to construct their own understanding and take responsibility for building their own knowledge base. Educating citizens who attach great importance to researching, questioning and striving to reach the truth rather than blindly believing what is taught or said to them is one of the main objectives of developed societies (Aycan and Arslan, 2013). Science education requires three basic levels of understanding about symbols, equations and calculations (Johnstone, 2000). These are micro level, symbolic level and macro level. Yet, as revealed by various studies, transition from one level to another is not easy for students (Çökelez, 2009). In Figure 1, these levels are schematically presented.

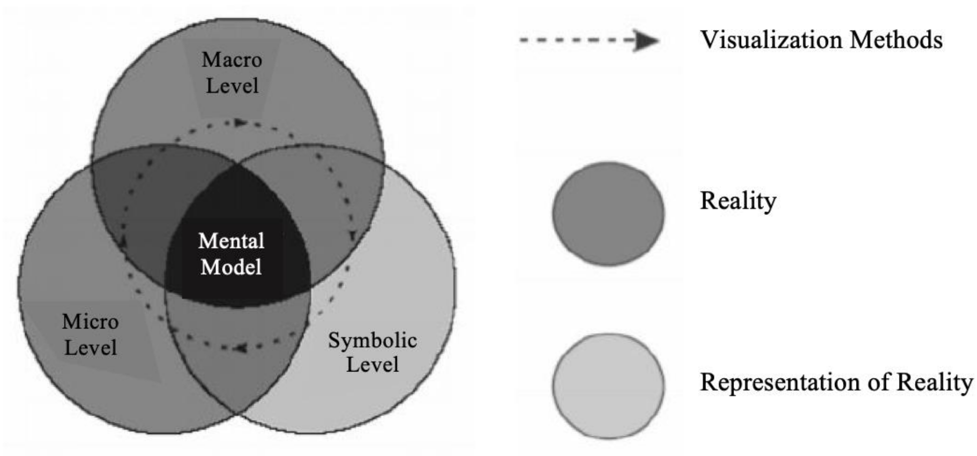

Figure 1. Scientific concepts entanglement models (Devetak, 2005; Devetak, 2007; cited in Sezen and Çıldır, 2012).

In Bloom’s taxonomy, it has been illustrated that learning occurs in cognitive, emotional, and psychomotor domains and these domains are divided into subheadings by addressing learning levels (Çepni et al., 2007; cited in Ayvacı and Türkdoğan, 2010). Models are effective in teaching, especially in teaching science. Harman (2012) stated that as a result of the model-based instruction in which students are active, they can create scientifically acceptable models of the subject. Models are of great importance in scientific research. Model-based learning is important in both individual and group learning in terms of learning activities and application of the learned information into the real life (Gobert and Buckley, 2000). The Information Transposition Theory proposed by Chevallard (1985) refers to all the changes occurring while scientific information produced by scholars is converted into the kind of information internalized by the student. Develay (1992) summarizes this process in three stages:

1. From Scientific Information to Information to be Taught: This stage is the responsibility of program developers and involves determining the extent to which scientific information will be utilized and determining the general framework of the curriculum.

2. From Information to be taught to Information Taught/School Information: This stage is the responsibility of the teacher and involves the teacher’s converting the information presented in the curriculum and textbooks into information to be presented to students by using various classroom activities.

3. From Information Taught to Internalized Information: In this last stage which is the responsibility of the student, the student interprets the information taught to convert it into a form that he/she can understand by getting it through different phases (Develay, 1992, cited in Çökelez, 2009).

