# INVESTIGATING PRESERVICE SCIENCE TEACHERS' UNDERSTANDING OF ROLE AND DISTRIBUTION OF OZONE LAYER AND OZONE LAYER DEPLETION THROUGH MENTAL MODELS AND ONTOLOGICAL BELIEFS

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Approval of the Graduate School of Social Sciences

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This is to certify that we have read this thesis and that in our opinion it is fully adequate, in scope and quality, as a thesis for the degree of Master of Science.

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## ABSTRACT

INVESTIGATING PRESERVICE SCIENCE TEACHERS' UNDERSTANDING OF ROLE AND DISTRIBUTION OF OZONE LAYER AND OZONE LAYER DEPLETION THROUGH MENTAL MODELS AND ONTOLOGICAL BELIEFS

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The purpose of this study was to investigate preservice science teachers' mental models about the role and distribution of ozone layer and ozone layer depletion regarding their ontological orientation. This study was conducted with twenty four preservice science teachers who were enrolled in Elementary Science Education Program of Education Faculty of one public university located in Central Anatolia. From each grade level six preservice science teachers were selected; two from low achiever, two from middle achiever and two from high achiever. Moreover, in the study, data were collected by using semi structured interview and interview consists of eleven questions and with five questions having multiple parts. Interview recordings were transcribed and analyzed qualitatively. In the following steps of the analysis, researcher proceeded with the already formed and described codes in an

easygoing way. The results revealed that preservice science teachers' responses were mostly seen as skin cancer and sunburn as harmful effects of ultraviolet rays and preservice science teachers' responses were mostly seen as activation vitamin D and photosynthesis of plants as beneficial effects of Sun's rays. Half of preservice science teachers thought that ozone layer exists in the atmosphere. Moreover, preservice science teachers' responses were mostly seen as perfume, deodorant, car, and spray as harmful materials to ozone layer. Chlorofluorocarbon, carbon monoxide, and carbon-dioxide were the most seen responses as harmful chemicals to ozone layer. Similar misconceptions were identified when compared with past studies. Also, different misconceptions were found in the study. Ten distinct models were formed regarding role and distribution of ozone layer and five distinct models were formed regarding ozone layer depletion. Moreover, absorbing and reflecting surface was mostly seen ontological belief regarding role and distribution of ozone layer. Hole was mostly seen ontological belief regarding ozone layer depletion. Generally, achievement and grade level did not make difference among preservice science teachers forming which type of mental models and having ontological beliefs.

Keywords: Mental Model, Ontological Belief, Preservice Science Teachers, Ozone Layer, Ozone Layer Depletion

# ÖZ

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ OZON TABAKASININ İÇERİĞİ, GÖREVLERİ VE OZON TABAKASININ İNCELMESİ KONUSU İLE İLGİLİ ZİHİNSEL MODELLERİ VE ONTOLOJİK İNANÇLARI

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Bu çalışmanın amacı fen bilgisi öğretmen adaylarının ozon tabakasının içeriği, görevleri ve incelmesi konusu ile ilgili zihinsel modelleri ve ontolojik inançlarını belirlemektir. . Bu çalışma İç Anadolu'da bir üniversitenin Eğitim Fakültesi Fen Bilgisi Öğretmenliği Anabilim Dalı'nda eğitim gören yirmi dört öğretmen adayıyla yapılmıştır. Her bir sınıf düzeyinden ikisi düşük derecede başarılı, ikisi orta derecede başarılı ve ikisi yüksek derecede başrılı olan aday olmak üzere altı aday seçilmiştir. Çalışmada, yarı yapılandırılmış görüşme yapılarak veri toplanmıştır. Görüşme on bir sorudan oluşmaktadır ve bunlardan beşi daha ayrıntılı sorular içermektedir. Görüşme kayıtları yazıya aktarılarak nitel veri analizi kullanılmıştır. Analizin ilerleyen basamaklarında, araştırmacı önceden oluşturulmuş ve tanımlanmış kodları kullanmıştır. Araştırma sonuçlarına göre Fen Bilgisi öğretmen adaylarının ultraviyole ışınlarının zararlı etkilerine cevapları çoğunlukla cilt kanseri ve güneş

