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Qualitative Evaluation of Prospective Science Teachers' Concept Maps about the Atom

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Abstract

Concept maps are used to assess and improve prospective teachers' conceptual understanding levels. In this research, the aim was to describe prospective science teachers' conceptual understanding of the atom by using concept maps. The research employed the case study approach, one of the qualitative research patterns. The research group consisted of 15 fourth-year prospective science teachers. The concept maps drawn by the participants were used to describe their conceptual understanding of the atom. For data analysis, the descriptive analysis method, one of the qualitative analysis methods, was used. The data obtained from the concept maps were divided into the categories previously defined by the researcher. The created categories were evaluated by two academics with expertise in physics education, and a correspondence analysis was conducted. As a result of the research, it was concluded that prospective teachers could establish successful and meaningful propositions in concept maps, however, most of the propositions were collected in the categories of "meaningless," "improvable," or "acceptable."

Keywords: Atom, Concept Map, Conceptual Understanding, Qualitative Analysis, Physics Education

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INTRODUCTION

Science education aims to bring up scientifically literate individuals. Determination and evaluation of students' cognitive structures constitute a significant characteristic of science literacy (Bybee, 1996). It is important to reveal students' knowledge levels to achieve meaningful learning in science education (Robertson, 1994). The development of meaningful learning is realized via the restructuring of the present conceptual frameworks (Regis, Albertazzi, & Roletto, 1996). For meaningful learning, students should associate newly-learned concepts with previously-learned ones and be given the chance to build their own understanding of the topic (Enger, 1998). Research shows that there are rich, important associations among scientific concepts (Novak J. D., 1998; Novak & Gowin, 1984; Novak, Gowin, & Johansen, 1983; Novak & Ridley, 1988). Concept maps, which were developed as a research instrument in the 1970s, are used by thousands of teachers worldwide, who adapt them to various subjects to facilitate students' understanding of the concepts. In this technique, students are requested to link the concepts in a field and to explain the relationships between them. Concept maps are among the cognitive maps designed to determine students' knowledge of a subject. Through the synthesis of concepts, they reflect students' knowledge and conceptual understanding of a subject. For this reason, structures such as concept maps, which schematize knowledge, are useful for science education (Wandersee, 1994).

Concept maps are the teaching materials that can be developed for various purposes, such as evaluating the knowledge of an individual or a group about a subject, developing new ideas, revealing complicated ideas, sharing information, or explaining the purposes of a certain subject (Cornwell, 1996; Siau & Tan, 2008). Concept maps enable meaningful learning as they require students to analyze their own knowledge and organize the concepts and relationships among them in a structured way. Besides being used in the learning and teaching process, concept maps can also be used to evaluate students' knowledge levels (Bauman, 2018).

Moreover, the accuracy of students' knowledge and the complexity of the knowledge structures formed in their minds can be found out by examining their concept maps. Scientific concepts and propositions, the relationships among them, and the degree of conceptual unity can be revealed through concept maps (Wandersee, 1994). Additionally, students' misconceptions and the relationships they establish between irrelevant concepts can easily be revealed by concept maps. In this regard, concept maps are used as an instrument in achieving meaningful learning, evaluating and planning the teaching process, finding alternative concepts, or exploring students' misconceptions (Cheema & Mirza, 2013; Enger, 1998; Nesbit & Adesope, 2006; Novak & Cañas, 2006; Novak J. D., 1980).

The most significant characteristic distinguishing concept maps from many other graphic organizers is their use for both increasing meaningful learning as an educational strategy and evaluating the conceptual understanding as an assessment instrument. It is the optimum evaluation instrument in which students freely express exactly what they know, without referring to any source. Following an average of 4-5 hours of training on how to create concept maps, students' conceptual understanding of a subject can be assessed very easily. Before teachers use the concept maps as an evaluation instrument, they should create concept maps together with students for at least 3-4 weeks, depending on the students' levels. Doing so will increase the reliability and validity of concept maps as an assessment and evaluation instrument (Kaya, 2003).