The interdisciplinary use of some concepts is highly prevalent. For example, according to Liu and Lesniak (2005), physical and chemical changes are one of the topics difficult for students to understand in science and particularly in chemistry. Similarly, the concept of atom and its models are among the topics studied both in physics and chemistry classes. Çökelez, Dumon and Taber (2008), in the study conducted on French middle school children, emphasized the importance of the modeling process in different fields. They found that the students think that atom is invisible; accordingly, indivisible. Similar studies on atom models have been conducted by different researchers. Coll and Taylor (2002) attempted to determine the mental models of the middle, university and graduate students about chemical bonds through interviews in New Zealand. They concluded that the students in general have the simple and realistic models found in nature and that they do not use complex and mathematical models during learning. According to Harrison and Treagust (1996), who attempted to determine the middle school students' mental models of atoms and molecules through interviews, the students have alternative concepts. Öztuna-Kaplan and Boyacıoğlu (2013) aimed to elicit students' knowledge, opinions and if there are any, misconceptions about the granular structure of the matter by means of the drawings they produced. Mental models of the granular structure of the matter seem to be stored as false information in the minds of many students ranging from elementary education to post-graduate education. For example, Balım and Ormancı (2012) tried to determine the elementary school students' levels of understanding of the unit called *the granular structure of the matter* through drawings and found that their level of understanding is mostly at a medium level. In a similar manner, Karagöz and Sağlam-Arslan (2012) investigated the elementary school 7^{th} grade students' mental models about the structure of atom. As a result of this study, it was found that all the students correctly stated that atom is made up of proton, neutron and electron; yet, that they have different mental models about their movements and locations. The middle school students' opinions about the matter were explored by Ormancı and Balım (2014) by means of the drawing method and their findings showed that the students have moderately successful in the drawing of cell-atom model and in determining the relationship between them and that the students have high level of understanding of the granular structure of the matters made up of atom-compound-mixture. High school students' mental models of the structure of the matter were explored by Kurnaz and Emen (2013) on 107 Turkish high school students. The researchers found that the students cannot transport matters they have observed at macro level to micro level; that is, they cannot describe their inner structure.

When the research on mental models has been reviewed, it is seen that they mostly focus on a single group. This group is comprised of either elementary school students (Çökelez, 2009; Karagöz and Arslan, 2012), high school students (Kurnaz and Emen, 2013; Harrison and Treagust, 1996) or pre-service teachers (Kurt, Ekici and Aksu, 2013; Nakipoğlu, Karakoç and Benlikaya, 2002). Karagöz and Arslan (2012) investigated the elementary school 7^{th} grade students' mental models of the structure of atom and found four different mental models (Solar System, Granular Food, World, Swing Ride. Harrison and Treagust (1996) classified the 8-10^{th} grade students' mental models of atom into six groups (solar system, orbit, multi-orbits, nested orbits, electron cloud, ball model). Nakipoğlu and Karakoç (2002) collected the pre-service teachers' mental models of atom under six groups and found that most of them illustrated it similar to the Bohr Atom Model. Illustrations about the structure of Atom have also been shown to students by means of the traditional Turkish art of marbling (Aycan and Güç, 2017). Cheng (2018) investigated the 10^{th}, 11^{th} and 12^{th} grade students' drawings of atoms' interaction in the occurrence of chemical reactions.

When the relevant literature is reviewed, it is seen that though there are many studies focusing on single group of students, the number of studies conducted with samples made up of students from different levels of education is considerably small. Thus, the primary purpose of the current study is to elicit the internalized knowledge of the elementary, undergraduate and graduate students about the structure of atom and to determine the models they created in their minds. The secondary purpose of the study is to determine the extent to which the participants can question the well-established facts about the issue. Within the context of a philosophical thinking approach requiring the questioning of what would happen if the world operated under the rules which are completely opposite of the ones which science has made us believe, the students were asked to respond to the question "How would the reality be constructed if the structure of the atom were exactly the opposite of what has been accepted?" to determine whether they have been educated in compliance with the inquiry-based conception of education.

Method

Research Model

The current study employed both quantitative and qualitative research designs. From among the qualitative research designs, the phenomenological design was used. In the phenomenological design, focus is on the phenomena which we are aware of but we do not have deep and elaborate understanding about (Holstein and Gubrium, 1996). We can encounter phenomena in various forms as events, experiences, perceptions, tendencies, concepts and states. In phenomenological research, data sources are the individuals or groups who have experienced and can express the phenomenon under investigation (Yıldırım and Şimşek, 2013:78-80).

Problem Statement

1. What are the mental atom models of the students from different levels of education?
2. What are the opinions of students from different levels of education about the identical and opposite charges in atom?

Sub-problems

1) What are the mental models of the fourth grade middle school students about the structure of atom?
2) What are the mental models of the first-year and fourth-year pre-service science teachers about the structure of atom?
3) What are the mental models of the chemistry and physics graduates enrolled in a pedagogical formation program about the structure of atom?
4) What are the opinions of the middle school fourth grade students about what would happen if the facts about the positive and negative charges in atom were the exact opposite?
5) What are the opinions of the first-year and fourth-year pre-service science teachers about what would happen if the facts about the positive and negative charges in atom were the exact opposite?
6) What are the opinions of the chemistry and physics graduates enrolled in a pedagogical formation program about what would happen if the facts about the positive and negative charges in atom were the exact opposite?

