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THE USE OF ANALOGY FOR THE DETERMINATION OF PRE-SERVICE SCIENCE TEACHERS' COGNITIVE STRUCTURES ABOUT THE CONCEPT OF ATOM[i]

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Abstract:
Students try to understand many abstract concepts by using mental models they have created by thinking and imagining. Students must have a functional and dynamic atomic model in their minds in order to understand the atomic and atomic concepts. In this study; it was aimed to determine the models of science student candidates using the analogy of atomic concepts by using analogies. The study carried out in the spring semester of 2016 - 2017 academic year; 47 science teachers were involved with the undergraduate students studying in the second grade. In the study, it was desired to establish an analogy of the atomic concept and to explain this analogy in order to determine the atomic models in the minds of the prospective teachers. Subsequently, in the course of modern physics, the students were told about the atom and atom modeling, and they were asked to establish an analogy with the atomic concept. First of all, their characteristics were examined by analyzing the types of analogies, origin, relationship and similarity that teacher candidates established. Then the answers given by the teacher candidates were separated by categorized by qualitative analysis method and the frequency values were obtained. It has been determined that prospective teachers use daily information in their analogies and use concrete concepts to establish analogies. It is also seen that teacher candidates often try to establish similarities in their analogies in their constructs. Teacher candidates have established similarities in the

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analogies of atoms such as shape, orientation, disintegration. The analogies used by the prospective teachers initially represented Dalton, Thomson and Bohr atom models; and modern atomic theory, Bohr and Rutherford atomic models. It has been determined that the students do not represent any atomic model of the analogy established by the 7th modern physics lesson before 19th.

Keywords: atom, atom models, analogy, pre-service science teachers

1. Introduction

1.1 Analogy

Comparing is an act that is inherent in man. Individuals make comparisons to recognize similarities and differences between something they encounter and things they know. Analogies are links constructed between the similarities of concepts, principles and formulas. In other words, analogy is the bridge between the prior information and the new information (Harman & Çökelez, 2017; Kesercioğlu, Yılmaz, Huyugüzel Çavaş, & Çavaş, 2004). Transfer of information from an unknown area to a known area facilitates and accelerates the understanding (Wong, 1993). Analogies express individuals' thoughts and are important to understand how individuals learn (Mozzer & Justi, 2012). Therefore, by using analogies, we can obtain new information about individuals' opinions or change the existing information.

Studies in the bibliography on analogies usually focus on how analogies are used by teachers in class or their contribution to students' learning (Mozzer & Justi, 2012). Students can sometimes produce analogies themselves, but often use analogies created by teachers (Coll & Treagust, 2008).

Analogies have a positive effect on concept teaching, visualization of concepts, relating to daily life, conceptual understanding and conceptual change, identification and elimination of misconceptions, determination of the persistence of knowledge, organization of knowledge and creating links between pieces of information (Harman & Çökelez, 2017). For this reason, teachers, pre-service teachers and students' creating and using analogies are of great importance in terms of learning concepts, establishing relationships between concepts and organizing information. In the study by Wong (1993) analogies created by secondary school pre-service teachers from different disciplines were investigated and it was concluded that students create their analogies on the basis of their prior knowledge, conceptual changes can occur in their prior knowledge and analogies can be a tool to determine the model in the mind of the student. If students are asked to produce, use and modify their own analogies instead

of being given by others, this contributes positively to their explanation of scientific concepts and supports conceptual change (Cosgrove, 1995; Pittman, 1999; Mendonça, Justi, & de Oliveira, 2006; Mozzer & Justi, 2012). At the same time, with the help of analogies created by students, misconceptions in the minds of students can be detected (Wong, 1993). Such studies are important in terms of improving science teaching and concept teaching.

1.2 Purpose of the Study

Students try to understand many abstract concepts, using mental models they have created by thinking and imagining. Students must have a functional and dynamic atomic model in their minds to understand atom and concepts related to atom. In this study, students' analogy logic is taken as a creative process and it is aimed to determine the pre-service science teachers' models in their minds related to the concept of atom by using analogy.

2. Methods

In this study, the case study approach was used as the qualitative research design. The case study is a research method used to explore an up-to-date phenomenon in its natural environment where the border between the phenomenon and the context surrounding it is not clear and there is more than one evidence or data source (Yıldırım & Şimşek, 2016).

2.1 Sampling

The research was conducted with the participation of 47 undergraduate students studying in the second year of science teacher education in the spring semester of 2016-2017 academic year.

