

# Determining the pre-service teachers' perceptions of atom and atomic structure through word association test

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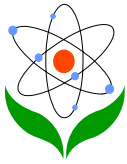
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## Abstract

The aim of this study is to determine the pre-service teachers' perceptions of atom and atomic structure through a word association test. It is important to concretize the concepts having a significant influence on the learning of subjects. Through this concretization, students' understanding of the concepts and accordingly of the subjects is facilitated. The word association test used in the current study consists of nine key concepts chosen from the unit "Atom and Atomic Structure". It was given 15 seconds to the participants for each key concept. Content analysis was conducted for the analysis of the data. The frequency table was formed taking into consideration the frequency of given responses. Accordingly, the mind maps were generated to indicate the relations among concepts. With the word association pre-test, it is found that the pre-service teachers couldn't express many concepts related to the unit

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correctly. Although the findings of the post-test indicate that there is slight increase in the pre-service teachers' correct expression of the concepts, the results show that the pre-service teachers still have difficulty in perceiving the concepts in the unit "Atom and Atomic Structure".

**Keywords:** Atom, atomic structure, cognitive structure, perception, word association test, mind maps, pre-service science teachers.

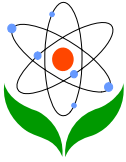
## Introduction

The individual processes information he/she received from the environment at different levels being the sensation and perception. Sensation means the individual's forming sensitivity towards actual events. Hotness of tea, sound of a bird and scent of a flower can be shown as an example. Perception is on the other hand is making sense of the sensations received from the environment (Kaya, 2012). Relaxing effect of a beautiful fragrance on the individual occurs as a result of the perception this individual has created in response to physically felt fragrance. The individual perceives his/her environment through his/her sense organs. The individual's creating a response after processing the information perceived through sense organs with his/her brain means that the perception towards this information has developed.

Learning of a subject and reinforcing of this learning depend on many factors. One of the most remarkable of these factors is concepts. Concepts are the mental tools necessary to maintain healthy interpersonal communication (Senemoğlu, 2010). On the basis of the subjects lay the concepts; thus, teaching of concepts is necessary before teaching subjects (Kaya, 2010).

In a learning environment, concepts are presented to students by means of various techniques. The learning of these presented concepts by the student is a process of structuring and constructing (Karamustafaoğlu, Karamustafaoğlu & Yaman, 2005). In the learning of concepts, construction of relationships between these concepts is of great importance. The student constructs various perceptions of the information sensed while learning concepts. If he/she uses an appropriate technique, the student will be able to construct the concept correctly by establishing an accurate relationship between the concepts he/she has perceived.

By its nature science is a discipline including abstract concepts. Correct perception of concepts by the student is of great importance (Schulte, 2001; cited in Bacanak, Küçük & Çepni, 2004). In a study by Bacanak et al., (2004), the fifth and eighth grade students' level of understanding the concepts of photosynthesis and respiration



and their misconceptions about these topics were investigated. As the participants of the study are in the period of transition from concrete period to abstract period, they preferred to use the concrete meaning of the concept of respiration. This indicated that the students have some misconceptions about this topic.

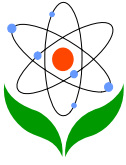
The conceptualization of abstract concepts during concept teaching will make it easier for the student to perceive the concept (Ayas, 2015). If the student has difficulty in associating the newly learned information to his/her prior knowledge network and if he/she cannot construct this new information, it will be highly difficulty for him/her to recall this information (Bahar, 2001). In addition, misunderstandings that science teachers have can cause similar misunderstandings in students (Bradley & Mosimage, 1998, Bacanak et al., 2004). For this reason, the teacher's having a high level of perception and knowledge will help the student to perceive the new information correctly while structuring this information.

Atomic concept has an important place in teaching many concepts in physics and chemistry courses (Çökelez & Yalçın, 2012). One of the factors that play a role in constructing this abstract concept correctly and meaningfully in the minds of the students is the teachers because, as it is known, teachers have the greatest role in the formation of misconceptions about concepts (Nakiboğlu, 2000). There are many studies investigating the mental models and misconceptions of individuals at different educational levels (elementary school, secondary school, university) about the topic of atom (Harrison & Treagust, 1996; Demircioğlu, Demircioğlu & Ayas, 2004; Tezcan & Salmaz, 2005; Nakiboğlu, 2008; Çökelez & Yalçın, 2012; Karagöz & Sağlam Arslan, 2012). While the mental models constructed by individuals about the atomic concept are sometimes correct, they sometimes hold misconceptions about the concept.

It has been increasingly observed with each year that traditional methods are not enough to measure the levels of learners' knowledge or to evaluate the levels of their learning in a subject. The training of students according to a particular pattern can lead to difficulties in shaping and directing the information they acquire. In order to overcome these difficulties, it seems to be necessary to make use of alternative instructional and evaluation methods rather than traditional ones, which is believed to have significant influences on students' development (Ercan, Taşdere & Ercan, 2010; Kurt, Ekici, Aktaş & Aksu, 2013; Özata Yücel & Özkan, 2014; Atabek Yiğit, 2016).

The word association test (WAT), one of the oldest and most common educational tools used to measure the cognitive structure of learners, is a technique used to measure the concepts in the long-term memory of learners and the adequacy of the relationships between these concepts (Bahar, Johnstone & Sutcliffe, 1999; Kurt et

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al., 2013; Bahar, Nartgün, Durmuş & Bıçak, 2015). It is thought that whether meaningful learning occurs in individuals and the relations between the concepts in their minds can be determined by the WAT, an alternative measurement and evaluation technique (Özatlı & Bahar, 2010). In the WAT, the number of the responses given to the key concept on the answer sheet by students is used to evaluate the students' cognitive conception of the related topic (Özata Yücel & Özkan, 2014; Atabek Yiğit, 2016). The WAT, which can also be used as a diagnostic tool, is used at the beginning of teaching to determine the knowledge possessed by students about a subject and after the completion of the teaching about the subject it can be reapplied and the results of these two applications can be compared (Bahar et al., 2015).

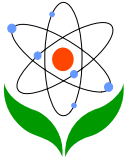
Bahar et al. (1999) is the first study having been conducted by using the WAT in Turkey. Since then, an increase has been observed in the number of studies conducted by using the WAT both in the field of natural sciences (Uşak, 2005; Kırtak, 2010; Yıldırım, 2011; Yaman, 2012; Özata Yücel, 2013) and in the field of social sciences (Aktürk, 2012; Aydemir, 2014).

### **Significance of the Research**

The family and the physical environment in which the individual lives have an important role in his/her mental development from birth (Engelmann & Engelmann, 1966; cited in Çabuk, 2014). With the beginning of the education life, teachers get involved in this process and they contribute to the development of skills such as communication (Baykara Pehlivan, 2005), problem solving (Altunçekiç, Yaman & Koray, 2005), computer use (Aşkar & Umay, 2001). The development of these skills can be achieved through a well-organized environment and the contribution of a teacher having a high level of perception and knowledge (Çabuk, 2014). Therefore, it is important to determine how pre-service teachers perceive concepts. In science education, the subject of "Atom" is a basic concept having an important place in physics and chemistry classes. It is important for pre-service teachers to learn exactly the atomic concept and to determine their perceptions of the relevant basic concepts in terms of science education. For this reason, in the current research, it was attempted to determine the pre-service teachers' existing knowledge about the concepts within the topic of atom and perceptions of these concepts.

### **Purpose of the Study**

The current study aimed to determine the pre-service science teachers' perceptions of the concepts in the topic of "Atom and Atomic Structure" by using the mind maps. In order to prepare the pre-service teachers' mind maps, the WAT was used. The concept of atom was selected as the subject of the current research as it is one of the main subjects in the fields of Physics and Chemistry and as they will have to



somehow address this concept at every stage of secondary education. The criterion pursued in the selection of the participants was their having passed the general physics and general chemistry courses. During the study, the pre-service teachers also took the course of modern physics. Moreover, the effect of the modern physics course on the pre-service teachers' perceptions was also investigated.

## Method

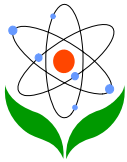
The current study employed the phenomenological design, one of the qualitative research methods. Determination of the essence of how people acquire phenomenon by associating them with various meanings is known as phenomenology (Christensen, Johnson & Turner, 2015; Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, & Demirel, 2016). The purpose of phenomenological research is to elicit individuals' perceptions and experiences related to a phenomenon and the meaning they assign to it. The WAT was used to determine the relationships between the concepts in the unit "Atom and Atomic Structure". In order to reveal the relationships of the key words with each other and their relationships with the response words given to them, mind maps were constructed on the basis of the data obtained with the WAT. In order to reveal the pre-service teachers' mind maps and the relationships they established between the concepts, frequencies of the responses given to the concepts by the pre-service teachers were examined.

### Participants

The current study was conducted on 51 pre-service teachers attending the Department of Science Teaching in the spring term of 2016-2017 academic year. In the selection of the study group, the purposive sampling method was used. This sampling method is preferred in studies focusing on special cases having certain characteristics (Büyüköztürk et al., 2016). While selecting the participants, the criterion pursued was their having taken the courses related to the concept of "Atom". Therefore, the current study was conducted on 51 undergraduate students having taken the first-year and second-year general physics and chemistry courses.