Data Collection Tools

A data collection tool including some demographics (age, grade level, field of study, preferred type of movies, preferred type of books) and three open ended questions to elicit the participants' mental models about the structure of atom and the extent to which they can use their knowledge in practice was developed. The data collection tool was prepared by reviewing the literature and the alternative concepts reported in this literature and considering how students perceive events. In order to establish the reliability and validity of the data collection tool, it was subjected to review of the experts in the field and then in light of their feedbacks, some corrections were made and the final form of the data collection tool was given.

Sampling

The sampling of the current study is comprised of 19 middle school fourth grade middle school students from the central province of the city of Muğla and 8 middle school fourth grade students from a village of the city of Muğla, 42 first-year and 32 fourth-year pre-service science teachers from the

Education Faculty of Muğla Sıtkı Koçman University and 15 physics graduates and five chemistry graduates enrolled in the pedagogical formation program offered in the same faculty. In the selection of the sampling, the random sampling method was used. Of the participating middle school students, 33.3% (*n*=9) are females, 66.7% (*n*=18) are males; of the undergraduate students, 68.1% (*n*=64) are females and 31.9% (*n*=30) are males. Some characteristics of the participants are given in Table 1.

Table 1**.**
Distribution of the participants according to their level of education (n=121)

Participants	**Middle school**	**Pre-service science teachers**		**Pedagogical formation**	
Level of education	**4th grade**	**1st year**	**4th year**	**Physics**	**Chemistry**
The number of students	27	42	32	15	5

Data Analysis

The data collected in the study were analyzed by using the content analysis method. In such analysis, the main objective is to arrive at concepts and relationships that can explain the collected data. In the content analysis of data, coding is performed by assigning names to the meaningful sections between new data. From the codes, categories and themes are created. Categories and themes are more general and abstract than the concepts obtained in the content analysis (Yıldırım and Şimşek, 2013). Moreover, frequencies and percentages for the created categories and themes were calculated. In the quantitative data analysis, SPSS 20.0 statistical program package was used.

Findings

1. Within the context of the first problem of the study, answer to the question “What are the mental atom models of the students from different levels of education?” was sought.

The participants’ responses to the question in the data collection tool “What does atom mean to you? Please explain through drawing.” were analyzed. The participants’ responses were grouped into themes as a result of the content analysis and literature review. The frequencies and percentages belonging to these themes are presented in tables and samples from their drawings were directly quoted.

1.1. The middle school students’ mental atom models

On the basis of the characteristics of the students’ responses, categories were determined and then by reviewing the literature, three different mental atom model themes were constructed from these categories. The models derived from the students’ drawings are subsumed under three themes; *(1) Electron cloud model, (2) Ball model, (3) Mediatic model (Rutherford atom model)*. Some models derived from the students’ drawings are shown in Figure 2.

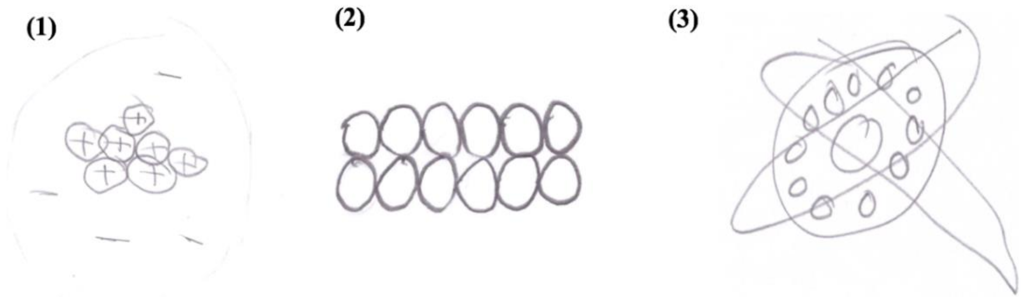

Figure 2. Samples for the middle school students' atom models

Frequencies and percentages for the themes emphasized by the middle school students are given in Table 2.