2.2 Data Collection

During the data collection process of the study, the students were asked to create an analogy related to the concept of atom to elicit the models in their minds and explain this analogy. Then the students were taught the subjects related to atom and atom models within the context of the modern physics course and they were asked again to create an analogy about the concept of atom.

2.3 Data Analysis

In the analysis of the research data, the answers given by the students to the questions were investigated by means of descriptive analysis; one of the qualitative analysis methods, and the results were interpreted on the basis of frequencies and percentages calculated.

In the analysis of the data obtained from the analogies created by the students, the students' responses were grouped under three categories that are "correct", "false" and "no response".

These categories are as follows;

- Correct: Responses including scientific information about any atom model are put into this category.
- False: Responses not related to any atom model or responses having no scientific value are collected in this category.
- No response: If students do not give any response or give a response such as "I do not remember", "I cannot explain" or "I do not know", then they are included in this group.

3. Findings

In this section, findings obtained from the research data are presented.

3.1. Investigation of the pre-service teachers' atom-related analogies

In this section, the analogies created by the pre-service teachers were examined in terms of their various features. In Table 1, the features and frequencies of the analogies created by the pre-service teachers on the basis of their prior knowledge can be seen.

Table 1: Examination of the pre-service teachers' analogies and prior knowledge

Analogy	Type[1]	Source[2]	Established connection	Similarity	f
Sphere	C	S.K	Fullness	It looks like some atom models	3
			Roundness	Similarity in form	3
Heart	C	S.K.	Veins surrounding the heart	It surrounds atom with orbits	1
Dot	C	D.I.	Smallness	Dimension	1
Raisin pie	C	D.I.	Fullness and grapes inside	Thomson atom model	4
Marble	C	D.I.	Round and stratified	Similarity in form in in textbooks	2
			Small and round	Similarity in form in in textbooks	1

Planets	C	D.I.	Planets make up systems and systems make up the galaxy	Subatomic particles make up the atom and atoms make up elements	1
Water melon	C	D.I.	It is full, round and it has seeds	It is in harmony with some atom models	1
Ball	C	D.I.	Round	Similarity in form	3
Universe	C	D.I.	The organization in its structure	Atom also has a regular structure	1
			Porous structure	There is emptiness inside atom	1
Galaxy	C	S.K.	Gravitational field in its center	The nucleus holds the power in order	1
			Planets around the sun	The nucleus in the center and electrons around it	2
World	C	S.K.	Iron nucleus in its center	Its nucleate structure	1
			It is made up of particles	Atom's being made up of particles	1
			Similarity in form	It is not full round	1
			World and ozone layer	Nucleus and strata	1
			It has orbits	Atom has also orbits around which it turns r	2
Apple and peach	C	D.I.	There is a nucleus in its center r	It nucleate structure ı	2
Orange	C	D.I.	It has a nucleus and shells	Its nucleate and stratified structure	1
Clock	C	D.I.	There are central and moving hour and minute hands	The nucleus turns around it at an orbit	2
Puzzle	C	D.I.	It has got parts	Meaningful as a whole	1
The brain of an organism	C	S.K.	The unit of processing	Structural unit of an element	1
Development of the fetus	C	D.I.	Like a development of baby	The smallest unit of the universe	1
Cell	C	S.K.	It is the smallest building unit of a human	The smallest structural element of the matter r	1
Teacher	C	D.I.	It constructs the structure of knowledge	It makes up the structure of an element	1
Gene	C	S.K.	Genes carry the characteristics of humans	It has the features of the matter	1
Hula hoop Turning girl	C	D.I.	It turns around a specific orbit	The nucleus is at the center and turns around a specific orbit	1
Matryoshka doll	C	D.I.	It breaks up and new parts emerge	It is made up of subatomic particles	1
Space	A	D.I.	It has a complex structure	The structure of atom	1

Space ship	C	D.I.	A ship around which objects are turning	Orbit	1
The Mall	C	D.I.	It includes different types of shops	It includes different particles	1
TOTAL					47

[1]C: Concrete, A: Abstract; [2]S.K.: Scientific knowledge, D.I.: Daily information

When Table 1 is examined, it is seen that 47 pre-service teachers created analogies and in general, these analogies are concrete and are based on everyday knowledge. When the connections established by the pre-service teachers are analyzed, it is seen that they have features such as fullness, emptiness, roundness, moving, orientation and having particles. When the similarities between the pre-service teachers' analogies and atom are examined, nucleus and orbit seem to be the part of the most analogies.