Considering the studies using concept maps as an evaluation instrument (McClure, Sonak, & Suen, 1999; McClure & Bell, 1990; Novak & Gowin, 1984; Ünlü, İlgeç, & Taşar, 2006), the difference in the scoring method draws attention due to the criteria related to the determination of the evaluation topics because concept maps can be used for both quantitative and qualitative evaluation (Williams, 1998). Kinchin, Hay, & Adams (2000), who used concept maps as a qualitative evaluation instrument, stated that concept maps as an instrument could be used to determine students' knowledge levels as well as to guide future learning processes.

As with the evaluation process, the ways to create and use concept maps are quite diverse (Williams, 1998). Some researchers such as Novak & Gowin (1984), who pioneered concept mapping, think that a concept map should have a hierarchical structure, whereas other researchers such as Harnisch, Sato, Zheng, Yamagi, & Connell (1994) believe that it should have a structure like a spider web in which there is a concept in the center and relationships are established with the surrounding concepts. In the development of concept maps, the technique "fill in the blanks in the drawn map," which is a highly guiding technique, or the technique "draw a map from scratch," which is a less-guiding technique, can be used. In their study, Ruiz-Primo, Schultz, Li, & Shavelson (2001) discussed these two different techniques and concluded that the technique "draw a map from scratch" reflected the difference between students' knowledge structures more effectively. Besides, concept maps, which can be prepared by students individually, can help students acquire a strong grasp of the subject being taught as well as develop high-order thinking skills such as problem-solving skills (Eden, 1988).

Purpose

The mapping process is "a self-learning experience" as the creation of a concept map requires students to define the relationships between concepts (Jacobs-Lawson & Hershey, 2002). Concept maps present an image of how the basic concepts in a field are organized and structured in a person's mind. The image of the scientific concepts in a prospective science teacher's mind is of great importance for the correct teaching of the subjects to students. It is, therefore, important for each prospective science teacher to learn the scientific concepts properly and to express the relationships between the concepts accurately. In the study, the concept maps were developed based on the "draw a map from scratch" technique. The atom, which is one of the basic concepts of both physics and chemistry, was selected as the subject of concept maps since it is not only an interdisciplinary concept but also frequently used in daily life. Hence, it is important to reveal how prospective teachers organize the concept of the atom in their minds. The study was carried out to qualitatively evaluate the concept maps developed by prospective science teachers about the atom. Furthermore, it was aimed to identify the structural mistakes that were made while developing the concept maps.

METHOD

In this qualitative research, which was conducted to determine prospective teachers' conceptual understanding of the atom by means of concept maps, the integrated single-case pattern from case study methods was used. A case study seeks to investigate the detailed results through the in-depth examination of a case. A case study is also a way of seeing what is actually happening in the environment, systematically collecting and analyzing data, and presenting the results. The output of case studies is the proper demonstration of why the case happened in the way it happened and what future research should focus on (Aytaçlı, 2012; Davey, 1991). In this research, this pattern was employed to describe prospective science teachers' conceptual understanding of the atom.

Study Group

The research was conducted with the participation of 15 fourth-year prospective science teachers attending a state university. To create the study group, the criterion sampling method, which is one of the purposive sampling methods, was used. The purposive sampling enables the selection of appropriate cases depending on the purpose of the study and the execution of in-depth research (Büyüköztürk, Çakmak, Akgün, Karadeniz, & Demirel, 2016). Criterion sampling is the creation of the sampling units by the researcher in line with a series of pre-defined criteria (Baş & Akturan, 2017). While determining the study group, the following criterion was established: having taken all the physics and chemistry courses covering the subjects related to the atom. Prior to the research, the participants were informed about the subject and the process of the study. Moreover, the participating prospective teachers were asked to consent to the use of their concept maps as research documents.