### Data Collection Tools

The data of the current study were collected with the WAT developed by the researchers. Some concepts involved in the topic of atom were determined as the key words and then the WAT was developed. The developed WAT includes nine basic concepts related to the topic of atom. These concepts are atom, nucleus, electron, proton, neutron, orbit, spin, orbital and quark. In order to establish the content



validity of the WAT, expert opinions of two physics educators and two science educators were sought. Expert opinions were elicited and in line with these opinions, some adjustments were made to the WAT and final form of the WAT was given. The concepts in the WAT given to the participants were written as a list and the participants were asked to write the first sentence related to the concept that comes to their minds next to each word.

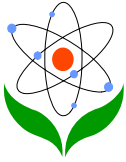
The participants were asked to write five or 10 responses only for the concept of atom and 5 responses for the other concepts each. For each response, the participant was given 15 seconds. There is no certain rule for the determination of this time. This time is determined by checking how much time it takes for all the participants to finish writing or is pre-determined (Karamustafaoğlu et al., 2005, s. 51). For the current study, considering the academic and cognitive levels of the participants, it was determined that 15 seconds would be suitable for each response. Thus, for the concept of atom for which a total of 10 responses were asked, 150 seconds and for each of the other concepts, 75 seconds were given. The participants could decide when to pass from one word to another.

### **Data Collection**

Throughout the application, first the pre-service teachers who had completed the general physics and general chemistry courses were determined. Then the WAT was administered to the selected pre-service teachers. By evaluating the pre-service teachers' responses to the WAT, their perceptions of the concept of atom were determined. Following the WAT administration, the pre-service teachers started to take the modern physics course. Within the context of the modern physics course, they revised the topics of atomic structure and atomic models. After the completion of the modern physics course, it was attempted to determine whether the pre-service teachers' perceptions of the concept of atom had changed. In the second stage of the study, the WAT was re-administered to investigate the effect of the modern physics course on the participants' perceptions and then the change in their perceptions was explored.

### **Data Analysis**

First, the propositions written by the pre-service teachers for all the key concepts were examined. The propositions written by the pre-service teachers were evaluated as correct / wrong. Then, on the basis of the pre-service teachers' responses, the mind maps related to the concept of atom were prepared. While preparing the mind maps, the pre-service teachers' responses were subjected to content analysis. What was done within the context of the content analysis was to gather similar data under certain concepts or themes and then to interpret these concepts and themes at the



level that is comprehensible to readers (Yıldırım & Şimşek, 2013). After the similar responses given by the pre-service teachers were gathered together and analyzed, a frequency table was formed. The words that were responded to with similar meanings were classified according to their repetition frequency. In this table, the responses' repetition frequencies were checked. Depending on these frequencies, mind maps were elicited. The quantity and quality of the words associated with the key concept are used to determine the extent to which the key concept has been understood. The number of the response words is one of the methods most commonly used in the interpretation process of the data of this technique (Ercan et al., 2010). While establishing mind maps, the "Cut Point (CP)" technique proposed by Bahar et al. (1999) and used in many studies in the literature (Ercan, et al., 2010; Özatlı & Bahar, 2010; Işıklı, Taşdere & Göz, 2011; Atabek Yiğit, 2016) was employed. The CP technique; instead of complicated schemes, presents more comprehensible relationships between factors in the process of determination of mind maps. For this reason, it is a considerably enlightening technique (Bahar et al., 1999).

In order to determine whether the modern physics course taken by the pre-service teachers had affected the pre-service teachers' perceptions of the concept of atom, the mind maps prepared "before the modern physics course" (BMPC) and "after the modern physics course" (AMPC) were compared.

## Findings

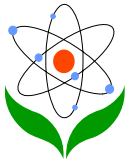
In this section, the findings derived from the pre-service teachers' responses to the WAT are examined.

### Findings related to propositions written by the pre-service teachers for the key concepts

The frequencies of the correct propositions written by the pre-service teachers for the key concepts and the frequencies of all the propositions written by them for the key concepts are given in Table 1.

**Table 1.** The Number of the Response Words Written for the Key Concepts

No.	Validity (V)	
	BMPC	AMPC
	Correct propositions/all the propositions	Correct propositions/all the propositions



Atom	29 / 45	26 / 37
Nucleus	16 / 31	26 / 37
Electron	19 / 24	17 / 24
Proton	11 / 20	11 / 18
Neutron	4 / 17	7 / 9
Orbit	9 / 23	11 / 17
Spin	13 / 21	10 / 13
Orbital	12 / 17	7 / 11
Quark	4 / 11	6 / 9
<b>Total</b>	<b>117 / 209</b>	<b>115 / 161</b>

As can be seen in Table 1, the pre-service teachers wrote a total of 209 propositions for the nine key concepts related to atom in the WAT before they took the general physics and chemistry courses and 117 of these propositions (55.98%) are correct. It is also seen that a total of 161 propositions were written for the nine concepts in the WAT after they had taken the modern physics course and 115 of these propositions (71.43%) are correct.

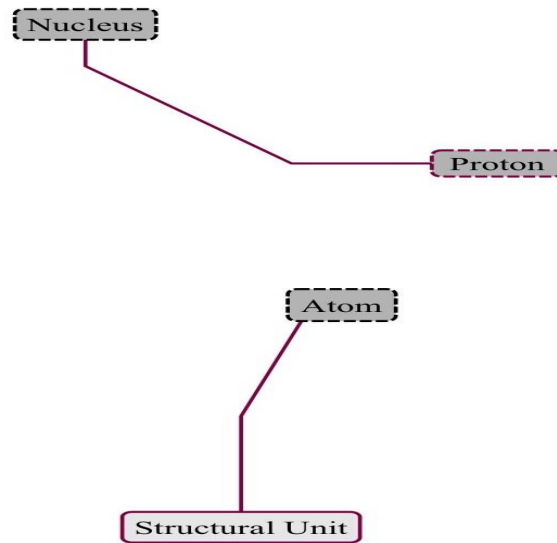
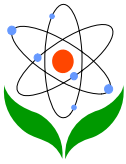
### **Findings related to the mind maps derived from the responses written by the pre-service teachers to the key concepts**

In this section, the findings obtained from the mind maps prepared as a result of the content analysis applied to the propositions written by the pre-service teachers for the nine key concepts in the WAT are presented.

*The mind maps showing the effect of the general physics and chemistry courses on the pre-service teachers' perceptions of atom*

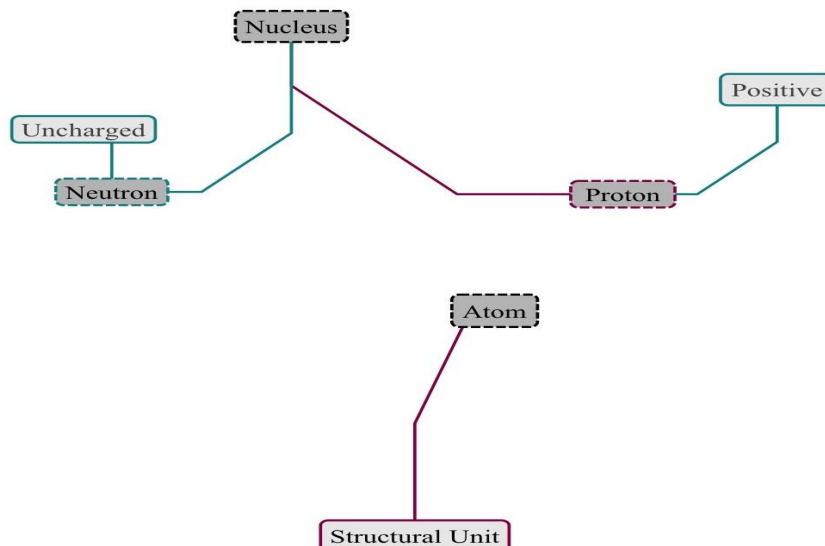
In this section, the BMPC mind maps showing the pre-service teachers' perceptions of the concept of atom after they took the general physics and chemistry courses are listed according to the cut point rule.





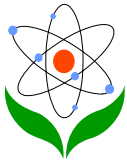
**Figure 1.** For CP 50 and Above, The Pre-service Science Teachers' BMPC Mind Map

For CP 50 and above, the pre-service teachers' BMPC mind map is shown in Figure 1. For CP 50 and above, it is seen that the pre-service teachers most frequently defined the key concept of "Atom" as the structural unit and associated the key concept of "Nucleus" with the concept of "Proton".

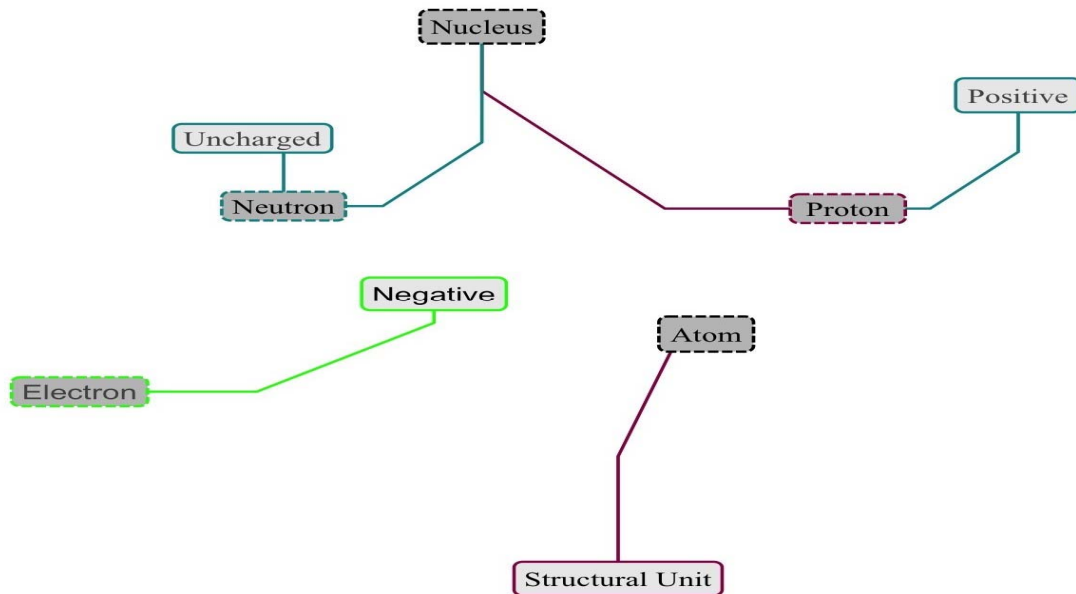


**Figure 2.** For CP 49 – 45, the Pre-service Science Teachers' BMPC Mind Map

For CP 49-45, the pre-service teachers' BMPC mind map is shown in Figure 2. It is seen that the number of key concepts and associations did not increase for CP 49-45.