When the examples of analogies created by the pre-service teachers on the basis of their prior knowledge are examined, it is seen that they created different analogies such as "*Atom looks like a raising pie, its grapes are protons.*", "*Atom looks like a sphere, it is round and full.*", "*Atom looks like any form that is round because it is illustrated as round in textbooks.*", "*Atom looks like a marble, its internal side carries protons and neutrons and its outer surface carries electrons.*", "*Atom looks like the brain of an organism; the brain is the processing unit of the organism and atom is the processing unit of the matter.*", "*Atom looks like the world; there is a nucleus in the center and it is round like the world.*", "*Atom looks like a cell; the cell is the structural unit of the living organism and atom is the structural unit of the matter.*"

In Table 2, the features and frequencies of the analogies created by the pre-service teachers on the basis of the knowledge they have learned in the course of modern physics.

Table 2: Examination of the pre-service teachers' analogies

Analogy	**Type**	**Source**	**Established connection**	**Similarity**	**f**
Solar system	C	S.K.	The sun is in the center planets turns both around it and around themselves	The nucleus is in the center, they turn around it and around themselves	11
Sphere	C	S.K.	Its homogenous structure	Structural similarity	1
			Inside is empty and it is round	Similarity in form	4
			Fullness	Similarity with some atom models	1
Cloudy structure	C	D.I.	It does not have a certain shape	Similarity in form	3
The Mall	C	D.I.	It is made up of shops	It is made up of subatomic particles	2

Intersection and cars	C	D.I.	At an intersection,, cars turns according to a certain order	They turn around a nucleus in a certain order	1
Raising pie	C	D.I.	Grapes are scattered inside the cake	It is in harmony with atom models	1
Lego	C	D.I.	When parts come together, a meaningful whole appears	Elements make up components.	1
Sunflower	C	D.I.	In its center, there is a full nucleus, leaves are around it	It is in harmony with atom models	1
Ball	C	D.I.	It is round	Similarity in form	1
Hula-hoop	C	D.I.	It turns around a particular center	The nucleus is in the center and it turns around it	2
World	C	S.K.	It is made up of small basic structures	Subatomic particles make up atom	1
			There is a moon turning around it	The nucleus is in the center and it turns around it	2
Matryoshka doll	C	D.I.	It is stratified	There is a nucleus in strata and center	1
Egg	C	D.I.	Yolk is in the center surrounded by egg white	There is a nucleus in the center and there are orbitals around it r	1
Water melon	C	D.I.	Its nuclei are scattered	It is in harmony with atom models	1
Apple /peach	C	D.I.	There are seeds in their centers	There is a nucleus in the center ıf atom	3
Universe and planets	C	S.K.	Orbital movement	There is a nucleus in the center of atom and elements around it	1
Nothing	C	D.I.	Very small	Atom is the smallest structural unit of the matter	3
Merry-go-round	C	D.I.	It is fixed in the center, and there are toys turning around it	The nucleus is in the center and elements turn around it	1
TOTAL					43

[1]C: Concrete, A: Abstract; [2]S.K.: Scientific knowledge, D.I.: Daily information

It was determined that 43 of the pre-service teachers created analogies related to the concept of atom but 4 pre-service teachers did not. It is seen that most of the analogies created by the pre-service teachers are concrete and 23 of them are based on scientific knowledge and 20 are based on everyday knowledge. When the connections between atom and analogies are examined, it is seen that generally connections are established in relation to its being made up of nuclei, nucleate structure and size. In their analogies,

the pre-service teachers mostly include formal and structural similarities and some pre-service teachers referred to some atom models.

When the examples of the analogies created by the pre-service teachers were examined, it was found that they created various analogies such as *"Atom looks like a sphere, it is round."*, *"Atom looks like the solar system; in the solar system planets turns both around themselves and the sun in atoms, elements also turn at their orbits and around the nucleus."*, *"Atom looks like the sunflower; in its center is there the nucleus and inside it is full and the leaves are in the regions where electrons are likely located."*, *"Atom looks like an apple / a peach; in their centers is there the nucleus."*, *"Atom looks like a girl turning a hula-hoop, in its center is there the girl like the nucleus and the hula-hoop turning represents the orbital."*, *"Atom looks like a matryoshka doll, inside are there layers and in its center is there a nucleus."*

3.2. Determination of the atom models in the minds of the pre-service teachers by using their analogies of atom

In this section, the changes in the atom models in the minds of the pre-service teachers before and after the course of modern physics were analyzed on the basis of the analogies they created. The percentages and frequencies related to atom models referred by the analogies created by the pre-service teachers on the basis of their prior knowledge are presented in Table 3. The percentages and frequencies related to atom models expressed by the analogies constructed by the pre-service teachers after they had been instructed about atom and atom models within the context of the course of modern physics are given in Table 4.