Table 2.
Descriptive statistics for the middle school students' mental models

Mental models	City		Village	
	f	**%**	***f***	**%**
(1) Electron cloud model	6	31.6	0	0
(2) Ball model	3	15.8	0	0
(3) Mediatic model (Rutherford atom model)	10	52.6	8	100

When middle school students' drawings were examined, it was found that the students from the city center have the *Mediatic model (Rutherford atom model*) to the greatest extent (52.6%, *n*=10) and the *Ball model* to the smallest extent (15.8%, *n*=3). On the other hand, the atom model possessed by all of the village middle school students (*n*=8) was found to be the *Mediatic model (Rutherford atom model)*.

1.2. University students' mental atom model

On the basis of the characteristics of the university students' responses, categories were determined and then by reviewing the literature, five different mental atom model themes were constructed from these categories. Some samples were selected from the students' drawings (Figure 3).

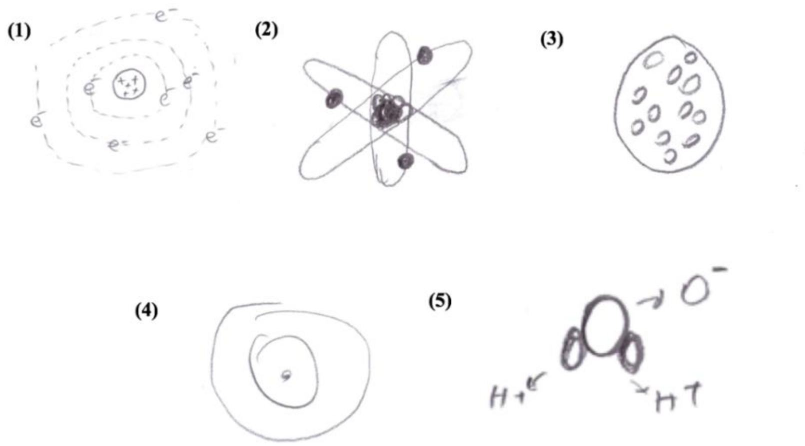

Figure 3. University students' mental atom models

From the responses of the pre-service science teachers (first-year and fourth-year) and physics and chemistry graduates, five different themes were constructed; *(1) Electron cloud model, (2) Mediatic model (Rutherford atom model), (3) Raisin pie model, (4) Bohr atom model, (5) Molecule affected model*. The percentages and frequencies for the themes emphasized by the students are given in Table 3 and Table 4.

Table 3.
Descriptive statistics for the mental models of the pre-service science teachers

Mental model	**Education faculty**			
	1st year		**4th year**	
	f	**%**	***f***	**%**
(1) Electron cloud model	12	28.6	18	56.2
(2) Mediatic model (Rutherford atom model)	7	16.6	7	22
(3) Raisin pie model	1	2.4	4	12.5
(4) Bohr atom model	18	43	2	6.2
(5) Molecule affected model	4	9.5	1	3.1

The mental models of the first-year and fourth-year pre-service science teachers were examined. The first-year students have the *Bohr atom model* to the greatest extent (46%, *n*=18) and the *Raisin pie model* to the smallest extent (2.4%, *n*=1); the fourth-year students have the *Electron cloud model* to the greatest extent (56.2%, *n*=18) and the *Molecule affected model* (3.1%, *n*=1) to the smallest extent.

Table 4.
Descriptive statistics for the mental models of the pedagogical formation students

Mental model	**Pedagogical formation**			
	Physics		**Chemistry**	
	f	**%**	***f***	**%**
(1) Electron cloud model	7	46.6	4	80
(2) Mediatic model (Rutherford atom model)	5	33.3	0	0
(3) Raisin pie model	0	0	0	0
(4) Bohr atom model	3	20	1	20
(5) Molecule affected model	0	0	0	0

The mental models of the physics and chemistry graduates enrolled in a pedagogical formation program were examined. The physics graduates were found to have the *Electron cloud model* (46.6%, *n*=7) to the greatest extent. Moreover, none of the physics graduates were found to have the *Raisin pie model and Molecule affected model*. The high majority of the chemistry graduates (80%, *n*=4) were found to have the *Electron cloud model* (%80, *n*=4) and they did not use the *Mediatic model (Rutherford atom model)*, *Raisin pie model* and *Molecule affected model* in their drawings.

2. Within the context of the second question of the study, answer to the question "What are the opinions of students from different levels of education about the identical and opposite charges in atom?" was sought.

The responses given to the second and third open ended questions in the data collection tool were separately examined and they were classified as true/false. Moreover, their responses to the third question in the data collection tool were examined once more to group those under two themes; *Philosophical point of view and non-philosophical point of view*. Sample responses for the themes are also presented.