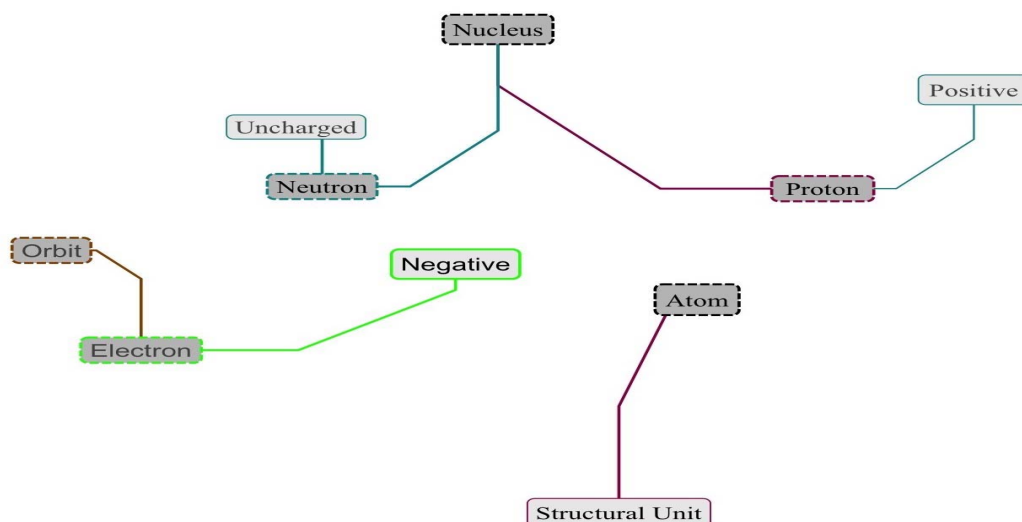


The pre-service teachers associated the key concept of “Nucleus” with the concept of “Neutron” in this CP. Moreover, they associated the key concept of “Neutron” with the response word “uncharged” and the key concept of “Proton” with the response word “positive”.

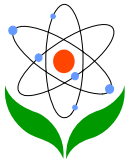


**Figure 3.** For CP 44-40, the Pre-service Science Teachers' BMPC Mind Map

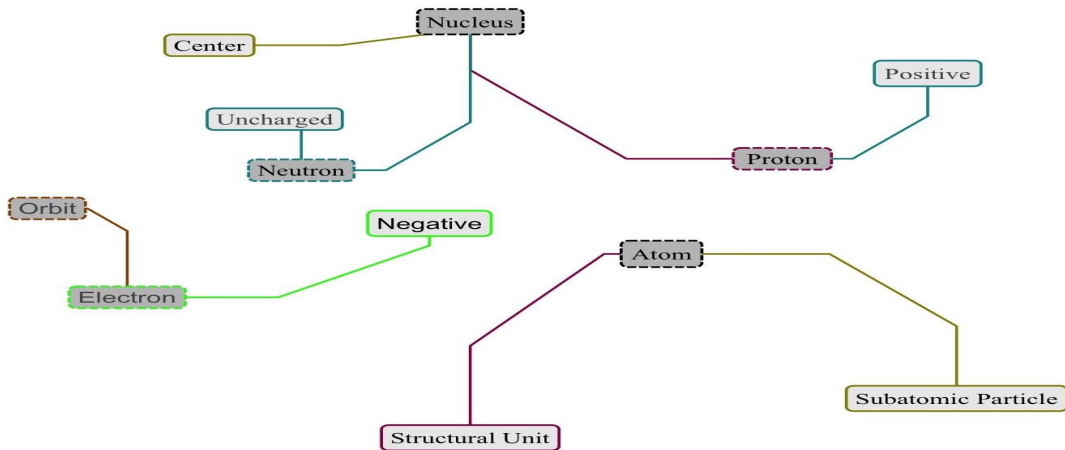
For CP 44 – 40, the pre-service teachers' BMPC mind map is shown in Figure 3. In CP 40 – 44, it is seen that the key concept of “Electron” emerged and the pre-service teachers associated this key concept with the response word of “negative”.



**Figure 4.** For CP 39 – 35, the Pre-service Science Teachers' BMPC Mind Map

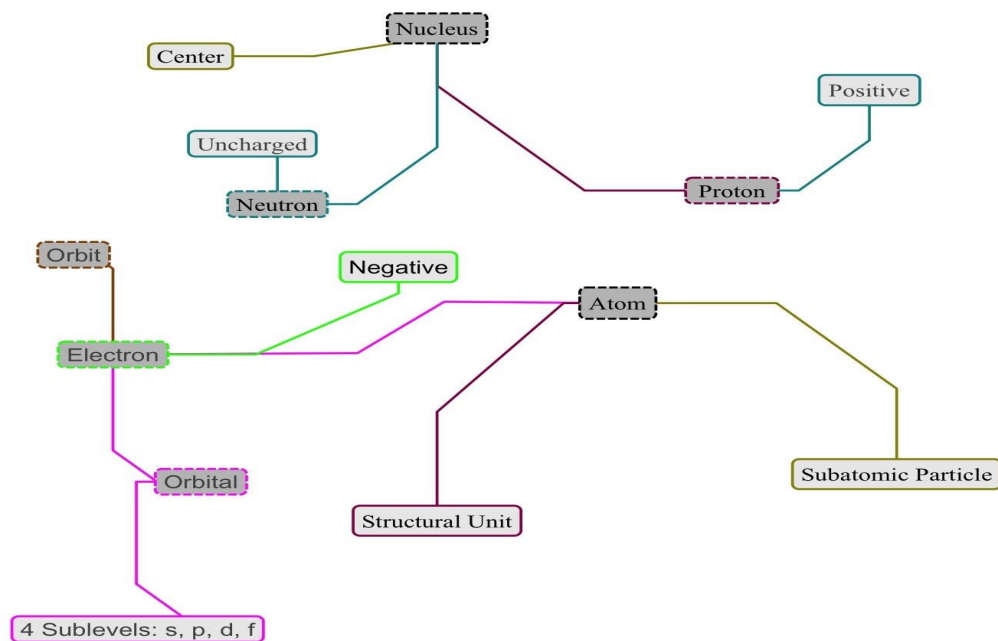


For CP 39 – 35, the pre-service teachers' BMPC mind map is shown in Figure 4. In CP 39 – 35, the pre-service teachers only associated the key concept of “Orbit” with the key concept of “Electron”.

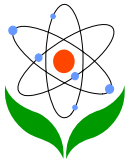


**Figure 5.** For CP 34 – 30, the Pre-service Science Teachers' BMPC Mind Map

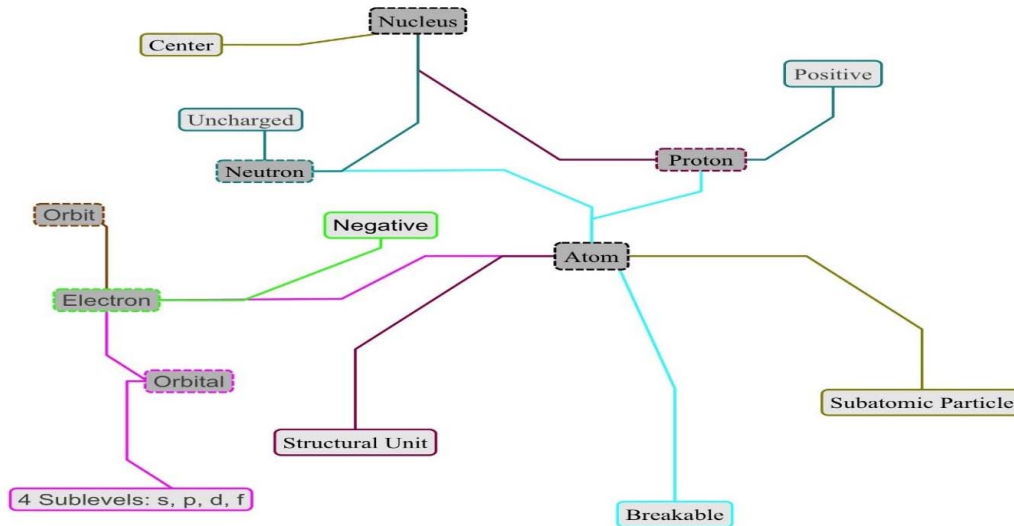
For CP 34 – 30, the pre-service teachers' BMPC mind map is shown in Figure 5. In CP 34-30, the pre-service teachers associated the key concepts of “Atom” and “Nucleus” with the response words of “subatomic particle” and “center”, respectively.