Data Collection Tool and Implementation

As the data collection tool, the concept maps developed by the participating prospective teachers were used. Firstly, prospective teachers were informed about concept maps. Afterward, a sample concept map was developed together with the participants. Then, the participants were divided into groups, and each group was requested to develop a concept map about physics. Once it was determined that they were able to develop concept maps, they were asked to create their own concept maps about the atom. Finally, the concept maps were separately examined to obtain data for the research.

Data Analysis

When the data collected by means of concept maps are subjected to quantitative analysis alone, numerical findings such as the number of concepts or of connections come to the fore. Doing so, in turn, minimizes the importance of the content of concept maps. To eliminate this problem, the present study employed the descriptive analysis method, one of the qualitative data analysis methods, to analyze the data obtained from concept maps. Descriptive analysis is the summarization and interpretation of the data obtained in a study according to the predefined themes (Yıldırım & Şimşek, 2016). Each concept map was separately examined. First of all, all the propositions in the concept maps were scientifically evaluated under four main categories: "successful," "acceptable," "improvable," and "meaningless." Two criteria were taken into consideration while the categories were created. The first criterion was whether the proposition was scientifically correct. When trying to interpret a proposition in a concept map, one needs to read first the concept at end of the arrow, then the concept at the tip of the arrow, and consequently the relationship between the two. The second criterion in the evaluation process was whether the proposition was structurally in compliance with the rule of establishing a proposition. The main categories used in the research are as follows:

Successful: The proposition is scientifically correct and complies with the rule of establishing a proposition in the concept map.

Acceptable: The proposition contains incomplete scientific knowledge and complies with the rule of establishing a proposition in the concept map.

Improvable: The proposition is scientifically incomplete/incorrect due to the incorrectly directed arrow.

Meaningless: The proposition is scientifically incorrect regardless of the direction of the arrow.

First, all of the propositions established by the participants were categorized regardless of their frequencies. Then, percentage and frequency analyses were performed for each category. Then, the propositions in each category were divided into three sub-categories (the atom," "the structure of the atom" and "atomic models"), and the frequency of the categorized propositions was determined. In this way, it was tried to determine the participants' incomplete knowledge about both the atom and the creation of concept maps.

After the propositions were categorized, the propositions in each category were reviewed in detail. In each category, the propositions related to the atom, the propositions related to the particles that comprise the structure of the atom, and the propositions related to the atomic models were examined by considering their frequency values. Besides, the hierarchies of the concept maps were taken into consideration while the propositions in the "acceptable" category were examined. The hierarchical connections of the propositions, which were meaningless alone but gained meaning with hierarchy, were included.

RESULTS

This section is devoted to the assessment of the findings obtained from the concept maps. First, the propositions were categorized without taking their frequency into account, and the number of propositions was determined. Percentage and frequency analyses were performed for each category. Percentage and frequency values of the propositions according to categories are given in Table 1.

Table 1. Percentage and frequency values of the propositions according to categories

Category	f	%	Sample proposition
Successful	25	26	*The nucleus is in the atom.
Acceptable	15	15.5	*Grape cake is a model.
Improvable	15	15.5	*The atom developed the Thomson model.
Meaningless	42	43	*Bohr proposed the modern atomic model.
Total	97	100	

When Table 1 is examined, it is seen that 97 different propositions were established by the participants. While categorizing the propositions, the propositions expressing scientifically correct information (e.g., “The nucleus is in the atom”) were gathered in the category of “successful” propositions. It was observed that 26% of the propositions were in the “successful” category. If the propositions contained incomplete scientific knowledge, they were included in the category of “acceptable” propositions. For example, the proposition “Grape cake is a model” was included in this category. Not the grape cake but the plum pudding is an analogy for Thomson’s atomic model (Han & Goldstein, 2013; Hentschel, 2009; Harrison & Treagust, 1996). However, in some coursebooks, this analogy is stated as the grape cake model (Karagöz & Sağlam Arslan, 2012). Hence, such propositions were not considered incorrect because the hierarchy was considered acceptable. As a result, 15.5% of the propositions were evaluated in the “acceptable” category. During the examination of the concept maps, some incorrectly linked terms (misdirected arrows) and, as a result, incorrect or meaningless expressions also emerged. It was thought that if the participants had learned how to use the concept mapping technique properly, a meaningful and successful proposition would have been established. Therefore, such propositions were evaluated in the “improvable” category. The propositions in the “improvable” category were those that contained scientifically correct information but failed to link the terms correctly. For example, the proposition “The atom developed the Thomson model” is meaningless, however, if the direction had been correctly indicated by the arrow, the proposition “Thomson developed an atomic model” would have been established successfully. 15.5% of the propositions were collected in the “improvable” category. On the other hand, 43% of the propositions were scientifically incorrect (e.g., “Bohr proposed the modern atomic model”). These propositions were collected in the “meaningless” category.