2.1. The middle school students' opinions about identical and opposite charges in atom

The responses given by the middle school students to the second and third questions were examined. Frequencies for these responses are given in Table 5.

Table 5.
Descriptive statistics for the middle school fourth grade students' responses to the open ended questions

Questions	City		Village	
	True (*f*)	**False (*f*)**	**True (*f*)**	**False (*f*)**
Question 2	10	9	2	6
Question 3	1	18	1	7

When the middle school students' responses given to the second question were examined, it was found that while 52.6% (*n*=10) of the students from the city gave true answers, only 25% (*n*=2) of the students from the village gave correct answers. Thus, the students attending urban schools seem to be more successful than the students attending rural schools. When their responses given to the third question were examined, it was found that only 5.26% (*n*=1) of the students from the city gave a true answer and 12.5% (*n*=1) of the students from the village gave a true answer. Both the students attending urban schools and the students attending rural schools could not achieve the adequate success in the third question.

Some sample responses given to the third question by the middle school students are given below.

Student 9: It would blow up. (Non-philosophical point of view)

Student 7: The gravity would not exist; objects would fly in the air. (Non-philosophical point of view)

Student 3: Not much would change, just 104 elements would be perplexed. The God would have created the universe in compliance with this new state. (Non-philosophical point of view)

Student 15: As there would not be atom, the world would not have been formed. (Philosophical point of view)

2.2. The university students' opinions about the identical and opposite charges in atom

The responses given by the pre-service science teachers to the second and third questions were examined. The frequencies for these responses are given in Table 6.

Table 6.
Descriptive statistics for the responses given by the pre-service science teachers to the open ended questions

Questions	Pre-service science teachers			
	1st year		**4th year**	
	True (*f*)	**False (*f*)**	**True (*f*)**	**False (*f*)**
Question 2	29	13	24	8

Question 3	23	19	10	22

When the responses given to the open ended questions given by the pre-service teachers were examined, it was found that 69.04% (n=29) of the first-year students gave true answers to the second question and 75% (n=24) of the fourth-year students gave true answers to the second question. When their responses to the third question were examined, it was found that 54.76% (n=23) of the first-year students and 31.25% (n=10) of the fourth-year students gave true answers.

Some sample responses given to the third question by the pre-service science teachers are given below.

Student 2: It would cause g-force. (Non-philosophical point of view)

Student 27: Everything would get into mess. (Non-philosophical point of view)

Student 47: Atom would come to steady state. (Non-philosophical point of view)

Student 48: Molecules would not form. (Philosophical point of view)

The pedagogical formation students' responses to the second and third questions were examined. Frequencies calculated for their responses are given in Table 7.

Table 7.
Descriptive statistics for the pedagogical formation students' responses to the open ended questions

	Pedagogical formation			
	Physics		**Chemistry**	
Questions	**True (*f*)**	**False (*f*)**	**True (*f*)**	**False (*f*)**
Question 2	8	7	5	0
Question 3	5	10	1	4

When the university graduate formation students' responses given to the open ended questions were examined, it was found that 53.3% (n=8) of the physics graduates and all of the (n=5) chemistry graduates gave true answers to the second question. When their responses to the third question were examined, it was found that 33.3% (n=5) of the physics graduates and 20% (n=1) of the chemistry graduates gave true answers to this question.
Some sample responses given by the pedagogical formation students to the third question are presented below.

Student 82: New matters would form. (Non-philosophical point of view)

Student 88: Atom would not exist. (Non-philosophical point of view)

Student 92: There would not be order in the universe. (Philosophical point of view)

Student 94: There would be turmoil, would not be shapes. (Philosophical point of view)

The findings of the study generally show that though both the middle school students, university students and university graduates are successful in answering the second question, their level of success in the third question is quite low. The responses given to the third question by the students from different levels of education seem to be similar.

Discussion and Results

Within the context of the study aiming to elicit the mental models of the middle school students, pre-service science teachers and physics and chemistry graduates enrolled in a pedagogical formation program about the structure of atom, the participants' responses to three open ended questions were examined. The data collected in the study revealed that the middle school students do not know the basic elements constituting atom or explain them erroneously to a great extent. The mental atom models elicited in the first question were divided into three themes through coding. While the middle school students from the city produced these three models in their drawings though in varying ratios, the middle school students from the village only depicted the *Mediatic model (Rutherford atom model)* in their drawings. Nearly 53% of the students from the city also drew the *Mediatic model (Rutherford atom model)*.