**Figure 6.** For CP 29 – 25, the Pre-service Science Teachers' BMPC Mind Map

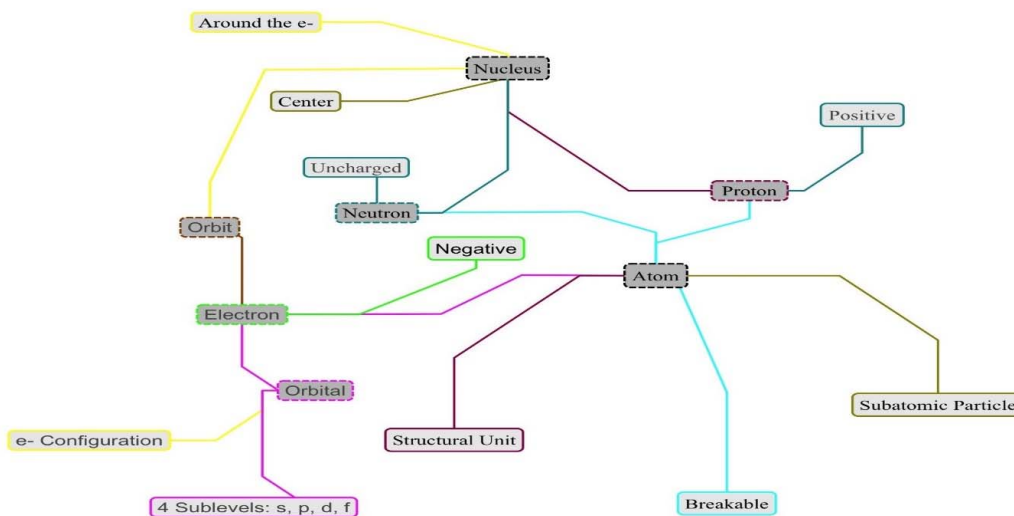


For CP 29 – 25, the pre-service teachers' BMPC mind map is shown in Figure 6. For CP 29 – 25, the pre-service teachers associated the key concept of “Electron” with the key concepts of “Atom” and “Orbital”. Moreover, it was also found that the pre-service science teachers made some explanations about the varieties of the key concept of “Orbital”.

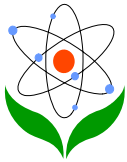


**Figure 7.** For CP 24 – 20, the Pre-service Science Teachers' BMPC Mind Map

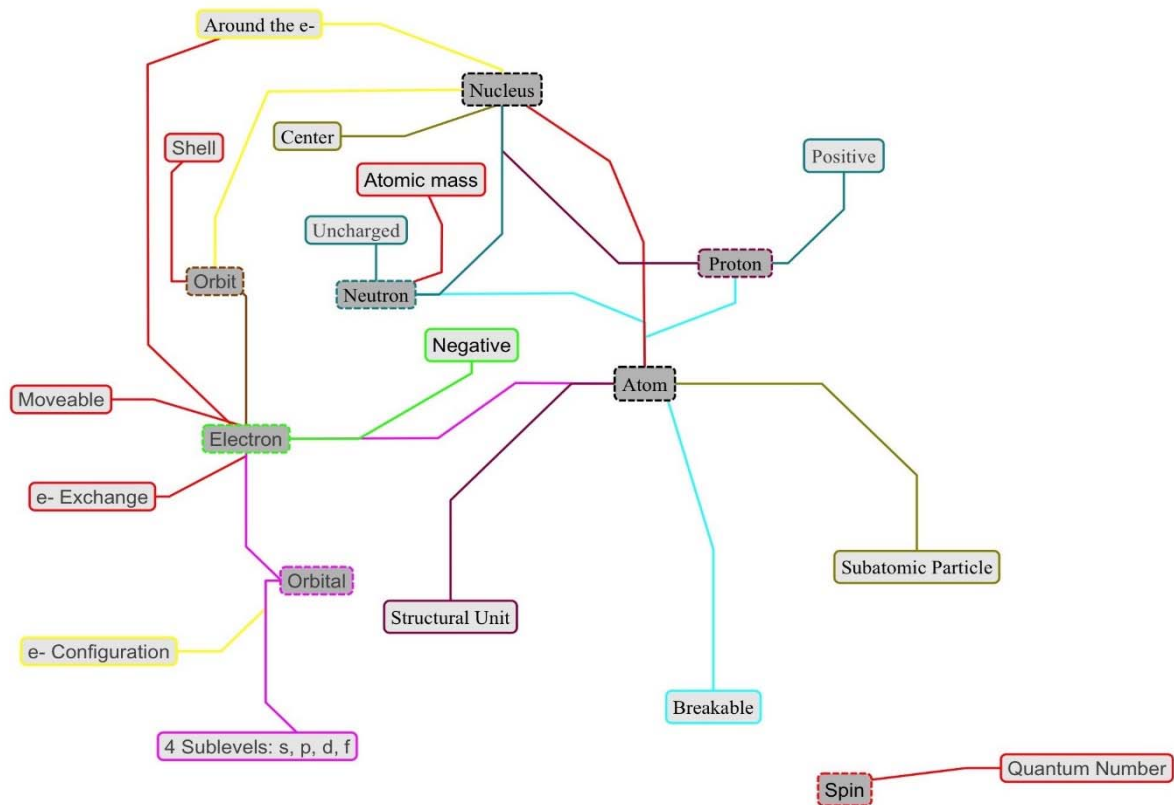
For CP 24 – 20, the pre-service teachers' BMPC mind map is shown in Figure 7. In CP 24 – 20, it is seen that the pre-service teachers associated the key concepts of “Neutron” and “Proton” with the key concept of “Atom” and they also associated the concept of “Atom” with the response word of “breakable” which is a feature of the concept of atom.



**Figure 8.** For CP 19 – 15, the Pre-service Science Teachers' BMPC Mind Map

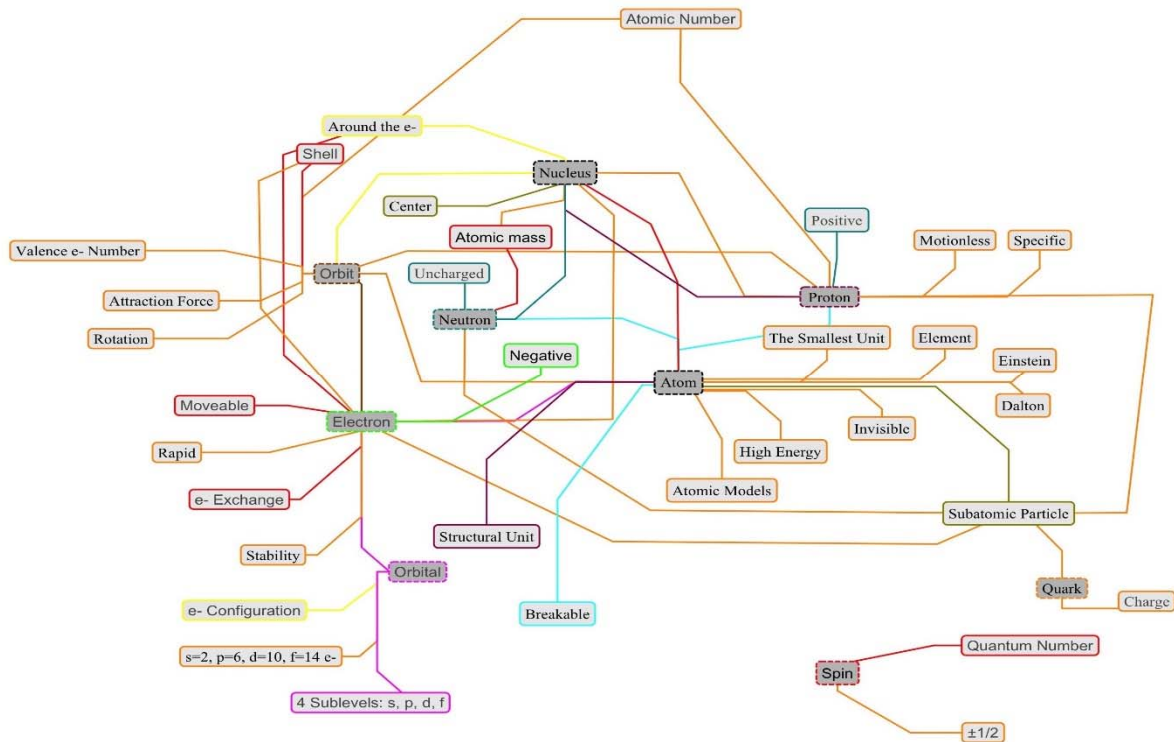
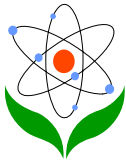


For CP 19 – 15, the pre-service teachers' BMPC mind map is shown in Figure 8. In CP 19 – 15, it was determined that the pre-service teachers associated the key concept of “Nucleus” with the key concept of “Orbit”. In this CP, the pre-service teachers were found to associate the features of both the key concept of “Nucleus” and the concept of “Orbital” with various response words.