Examination of the successful propositions

This section is devoted to the examination of the successful propositions established by the participants. Firstly, the propositions were divided into three sub-categories: “the atom,” “the structure of the atom” and “atomic models.” Then, the frequency of the categorized propositions was determined. The successful propositions are shown in Table 2.

Table 2. Successful propositions and their frequency values

Category	Proposition	f
The Atom	An atom contains protons.	9
	An atom contains neutrons.	9
	An atom contains electrons.	10
	There are atomic models.	5
	An atom consists of subatomic particles.	1
	The modern atomic model contains an energy level.	1

The Structure of the Atom	The nucleus is in the atom.	6
	The nucleus is the center of the atom.	2
	The spin is in the electron.	1
	The electron is in the orbital.	2
	Three quarks form a neutron.	1
	Three quarks form a proton.	1
	Quark is one of the subatomic particles.	1
Atomic models	The modern atomic model is one of the atomic models.	1
	Bohr proposed an atomic model.	4
	Rutherford proposed an atomic model.	5
	Dalton proposed an atomic model.	6
	Dalton's atomic model is similar to the solid sphere.	9
	Thomson proposed an atomic model.	6
	Thomson's atomic model is similar to a grape cake.	13
	The modern atomic theory contains the term "spin."	1
	The modern atomic theory contains the term "quark."	1
	Heisenberg articulated the uncertainty principle for the first time.	11
	Pauli articulated the exclusion principle for the first time.	10
	Schrödinger developed the wave equation.	9
Total	25	125

When Table 2 is examined, it is seen that 25 propositions are collected in the category of "successful" propositions. A majority of the propositions that fell under the sub-category of "the atom" were related to the parts of the atom: electrons, protons, and neutrons. Six participants said in their propositions that the nucleus was in the structure of the atom, and two mentioned the position of the nucleus in the atom. Besides, it was discovered that the participants established propositions related to the historical development of the atomic models. When the propositions about the historical development of the atomic models are reviewed, it is seen that 13 participants expressed an analogy for Thomson's atomic model, and nine mentioned an analogy for Dalton's atomic model. It was determined that only one of the successful propositions was related to the modern atomic model. Also, when Table 2 is examined, it is seen that the participants established propositions about Heisenberg's uncertainty principle, Pauli's exclusion principle, and Schrödinger's wave equation, but they did not include any information about these principles in their propositions. Finally, only one participant said that quarks make up protons and neutrons.

Examination of the acceptable propositions

This section is devoted to the examination of the acceptable propositions. When examining the propositions in this category, the hierarchies of the concept maps were taken into consideration. The propositions, which were meaningless on their own but gained meaning through hierarchies, were also evaluated in this category. As with the successful propositions, the acceptable propositions were also divided into three sub-categories: "the atom," "the structure of the atom" and "atomic models." The frequency and hierarchies of the categorized propositions were determined. Acceptable propositions and their frequency values are given in Table 3.