The models of atom produced by the university students were gathered under five different groups. A high majority of the pre-service science teachers were found to have *Electron cloud model*. Similar to them, majority of the physics and chemistry graduate pedagogical formation program students have the *Electron cloud model* as their mental model. The university students depicted their mental models of atom in the form of the *Electron cloud model* resembling more to the solar system model rather than the modern model. Thus, it seems that the effect of the historical models on the formation of mental models used to question scientific facts is great. This is believed to be because they cannot make a successful transition between scientific events. Similarly, in a study conducted by Kahraman and Demir (2011) on 145 first-year pre-service science teachers, the students were asked to draw the hydrogen atom according to the modern atom model and as a result of the analysis of the collected data, it was found that the students visualize electrons as particles moving on orbits around the nucleus. Çökelez and Yalçın (2012) conducted a study on the seventh grade students and found that before the application the students used to think of atom as a solid sphere, after the application they started to think of it as in Bohr atom model. Kaya (2010) arrived at the alternative concept for the concept of atom as "Electrons move on certain orbits". In Ireson's study (1999), the belief found to be dominant among the participants is that "Electrons move rapidly on certain orbits around the nucleus". In a content analysis study on atom models, when the models drawn by the students were examined, it was observed that mostly simple spheres or electrons located around the nucleus had been drawn by them and though the Electron cloud model had been taught in classes, very few students produced this model in their drawings (Demirci, Yılmaz and Şahin, 2016). Yaseen and Akaygün (2016) conducted a study on high school students and reported that with increasing grade level, the students' level of possessing the Synthetic model (an eclectic model having characteristics of more than one model) also increases.

When the students' responses to the second and third questions are examined, it is seen that though the rate of true answers is high, they have missing information or information full of misconceptions about the structure of atom and the charges found in atom. Similarly, Baybars and Küçüközer (2014) conducted a study on pre-service science teachers and found that before the intervention, many of them had "alternative" concepts about the issue of atom. It was determined that the students have the following alternative concepts; proton and neutron are in the nucleus, we cannot locate their exact places as electrons are very small and fast/protons and neutrons are in the nucleus and electrons are on certain orbits around the nucleus. In the study by Baybars and Küçüközer (2014), the obtained alternative concept "proton and neutron are in the nucleus and electrons are on certain orbits around the nucleus" which has been obtained in many other studies.

As for the third question, the participants were expected to question scientific facts and think antagonistically. Yet, they were found not to be able to philosophically question scientific facts in general. This is believed to be because they do not know the basic elements making up atom or express them erroneously as they made unscientific explanations without investigating the components of atom (Student 3: Not much would change, just 104 elements would be perplexed. The God would have created the universe in compliance with this new state (Non-philosophical point of view). Nakiboğlu, Karakoç and Benlikaya (2002) and Canpolat, Pınarbaşı and Sözbilir (2003) reported findings concurring with the findings of the current study. In a study in which middle school students' opinions about the matter were investigated through the drawing technique, it was found that the students were moderately successful in drawing cell-atom model and in determining the relationship between them and the students' level of understanding of the granular structure of the matters made up of atom-compound-mixture is high (Ormancı and Balım, 2014).

Suggestions

In light of the findings of the current study, the following suggestions can be made;

1) Delivery of instruction through applied activities that can enhance students' critical thinking and provide them with opportunities to exemplify correct and false atom models during the teaching of units addressing the issue of atom in science classes can contribute to occurrence of more permanent learning.

2) During university education, rather than focusing on theoretical information, students can be encouraged to prepare posters, models and make presentations about the topic of atom so that they can be introduced to different models of atom proposed by various scholars.

3) Rather than test technique and making up simple definitions of concepts to assess students, measurement techniques that allow students to make synthesis and utilize their imagination and encourage them to think about different situations should be employed so that students' learning can be made more permanent and misconceptions can be detected.

4) During the science education process, students can purposefully be introduced to false atom models and they can be encouraged to discuss why some models are false and some others are correct, which can lead students to questioning and recognition of their misconceptions.

5) By integrating the way of philosophical thinking that encourages students to think into curriculums of every level of education, students can be educated as individuals who can question and more importantly can think.

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