**Figure 9.** For CP 14 – 10, the Pre-service Science Teachers' BMPC Mind Map

For CP 14 – 10, the pre-service science teachers' BMPC mind map is shown in Figure 9. In CP 14 – 10, the pre-service teachers associated the key concept of “Atom” with the key concept of “Nucleus”. In this CP, it is seen that the associations concerning the key concept of “Electron” are more than the other key concepts. Moreover, the key concept of “Spin” first emerged in this CP and it was associated with the response word of “quantum number”.

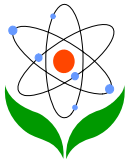


**Figure 10.** For CP 9 – 5, the Pre-service Science Teachers' BMPC Mind Map

For CP 9 – 5, the pre-service teachers' BMPC mind map is shown in Figure 10. In CP 9 – 5, it is seen that several characteristics belonging to all the key concepts were associated with various response words. Moreover, when the related mind map is examined, it is seen that the key concept of “Quark” emerged in this CP. It was determined that all the key concepts were somehow associated with each other or response words indicating their characteristics. Yet, it is seen that the key concept of “Spin” was not associated with the other key concepts. In a similar manner, it is seen that the key concepts related to the atomic models are not in the mind map.

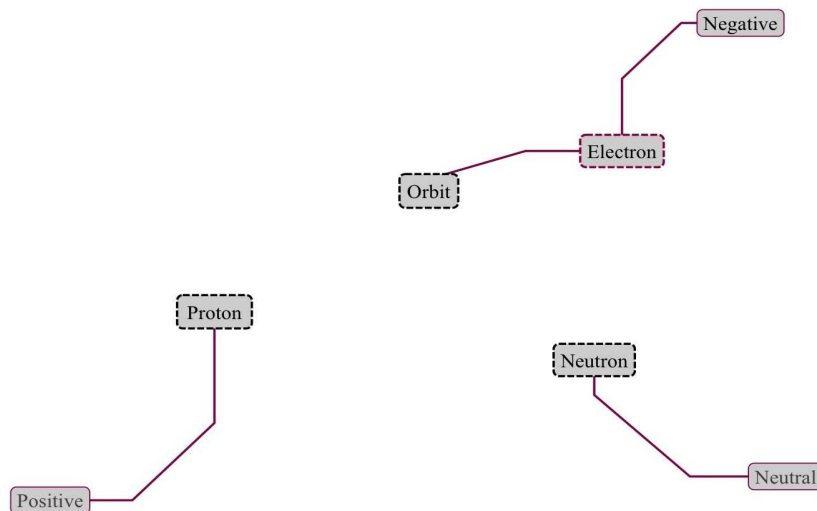
*Mind maps showing the effect of the modern physics course on the pre-service teachers' perceptions of atom*

Following the administration of the WAT, the pre-service teachers started to take the modern physics course. It was aimed in the current study to determine whether the modern physics course had changed the pre-service teachers' perceptions of the concept of atom. To this end, the participants were administered the WAT once more after they completed the modern physics course. In this section, the mind maps showing the pre-service teachers' perceptions of the concept of atom after they had taken the modern physics course are listed according to the CP technique.



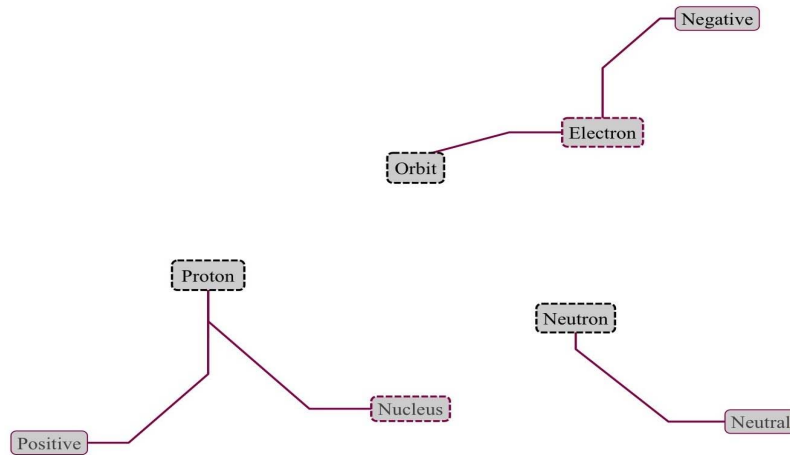
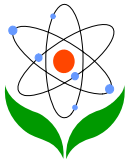
**Figure 11.** For CP 50 and above, the Pre-service Science Teachers' AMPC Mind Map

For CP 50 and above, the pre-service teachers' mind map is shown in Figure 11. For CP 50 and above, it is seen that the pre-service teachers only associated the key concepts of "Orbit" and "Electron" with each other.



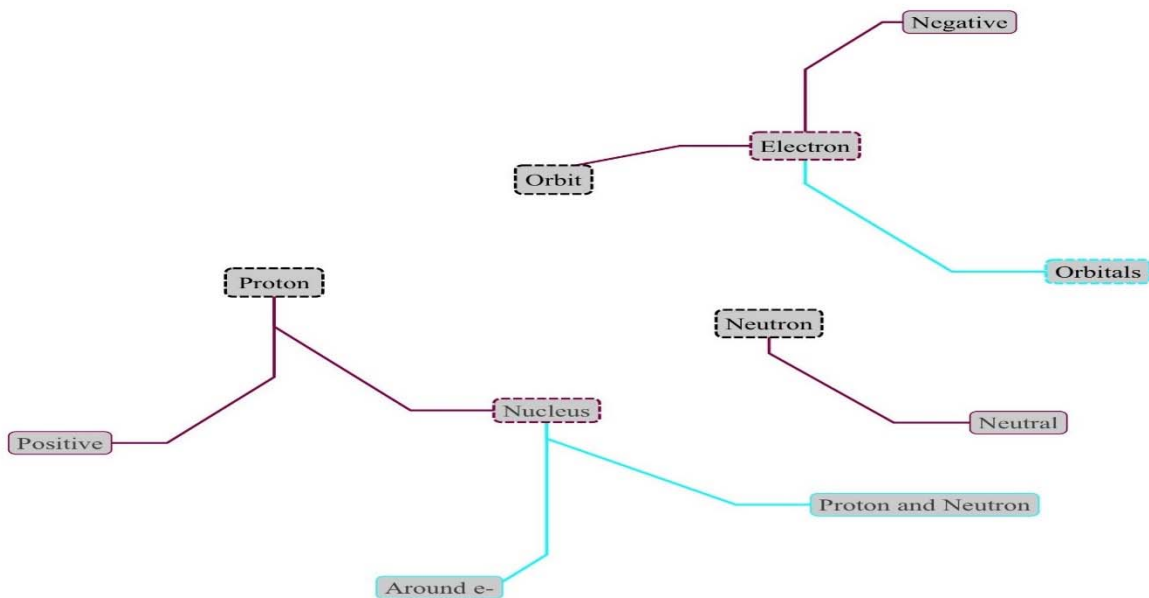
**Figure 12.** For CP 49 – 45, the Pre-service Science Teachers' AMPC Mind Map

For CP 49 – 45, the pre-service teachers' AMPC mind map is shown in Figure 12. In CP 45 – 49, the key concepts of "Proton" and "Neutron" emerged in the pre-service teachers' mind map. Moreover, the pre-service teachers associated concepts with the response words related to their charge in this CP.



**Figure 13.** For CP 44 – 40, the Pre-service Science Teachers' AMPC Mind Map

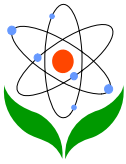
For CP 44 – 40, the pre-service teachers' AMPC mind map is shown in Figure 13. In CP 40 – 44, it is seen that the pre-service teachers only associated the key concept of "Nucleus" with the key concept of "Proton".



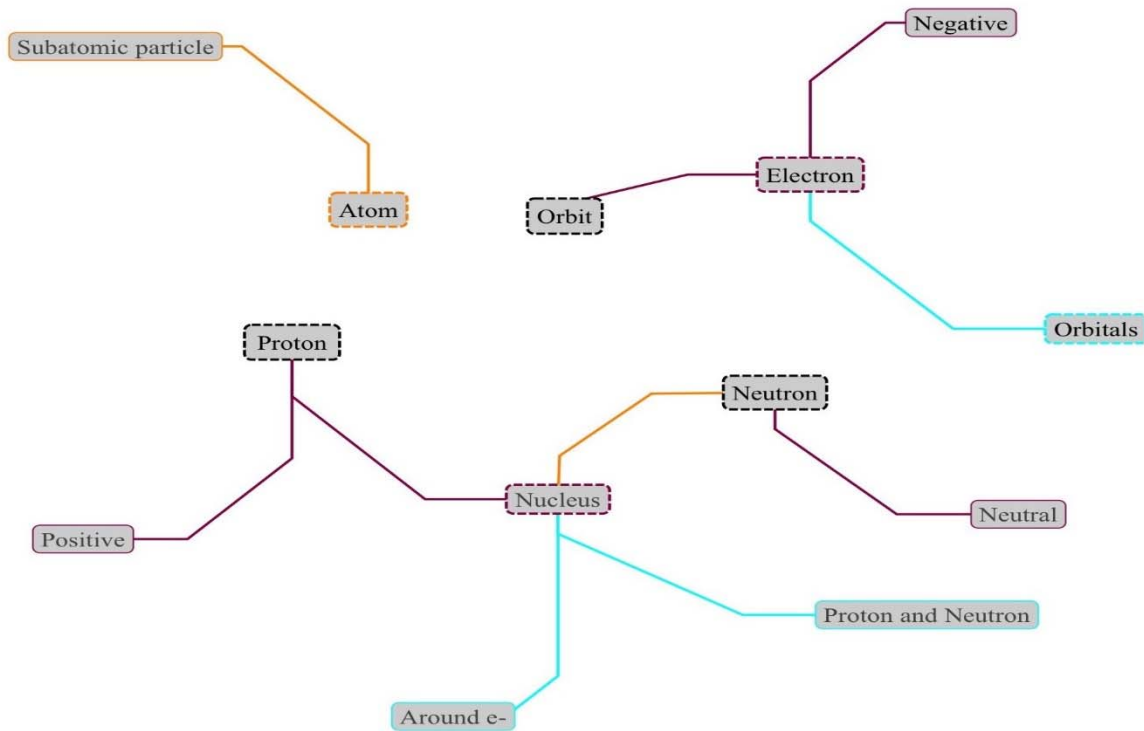
**Figure 14.** For CP 39 – 35, the Pre-service Science Teachers' AMPC Mind Map