Table 3. Acceptable propositions and their frequency values

Category	Proposition	f	Position in the concept map
The Atom	An atom is a filled sphere.	1	Dalton proposed an atomic model.
	An atom consists of protons.	2	
	An atom consists of neutrons.	2	
	An atom consists of electrons.	2	
	An atom is divided into orbitals.	1	Bohr proposed an atomic model.
The Structure of the Atom	An atom consists of a nucleus.	1	
	The nucleus consists of protons.	1	An atom consists of a nucleus.
	The nucleus consists of neutrons.	1	An atom consists of a nucleus.
	The nucleus is a subatomic particle.	1	An atom consists of subatomic particles.
	The orbital is the energy level.	2	The electron circulates in the orbital.
	The electron circulates in the orbital.	5	The orbital is the energy level.

Atomic models	The grape cake is an atomic model.	1	
	The orbital performs a spin motion.	1	The spin is in the electron.
	Pauli dealt with the atom.	1	Pauli articulated the exclusion principle for the first time.
	Heisenberg dealt with the atom.	2	Heisenberg articulated the uncertainty principle for the first time.
Total	15	24	

When Table 3 is examined, it is seen that 15 of the propositions are collected in the category of “acceptable” propositions. For example, a participant established the proposition “An atom is a filled sphere.” Atom is not a filled sphere; however, Dalton described the atom as a filled sphere when the history of the atomic models is reviewed. In the same hierarchy, the participant correctly proposed that “Dalton proposed an atomic model.” As it complements the aforementioned proposition, the proposition “An atom is a filled sphere” was evaluated in the “acceptable” category.

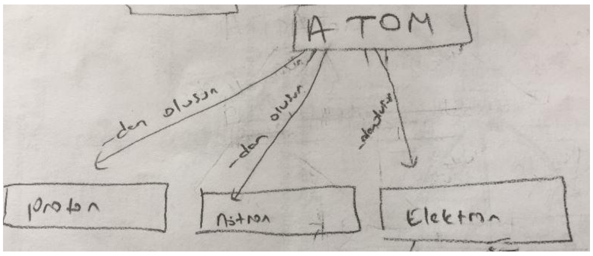

Figure 1. A sample concept map by Student 1

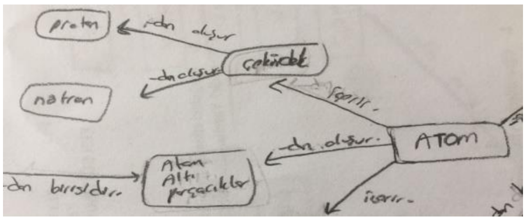

Figure 2. A sample concept map by Student 14

The propositions “An atom consists of protons,” “An atom consists of neutrons,” and “An atom consists of electrons” stated in Table 3 are not scientifically correct or successful. However, when the related concept map is examined in Figure 1, it is seen that the participant did not think the atom consisted of only protons, only neutrons, or only electrons. On the contrary, the participant tried to express that an atom includes all those in its structure. For this reason, these propositions were evaluated in the “acceptable” category. Similarly, the proposition “An atom consists of a nucleus” is not scientifically correct. Also, when the concept map in Figure 2 is examined, it is seen that the participant used “the nucleus” in the following hierarchy, in the propositions “The nucleus consists of protons” and “The nucleus consists of neutrons”. This indicates that the participant did not think the nucleus consisted of only neutrons or only protons; it was just that the participant could not express the relationship correctly. Therefore, this proposition was evaluated in the category of “acceptable” propositions.