yanığı olmuştur. Fen Bilgisi öğretmen adaylarının güneş ışınlarının yararlı etkilerine cevapları çoğunlukla D vitamininin aktivasyonu ve bitkilerin fotosentez yapması olmuştur. Fen Bilgisi öğretmen adaylarının yarısı ozon tabakasının atmosferin içinde olduğunu düşünmektedir. Bunlara ek olarak, fen bilgisi öğretmen adaylarının ozon tabakasına zararlı olan maddelere cevabı çoğunlukla parfüm, deodorant, araba ve sprey olmuştur. Fen bilgisi öğretmen adaylarının ozon tabakasına zararlı olan kimyasallara cevabı da çoğunlukla khloroflorokarbon, karbon monoksit ve karbon dioksit olmuştur. Geçmişte yapılan çalışmalarla karşılaştırıldığında, bu çalışmada benzer kavramsal yanılgılar bulunmuştur. Ayrıca, bu çalışmada farklı kavramsal yanılgılar da bulunmuştur. Ozon tabakasının içeriği ve görevleri ile ilgili on zihinsel model oluşturulmuş; ozon tabakasının incelmesi ile ilgili beş zihinsel model oluşturulmuştur. Ayrıca, ozon tabakasının içeriği ve görevleri ile ilgili en çok görülen ontolojik inançları içine emen ve yansıtan yüzey inançları oluşturmaktadır. Ozon tabakasının incelmesi ile ilgili en çok görülen ontolojik inancı delik inancı oluşturmaktadır. Genel olarak, başarı ve sınıf düzeyi fen bilgisi öğretmen adaylarının arasında hangi zihinsel modellerini oluşturduğu ve ontolojik inanca sahip olduğu hakkında farklılık göstermemiştir.

Anahtar Kelimeler: Zihinsel Model, Ontolojik inanç, Fen Bilgisi Öğretmen Adayları, Ozon Tabakası, Ozon Tabakası İncelmesi

To My Parents

Emine and Mehmet Ali Yanış

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AL: Achievement Level

LA: Low Achiever

MA: Middle Achiever

HA: High Achiever

CFC: Chlorofluorocarbon

CGPA: Cumulative Grade Point Average

GL: Grade Level

D Model: Ozone Layer Depletion Model

R&D Model: Role and Distribution of Ozone Layer Model

ODSs: Ozone Depleting Substances

# 1. INTRODUCTION

Human beings and environment influence each other. In the last two centuries, effects of human on the nature have become significant due to having active role in rapid population increase, industrialization, air pollution, river pollution, climate change, ozone layer depletion, greenhouse effect, acid rain, chemical wastes, extinction of species, nuclear pollution, toxic wastes, and reducing green areas (Erten, 2003; Mert, 2006).

Addressing human caused environmental problems and issues has taken attention of both public and researchers in science (Groves & Pugh, 1999). At each level of formal education environmental concepts are mentioned. With this approach it was aimed to provide an opportunity for students to understand different environmental problems and improve essential knowledge (Dove, 1996). Thus, teachers have an important role in teaching these environmental concepts in a scientific manner. Moreover, research has found that textbooks used in schools have inadequate or sometimes incorrect information regarding environmental topics (Soyibo, 1995). This situation put another emphasis on the importance of teachers and their knowledge about environmental concepts to teach environmental concepts effectively.

Similar to teachers if preservice teachers have poor understanding of environmental concepts, they are likely to transfer their wrong understanding or misconceptions about environmental topics when they become teachers. Remediation of these misconceptions generally took some time and during this remediation period they can transfer their misconceptions to many students. Misconceptions are conceptions that learners develop as an alternative to the scientifically accepted conceptions (Tekkaya & Balcı, 2003). They form these conceptions as a result of their experiences either during their daily life experiences or in science classes and these conceptions are far from being scientific. People try to understand natural events through observations and interpret and comprehend these observations by using their existing knowledge and intuition (Gallegos, Jerezano, & Flores, 1994). Untutored beliefs may also cause misconceptions, for example, people lack sufficient understanding due to lack of exposure to environmental issues may cause misconceptions (Hills, 1989).

In Turkey preservice teachers conceptual understanding have been studied for physics, biology, and chemistry concepts (Alkan, Azizoğlu, & Geban, 2006; Bayraktar, 2009; Gönen, 2008). However, there is a few research related to preservice science teachers' understanding of knowledge regarding environmental concepts. However, studies conducted in other countries revealed that from different sources individuals may develop misconceptions regarding different environmental concepts. Of these concepts, the most common environmental concepts which are misunderstood by preservice teachers are global warming, ozone layer depletion and acid rain (Dove, 1996; Khalid, 2001; Papadimitrou, 2004). In this study, role and

distribution of ozone layer and its depletion was studied to explore preservice science teachers' understanding of these concepts in Turkish context.