For CP 39 – 35, the pre-service teachers' AMPC mind map is shown in Figure 14. In CP 39 – 35, it is seen that the pre-service teachers associated the key concept of "Orbital" with the key concept of "Electron". Moreover, they associated the key



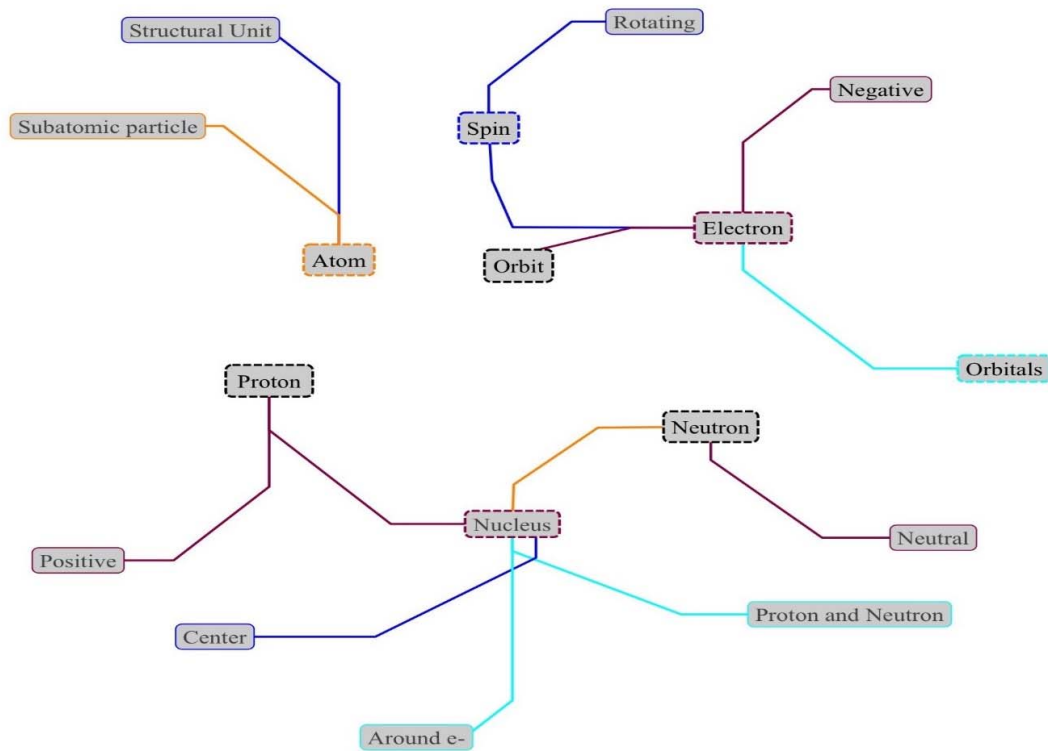
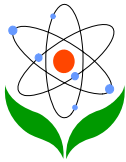


concept of “Nucleus” with the response words related to the characteristics of its structure.



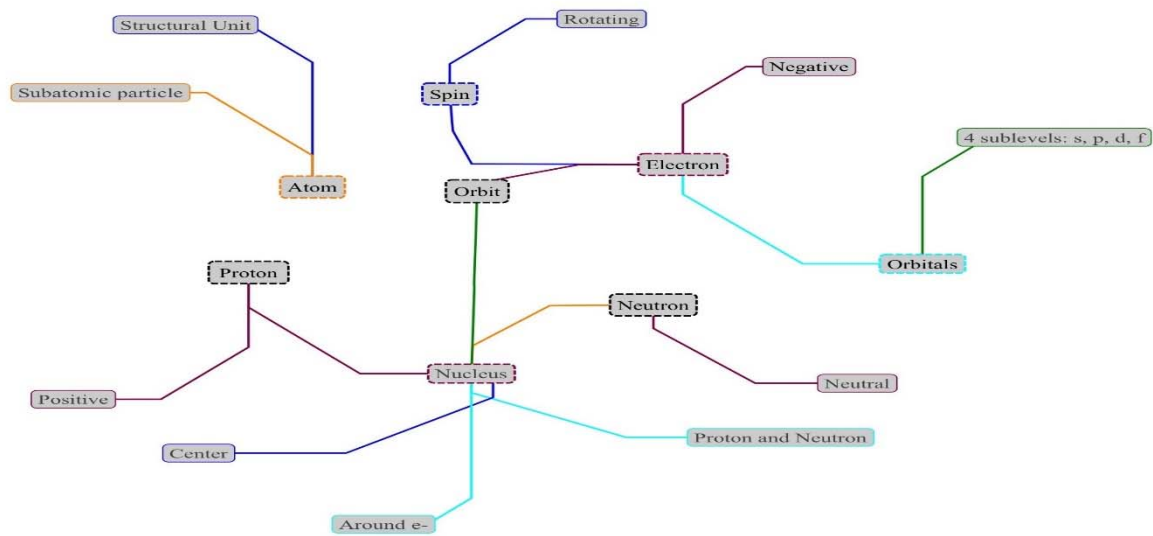
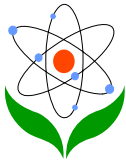
**Figure 15.** For CP 34 – 30, the Pre-service Science Teachers' AMPC Mind Map

For CP 34 – 30, the pre-service teachers' AMPC mind map is shown in Figure 15. In CP 34 – 30, the pre-service teachers associated the key concept of “Nucleus” with the key concept of “Neutron”. Moreover, in this CP, it is seen that the key concept of “Atom” emerged. The key concept of “Atom” was associated with the response word of “Sub-atomic particle”.



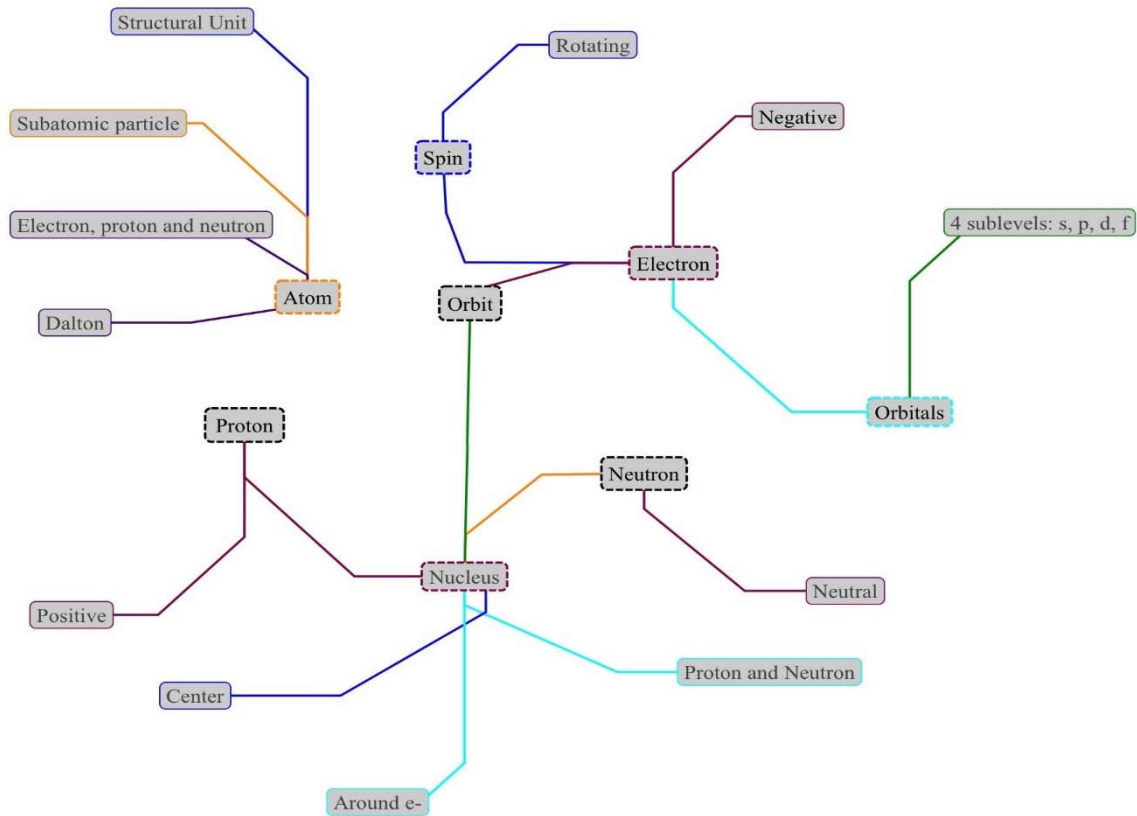
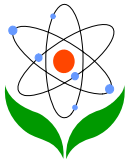
**Figure 16.** For CP 29 – 25, the Pre-Service Science Teachers' AMPC Mind Map

For CP 29 – 25, the pre-service teachers' AMPC mind map is shown in Figure 16. In CP 29 – 25, the pre-service teachers associated the key concept of “Nucleus” with the response word “center” and the key concept word of “Atom” with the response word “structural unit”. Moreover, the key concept of “Spin” emerged in this CP. It is seen that the key concept of “Spin” was associated with the key concept of “Electron” and the response word “rotating”.