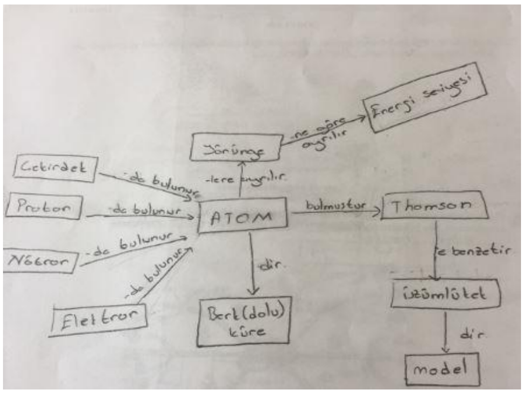

Figure 3. A sample concept map by Student 8

When Table 3 is examined, the acceptable propositions “An atom is divided into orbitals,” “The orbital is the energy level,” and “The electron circulates in the orbital” are seen. When Figure 3 is examined, it is seen that the propositions related to “Bohr’s atomic model” constitute the basis of these propositions. These propositions about Bohr’s atomic model were evaluated in the category of “acceptable” propositions. The propositions “Pauli dealt with the atom” and “Heisenberg dealt with the atom” were also evaluated in the category of “acceptable” propositions. When the concept maps were examined, it was discovered that the participants included in the hierarchy the propositions related to Pauli’s exclusion principle and Heisenberg’s uncertainty principle. This shows that the participants tried to express Pauli and Heisenberg’s studies on the atom.

As regards the proposition “The grape cake is an atomic model,” the grape cake is not an atomic model. The grape cake is an analogy for Thomson’s atomic model. However, the proposition gains meaning when it is evaluated together with the proposition related to Thomson’s atomic model. For this reason, the proposition was examined in the “acceptable” category. The proposition “The orbital performs a spin motion” was also included in the “acceptable” category. This proposition was supported by the proposition “The spin is in the electron.” It is obvious that the participant tried to establish a proposition related to the motion of the orbital by making use of the spin motion of the electron. This proposition, which was meaningless on its own, was evaluated as an acceptable proposition when examined together with the hierarchical structure.

Examination of the improvable propositions

This section is devoted to the examination of the improvable propositions. While the propositions in this category were being reviewed, care was taken to determine whether the proposition structurally complied with the rules of concept maps. As stated above, to interpret the propositions meaningfully in a concept map, one needs to read first the concept at end of the arrow, then the concept at the tip of the arrow, and consequently the relationship between the two. The propositions written by the participants by not complying with this rule were evaluated in the “improvable” category. These propositions were also divided into three sub-categories: “the atom,” “the structure of the atom,” and “atomic models.” The frequency of the categorized propositions and the propositions that would otherwise be correctly written if the direction had been correctly indicated by the arrow were determined. Improvable propositions and their frequency values are given in Table 4.

Table 4. Improvable propositions and their frequency values

Category	Proposition	f	The proposition that would have emerged if the direction had been correctly indicated by the arrow
The Atom and The Structure of the Atom	The atom is in the orbital.	2	The orbital is in the atom.
	The atom is in the structure of the nucleus.	3	The nucleus is in the structure of the atom.
	The atom is related to the orbital.	1	The orbital is a concept related to the atom.
	The nucleus is in the proton.	1	The proton is in the nucleus.
	The nucleus is in the neutron.	1	The neutron is in the nucleus.
	Energy levels are in the electron.	1	The electron is in the energy levels.
	The orbital is in the electron.	1	The electron is in the orbital.
	The atom is in the energy levels.	2	The energy levels are in the atom.
Atomic models	The atom developed the Bohr model.	6	Bohr developed an atomic model.
	The atom developed the Rutherford model.	5	Rutherford developed an atomic model.
	The atom developed the Dalton model.	5	Dalton developed an atomic model.
	The atom developed the Thomson model.	7	Thomson developed an atomic model.
	The atom conducted studies on Schrödinger.	7	Schrödinger conducted studies on the atom.
	The atom conducted studies on Pauli.	6	Pauli conducted studies on the atom.
	The atom conducted studies on Heisenberg.	6	Heisenberg conducted studies on the atom.
Total	15	54	

When Table 4 is examined, it is seen that 15 of the propositions are collected in the category of “improvable” propositions. For example, “The atom developed the Thomson model” is an “improvable” proposition. By reversing the direction of the arrow, the proposition can be made meaningful: “Thomson developed an atomic model.” It was found out that the propositions that fell under this category were mostly related to scientists investigating the atomic models. Five participants tried to establish propositions related to Dalton and Rutherford’s atomic models, six tried to establish propositions related to Bohr’s atomic model, and seven tried to establish propositions related to Thomson’s atomic model. When the propositions about the atomic models were reviewed, it was determined that they only contained information about the scientists who proposed these models. Besides, there were propositions related to the nucleus, protons, neutrons, and electrons, which constitute the atom and the structure of the atom. For instance, “The nucleus is in the proton” is an “improvable” proposition. When the direction of the arrow is reversed, this proposition can be made meaningful: “The proton is in the nucleus.” It is, therefore, possible to say that the corrected versions of the propositions related to the particles that comprise the atom and the structure of the atom are generally acceptable propositions.