Table 3: Percentages and frequencies related to atom models expressed by the analogies created by the pre-service teachers on the basis of their prior knowledge

Categories	Atom Model	f	%
Correct	Dalton Atom Model	7	15
	Thomson Atom Model	6	13
	Rutherford Atom Model	3	7
	Bohr Atom Model	10	22
	Modern Atom Model	2	5
False		19	41
No response		0	0
Total		47	100

As can be seen in Table 3, the analogies constructed by 41% of the pre-service teachers do not scientifically refer to any atom model. When the analogies created by the pre-service teachers are examined, it is seen that 22% of the atom models in their minds comply with the Bohr Atom Model, 15% with the Dalton Atom Model, 13% with the

Thomson Atom Model and 7% with the Rutherford Atom Model. Only 5% of the analogies were found to represent the modern atom theory.

Table 4: Percentages and frequencies related to atom models expressed by the analogies created by the pre-service teachers on the basis of the knowledge acquired in the course of modern physics

Categories	Atom Model	f	%
Correct	Dalton Atom Model	6	13
	Thomson Atom Model	2	5
	Rutherford Atom Model	6	13
	Bohr Atom Model	14	30
	Modern Atom Model	9	20
False		7	15
No response		4	9
Total		47	100

As can be seen in Table 4, 15% of the analogies created by the pre-service teachers do not refer to any atom model and 9% of the pre-service teachers did not respond. When the analogies of the pre-service teachers were examined, it was found that 20% of the atom models in their minds comply with the modern atom theory. Moreover, 30% of the analogies of the pre-service teachers comply with the Bohr Atom Model, 13% with the Dalton Atom Model, 13% with the Rutherford Atom Model and 5% with the Thomson Atom Model.

4. Results, Discussion and Suggestions

In general, when the pre-service teachers' analogies created in relation to the concept of atom are examined, it is seen that they mostly establish connections by using concrete and everyday concepts. Furthermore, the pre-service teachers' analogies widely include concepts that are used in textbooks and by teachers in their classes to define atom models such as "sphere", "raisin pie" and "solar system" (Yaseen & Akaygün, 2016). Thus, it can be maintained that the pre-service teachers were affected by their former textbooks and teachers while constructing their analogies. This finding concurs with the study by Coll & Treagust (2008).

Cosgrove, (1995), Mendonça, Justi, & de Oliveira (2006), Pittman, (1999), Mozzer & Justi (2012) argue that students' creating and using their own analogies make positive contributions to their explaining scientific concepts and promote conceptual changes. Nineteen of the analogies created by the pre-service teachers on the basis of their prior knowledge and seven of the analogies created after they had been instructed about

atom and atom-related concepts do not refer to any of the atom models. This indicates that some pre-service teachers experienced difficulties in expressing atom-related knowledge in their minds and had some misconceptions and after the instruction, they were able to better express their knowledge about atom.

It was found that the analogies constructed by the pre-service teachers mostly referred to the Dalton, Thomson and Bohr atom models; yet, after the instruction, their constructed more analogies complying with the Bohr Atom Model and Modern Atom Theory. This might indicate that the analogies commonly used in textbooks and by teachers in the class such as "sphere", "raisin pie", "solar system" and "stone fruit" are retained by students in their minds and thus they model atom in their minds through such concepts. This is parallel to the study by Wong (1993) claiming that through analogies, misconceptions in students' minds can be detected. It was also determined that the pre-service teachers used analogies found in textbooks and used by their teachers as the source of their analogies; yet, while they were expressing the modern atom theory about which not many analogies could be found in textbooks they generally created their own analogies. This concurs with the finding of Coll & Treagust (2008) stating that if there is any source, students use this source to create their own analogies. Students' own analogies are believed to enable them to more easily perceive and express concepts by improving their comparison skills. Analogies can be utilized in concept teaching as well as in determining students' level of learning a concept. Pre-service teachers' creating their own analogies is believed to be important in terms of their alternative use and the development of the skill of reifying abstract concepts.

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