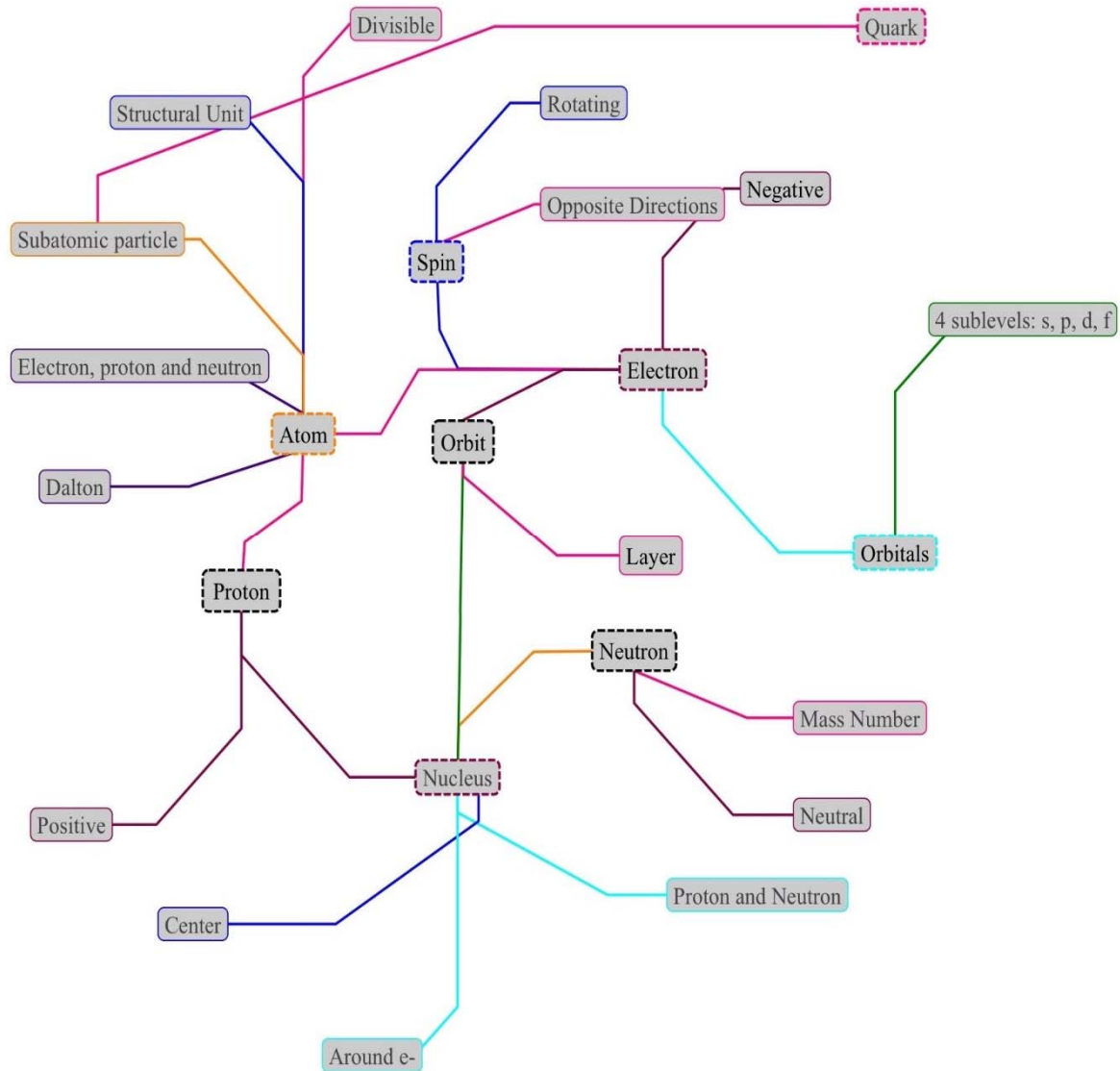
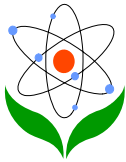
**Figure 17.** For CP 24 – 20, the Pre-service Science Teachers' AMPC Mind Map

For CP 24 – 20, the pre-service teachers' AMPC mind map is shown in Figure 17. In CP 24 – 20, it is seen that the pre-service teachers associated the key concept of "Orbit" with the key concept of "Nucleus" and the key concept of "Orbital" with the kinds of orbital.



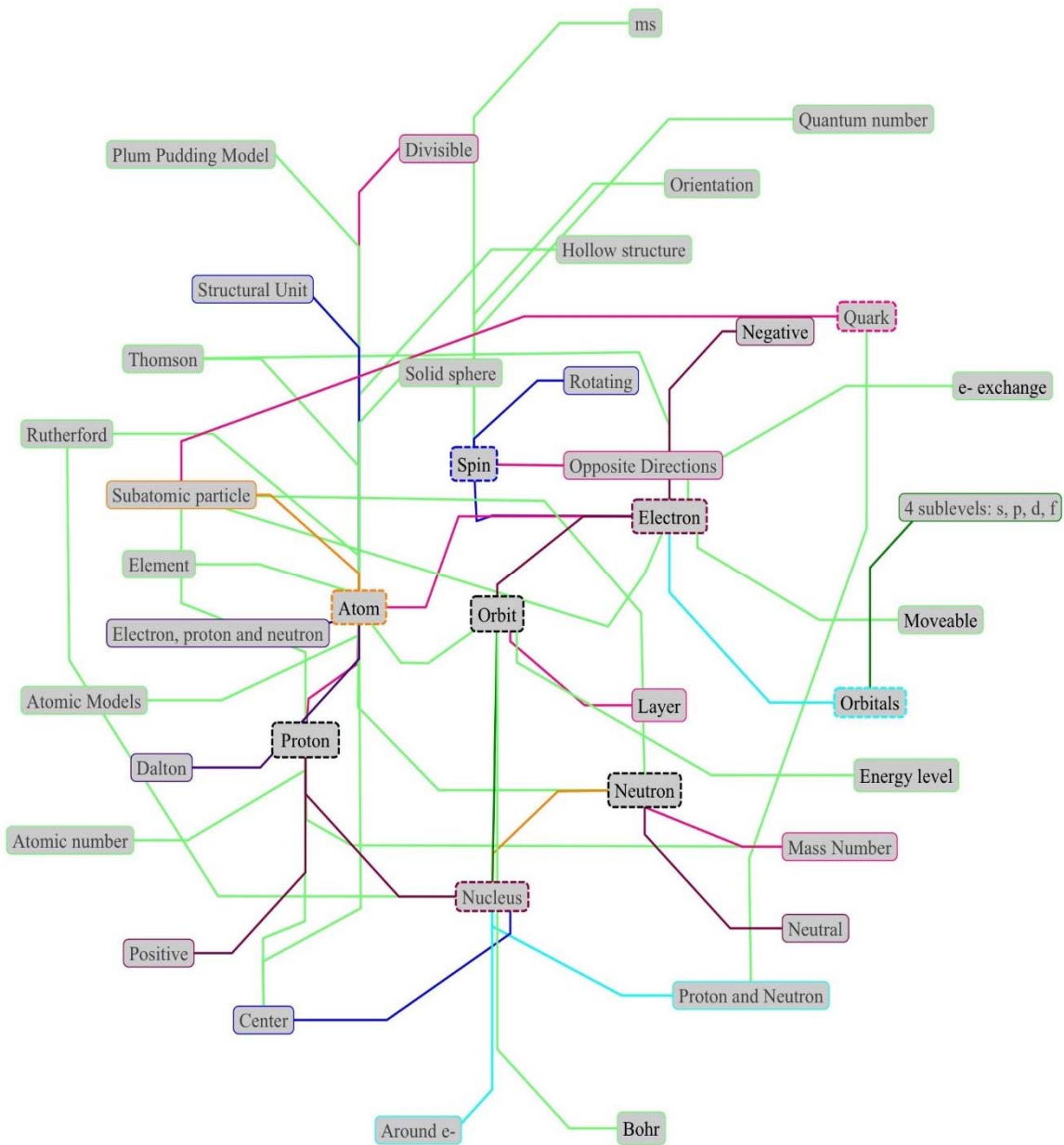
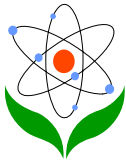
**Figure 18.** For CP 19 – 15, the Pre-service Science Teachers' AMPC Mind Map

For CP 19 – 15, the pre-service teachers' AMPC mind map is shown in Figure 18. In CP 19 – 15, it is seen that the pre-service teachers associated the key concept of “Atom” with different response words. Unlike the other mind maps, in this CP, it was determined that an atomic model was associated as the response word.