In Table 4, it is observed that the participants established propositions about the studies laying the foundation of the modern atomic model. However, they were unable to go beyond associating the names of the scientists with their theories in these propositions. When the corrected version of the propositions in this category was examined, it was discovered that not all the propositions were correct and some propositions were in the “acceptable” category. Moreover, Table 4 shows that the participants failed to establish new proportions: those in the “successful” and “acceptable” categories were reiterated.

Examination of the meaningless proportions

This section is devoted to the examination of meaningless propositions. Regardless of whether the arrow indicated the correct direction, scientifically incorrect propositions were gathered in this category. The frequency of the categorized propositions was determined. The meaningless propositions and their frequency values are given in Table 5.

Table 5. Meaningless propositions and their frequency values

Category	Propositions	f
The Atom	The atom is a sub-proton particle.	1
	The atom is a sub-neutron particle.	1
	The atom is a sub-electron particle.	1
	The atom is a sub-quark particle.	1
	The atom determines/is related to the number of orbitals.	2
	The atom determines/is related to the number of quarks.	2
	The atom determines/is related to the number of spins.	2
	The atom determines the energy level	1
	The atom is among quark-related concepts.	2
	The atom is among spin-related concepts.	3
	There is the theory of the atom wave equation.	3
	There is the atom exclusion principle.	3
	There is the atom uncertainty principle.	3
	The atom is among energy level-related concepts.	1
The Structure of the Atom	There is the nucleus electron.	1
	The electron consists of quarks.	1
	The electron consists of orbitals.	1
	The orbital is in the spin.	1
	Rutherford discovered the spin.	1
	The proton is in the orbital.	2
	The spin represents the energy levels.	2
	The orbital performs a quark motion.	1
	The energy level indicates the number of atoms.	6
	The quark indicates the number of atoms.	3
	The spin indicates the number of atoms.	3
	The orbital indicates the number of atoms.	3
	The nucleus forms an atom.	1
Atomic Models	Bohr proposed the modern atomic model.	8
	Bohr's atomic model has the wave equation.	1
	Heisenberg proposed an atomic model.	2
	Rutherford proposed the modern atomic theory.	1
	Rutherford used the reference of a sphere.	1
	Dalton's atomic model resembles a grape cake.	1
	Thomson's atomic model resembles a sphere.	1
	Dalton examined the solid sphere.	1
	Pauli proposed an atomic model.	2
	Pauli uses the wave equation.	1
	Schrödinger proposed an atomic model.	3
	Rutherford studied the wave equation.	1
	The exclusion principle is in Schrödinger's model.	1
	Schrödinger proposed the modern atomic model.	2
	The orbital was found in Bohr's atomic model.	1
Total		42

When Table 5 is analyzed, it is seen that 42 of the propositions are collected in the category of "meaningless" propositions. Eight of the propositions were "Bohr proposed the modern atomic model," and six were "The energy level indicates the number of atoms." When the propositions in this category are reviewed, it is observed that they include concepts such as spin, orbital, quark, subatomic particles, wave equation, the uncertainty principle, and exclusion principle, which were difficult for the students to express.

CONCLUSION

In this study, the aim was to describe prospective science teachers' conceptual understanding of the atom with the help of concept maps. During the study, the concept maps were evaluated qualitatively, and the participants' ability to describe the atom was analyzed in depth. As a result of the study, it was observed that prospective science teachers were able to establish successful and meaningful propositions in concept maps. However, when Table 1 was reviewed, it was concluded that most of the propositions were in the categories of "meaningless," "improvable," or "acceptable" propositions. On the other hand, Table 2 demonstrates some successful propositions related to the basic particles forming an atom and the historical development of the atomic models. The participating prospective teachers used various concepts related to the modern atomic theory in their meaningful propositions. Still, it was concluded that the participants were unable to establish meaningful propositions regarding the modern atomic theory. When Table 3 consisting of propositions in the "acceptable" category was examined, it was seen that the participants had difficulty in expressing the relationships between the concepts, thus, they were unable to establish scientifically correct propositions. Furthermore, as observed in Figure 3, it was concluded that the participants tried to associate all the concepts with the main concept in the center and had difficulty in using the hierarchical structure of the concept maps. It is also one of the results of the research that the prospective teachers tried to mention various scientists and their studies but were unable to establish the correct relationship. It was concluded that some of the participants failed to correctly indicate the direction of the arrows in their concept maps and some had incomplete/incorrect information about the subject. Even when the improvable propositions were corrected (i.e., when the direction of the arrow was reversed), duplicate propositions were obtained, resulting in no increase in the number of meaningful propositions. When Table 5 was examined, it was concluded that the participants wrote plenty of meaningless propositions and used similar concepts in their propositions. In short, when the meaningless propositions in the concept maps are viewed, it is seen that prospective teachers do not have in-depth knowledge about the atom.

DISCUSSION

Concept maps are the structures that visualize the concepts in students' minds on a certain subject. They enable learners to build and describe the relationships between the concepts and the ideas easily. With these features, concept maps help students to express clearly what they have learned, to analyze and synthesize their ideas, and to understand the new concepts quickly and easily (Romero, Cazorla, & Buzón, 2017). As a result of this study, it was found out the participating prospective science teachers were able to mention an adequate number of propositions but failed to correctly indicate the relationships between the concepts. This result indicates that the concepts were already in prospective teachers' minds, however, they were unable to build correct relationships between them. In other words, the knowledge of most of the participants about the atom was not at a conceptual level.

An attempt was also made to qualitatively evaluate the concept maps and to determine the points the participants had difficulty with while creating the concept maps. As concept maps are graphic structures that are easy to understand, they allow for an overall assessment of students' knowledge as well as a determination of the deficiencies in the teaching process (Bauman, 2018). It was discovered that the participants could establish correct propositions about the historical development of the atomic models and the basic structures forming an atom, but they could not establish correct propositions related to the modern atomic theory. The purpose of concept maps is to visualize the relationships between the concepts. For this reason, the presence of gaps in the relationships in students' maps may point to the weaknesses of the teaching process, to which teachers should pay more attention. This shows that prospective teachers could establish propositions related to the atomic theories that they had started to learn from their elementary education onward, but they had difficulty in understanding and expressing new subjects.

In the study, it was seen that the participating prospective teachers could mention many concepts in their concept maps, however, they had difficulty in building a relationship between the concepts, that is, in establishing a proposition. This can be associated with a lack of conceptual understanding of the atom. Another reason for this may be the difficulties experienced by the students in the creation of concept maps. Turkish sentence structure that is different from English can also be shown as a reason for the difficulty experienced in creating propositions in concept maps (Bahar, 2001; Bağcı Kılıç, 2003; Ünlü, İlgeç, & Taşar, 2006). In English, the relationship between any two concepts can easily be written due to the English sentence structure (subject-verb-object). As can be inferred from Table 4, the students expressed many propositions incorrectly because they failed to indicate the direction of the arrows correctly.

For students to develop accurate concept maps, they first need to have sufficient knowledge related to the subject and create an accurate image of these concepts in their minds. In the traditional teaching method, definitions, explanations, and relevant examples are given in general, however, no relationships between concepts are mentioned (Burdina, 2015). Usually, relationships between concepts are presented with complementary activities such as concept maps. Concept maps are used to improve students' academic performance as they are required to actively participate in the learning process through classroom discussions, linking concepts, and eliminating misconceptions (Cheema & Mirza, 2013).

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