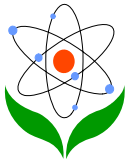
**Figure 19.** For CP 14 – 10, the Pre-service Science Teachers' AMPC Mind Map

For CP 14 – 10, the pre-service teachers' AMPC mind map is shown in Figure 19. In CP 14 – 10, it is seen that the key concept of “Quark” emerged. The key concept of “Quark” was associated with the response word “sub-atomic particle”. In this CP, it was determined that the key concept of “Atom” was associated with the key concepts of “Electron” and “Proton”. In this CP, the pre-service teachers associated the key concept of “Orbit” with the response word “layer” and the key concept of “Neutron” with the response word “mass number”.



**Figure 20.** For CP 9 – 5, the Pre-service Science Teachers' AMPC Mind Map

For CP 9 – 5, the pre-service teachers' AMPC mind map is shown in Figure 20. In CP 9 – 5, it was determined that all the key concepts were associated with each other and with various response words indicating the characteristics of these concepts. In the mind map produced in this CP, it is seen that all of the atom models were used as the response words.



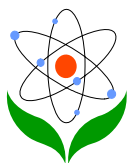
## Results

On the basis of the findings of the current study, it was attempted to determine the pre-service teachers' perceptions of atom. In this process, the WAT was used to determine how the concept of atom was associated with the related concepts. As it is an interdisciplinary subject, the subject of "Atom and Atomic Structure" is studied within the context of general physics and general chemistry courses during the undergraduate education but it is also studied in high school physics and chemistry classes. Moreover, the participants of the current study take the modern physics course after they have completed the general physics and chemistry courses. In the modern physics course, the students study the subject of "Atom and Atomic Structure" once more. Thus, the students are expected to have correctly learned the concepts related to atom and to establish correct relationships between the concepts. As can be seen in Table 1, of the prepositions produced by the students after that had taken the general physics and chemistry courses, 55.98% are correct. This means that nearly half of the prepositions produced by the students are wrong. On the other hand, of the prepositions written by the same students after they had taken the modern physics course, 71.43% were found to be correct.

As can be seen in Table 1, the number of correct prepositions written for the key concepts of "Electron" and "Orbital" decreased after the students had taken the modern physics course. On the other hand, the numbers of the correct prepositions written for the key concepts of "Orbit, Spin, Quark, Proton, Nucleus, Neutron and Atom" increased after the modern physics course.

When the pre-service teachers' mind maps are examined, it is seen that in CP 50 and above, first the key concept of "Atom" was associated with the response word "structural unit". Furthermore, in this CP, the pre-service teachers were found to have established an association between the key concepts of "Proton" and "Nucleus". In the mind maps produced after they had taken the modern physics course, in the same CP, the pre-service teachers associated the key concepts of "Electron" and "Orbit".

When the mind maps produced in CP 49-45, CP 44-40 and CP 39-35 were examined, it was concluded that the pre-service teachers associated the key concepts of "Nucleus, Electron, Proton and Neutron". While the pre-service teachers associated these concepts with each other, they also used "charge and location" that are their basic characteristics. In the first mind maps of the pre-service teachers, it was determined that they first associated the concept of "Atom" with the response word "structural unit". After the completion of the modern physics course, it was found that the pre-service teachers used the key concept of "Atom" in CP 34-30. In the



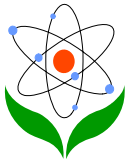
mind maps constructed after the completion of the modern physics course, the key concept of “Orbital” was first associated with the key concept of “Electron” in CP 44-40. In the first mind maps, the key concept of “Orbital” first emerged in CP 29-25. With decreasing CP, it is seen that the pre-service teachers combined the concepts of “Atom, Nucleus, Electron and Proton” in the relationships they established and expressed characteristics belonging to these key concepts. The key concept of “Quark” emerged in BMPC mind maps in CP 9-5 and after they had taken the modern physics course, it was seen in CP 14-10. It was also observed that in the first mind maps of the pre-service teachers, atomic models were not included yet after the completion of the modern physics course, atomic models and their characteristics were expressed in CP 9-5.

## Discussions and Interpretation

In the current study, it was revealed that the pre-service teachers wrote fewer propositions after they had taken the modern physics course; yet, the ratio of the correct propositions increased. This might indicate that in the understanding of the concepts involved in the subject “Atom and Atomic Structure”, modern physics courses are effective. The reasons for the low ratio of the correct prepositions might be the superficial knowledge of the pre-service teachers about the subject of “Atom and Atomic Structure”. At the beginning of the term, students’ superficial learning should be determined and then the required precautions should be taken to prevent them from being permanent.

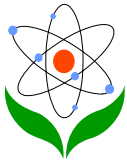
The subject of “Atom and Atomic Structure” includes many abstract concepts. When the pre-service teachers’ mind maps were examined, it was seen that the pre-service teachers associated the concepts with each other; yet, they could not express the relationships correctly. It has been revealed that the pre-service teachers have some mislearnings and misconceptions on the subject of “Atom and Atomic Structure”. This finding concurs with the findings reported by Ercan et al. (2010), Kurt et al. (2013) and Aydemir (2014) in the literature. By developing new methods and using alternative methods, “meaningful and deep learning” and “information network” should be able to be measured with correct techniques (Ercan et al., 2010). The use of analogies in the teaching of abstract concepts such as atom, molecule and chemical bond can make it easier for students to understand and perceive these concepts (Harrison & Treagust, 2000). This shows that the use of analogies during the instructional process may help students learn concepts correctly.





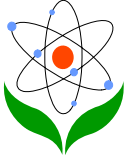
As a result of the current study, it was found that while the number of correct prepositions written for the key concepts of “Electron” and “Orbit” was decreasing, the number of the correct prepositions written for some key concepts such as “Spin, Quark, Neutron and Nucleus” increased. This might indicate that the pre-service teachers' perceptions of some special concepts related to the subject of “Atom and Atomic Structure” such as “Spin, Quark” developed after they had taken the modern physics course. It was also found that the pre-service teachers attempted to write more prepositions for the concepts of “Electron, Proton, Neutron and Nucleus”, which had been known by the pre-service teachers from elementary school, yet their prepositions were wrong to a great extent. This might indicate that the pre-service teachers associated the concepts they knew more easily but they did not correctly perceive even these concepts.

When the results related to the pre-service teachers' mind maps were examined, the first association seen was between the key concept of “Atom” and “structural unit”. This is believed to be a result of the fact that the pre-service teachers have been taught with the textbooks defining atom as the building block since elementary school (Akyol, 2009) and in the curriculum, atom is defined as the structural unit (MEB, 2013). Similarly, Niaz (1998) and Justi & Gilbert, (2000) stated that students' misunderstandings about the key aspects of the quantum mechanics model of atom result from the figures and explanations given in textbooks about atomic models. Tsapalis & Papaphotis (2009) argue that in the atom models in students' minds, the most commonly encountered model is the Bohr atomic model and this can be because this model is widely included in curriculums and textbooks. Moreover, the pre-service teachers' association of Proton with the Nucleus might be because of the atom weight calculations frequently used in general chemistry courses. In the mind maps prepared after the completion of the modern physics course, it is remarkable that the pre-service teachers established the relationship between “Electron” and “Orbit”. This might be an indicator of the pre-service teachers' attempt to locate the electron in their minds while constructing a model for the atom. Studies in the literature conducted at different age levels (Özmen, 2005; Akyol, 2009; Tsapalis & Papaphotis 2009; Çökelez & Yalçın, 2012; Yaseen & Akaygün, 2016) show that the atomic model in the individuals' minds is generally the Bohr Atomic Model. The model showing that there is an electron at an orbit around the nucleus is an indication of individuals' effort to locate the electron.



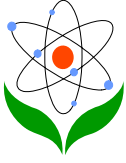
In their mind maps, the pre-service teachers first included the concept of “Nucleus” in their expressions of the atomic models. This is believed to be because of the importance attached to nucleus in the teaching of atomic models as of the elementary education. Moreover, the pre-service teachers were determined to be able to establish the structures making up atom such as electron, proton and neutron and the relationships related to their charges. This might be the result of the calculations made by using the charges of particles in chemistry and physics courses. In light of the mind maps derived from the findings of the current study, it was concluded that the general chemistry and physics courses had constructed the perception of structural unit in relation to the concept of atom in the students. After the completion of the modern physics course, the concept of atom created the perception of subatomic particles. In a similar manner, in the mind maps generated after the modern physics course, the concepts of electron and orbital were associated earlier. This is believed to be because the modern physics course taught the micro world. This might indicate that modern physics classes introduce students to the micro world and create the perception of the breakability of atom in students. After getting introduced to the micro world, it is seen that instead of orbit, the students started to use orbital to locate the electron. This might be because the students started to perceive the thinking style unique to the quantum world (Şen, 2002) and the relative nature of modern physics.

In their study, Eryılmaz & Ucer (2018a, b) found that the secondary school students stated that they had gained their misunderstandings about atom in different courses and from different teachers. From elementary education, abstract concepts that students experience difficulty in understanding at every level of education should be corrected and students' knowledge about science concepts should be determined in different courses before starting the course. However, learning continues without detecting the prior knowledge of students and without correcting their misinformation and misconceptions. This can also explain why most of the prior knowledge expressed by the pre-service teachers in the current study were wrong. As a result, the visuals used in textbooks to teach the concept of atom to students should be selected so that they can reflect the correct information about atom. Teachers should emphasize how scientific knowledge about atom has changed throughout the history of science. Students' prior knowledge should be determined at the beginning of the term and how permanent the learning occurring during the term should be tested at the end of the term by using various techniques such as WAT.

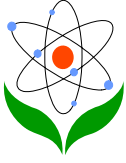


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