### 1.1. Research on Ozone Layer

In the last two hundred years, human activities have a harmful effect on Earth. Several environmental problems have started up due to the change in life style of people. According to Stern (2000), human environmental impact is connected to a variety of human necessities and desires. These desires are for physical comfort, mobility, relief from labor, enjoyment, power, status, personal security, maintenance of tradition and family, and so forth. Human beings have used environmental sources unconsciously and therefore many species have become extinct. Ozone layer and its depletion are one of the most important serious global environmental problems.

The ozone molecule ($O_3$) contains three atoms of oxygen and is mainly formed by the action of the UV rays of the sun on oxygen molecules in the upper part of Earth's atmosphere (called the stratosphere). About 90% of all ozone molecules are found in the stratosphere. Most of this ozone is found in the lower stratosphere in what is commonly known as the "ozone layer." The remaining 10% of ozone is in the troposphere, which is the lowest region of the atmosphere, between Earth's surface and the stratosphere. Scientists have known for many decades that the stratospheric ozone layer screens harmful ultraviolet radiation (UV) from the Earth's surface. In the last twenty years, ozone concentrations are decreasing by 2- 5% per decade in the middle latitudes. It has also been known that the ozone layer protects

against adverse effects on humans (e.g., skin cancer and cataracts), the biosphere (e.g., inhibiting plant growth and damaging ecosystems), and physical infrastructure of the modern era (e.g., degradation of materials). When the concentrations of ozone decrease, the amount of UV radiation from Sun which gets to Earth's surface will increase. Therefore, human and other livings are affected from this in a bad way (Cordero, 2001). Dove (1996) stated that increase in skin cancer, diseases like sunburn, cataract and immune system affection engaged people's attention to the ozone layer depletion. If there is an increase in concentrations of any of ozone depleting gases that contribute nitrogen, hydrogen, or halogen radicals to the stratosphere, there will be an increase in ozone-destroying radicals and hence in stratospheric ozone destruction. Ozone depleting substances (ODSs) such as the Chlorofluorocarbons (CFCs) have contributed to increases in global average surface temperature.

Boyes, Chambers, and Stanisstreet (1995) stated that ozone depletion and greenhouse effect are complex and abstract environmental issues. Previous research have shown that preservice teachers hold many misconceptions regarding these issues. Some of the commonly used terms such as 'ozone layer' and 'hole in the ozone' seem to cause confusion among students (Khalid, 2003). For example, the term 'ozone layer' is less likely used in daily-life. This phrase gives people an idea that ozone in the atmosphere is a thin layer-like or sheet-like covering around the earth. The other phrase 'hole in the ozone' is also a commonly used term which may cause some confusion among the students (Khalid, 2003). In Khalid's (2003) study some of the subjects thought of the 'hole' as some type of damage or a rupture in the

'layer'. If, the concentration of ozone gas molecules is reduced this means that reduction in the concentration of the gas is either thinning of the ozone or depletion of the ozone. In other words, the number of ozone molecules has been reduced (Khalid, 2003).

### 1.2. Misconceptions Regarding Ozone Layer and Its Depletion

Preservice teachers confuse greenhouse effect with ozone depletion as far as the mechanism through which they occur. Majority of them think that ozone holes causes global warming. They think that holes allow the sun rays enter and lead to raise in the Earth's temperature (Boys & Stanisstreet, 1993; Groves & Pugh, 1999). Some of them think that global warming is the incoming solar radiation through the ozone "hole" and ignore any entrapment (Boys & Stanisstreet, 1993). Moreover, some of them think that ozone layer as if it is consisted of many compounds and they believe that there exist one or more "holes" (Papadimitriou, 2004). Khalid's (2001) study revealed other misconceptions. These are ozone depletion and greenhouse effect are connected with each other; ozone layer has many functions which are controlling temperature, equilibrating the amount of atmosphere gases; the stratospheric ozone can be damaged by car and factory exhausts; one of the causes of ozone depletion is $CO_2$ and ozone depletion may increase Earth's temperature. These studies revealed that preservice science teachers should get deeper and better understanding of ozone layer depletion and greenhouse effect so that they can teach these concepts by considering the scientifically accepted explanations and not

transmit their misconceptions to students. In a study that consist of elementary physical science and geography preservice teachers and they held many misconceptions about atmospheric phenomena, so this formed concern about these teachers to instruct their own students correctly because they did not have proper understandings (Aron, Francek, Nelson, & Biasrd, 1994). We believe that during teacher education programs preservice teacher should be provided opportunity to remediate their misconceptions if they have and learn the types of misconceptions that their future students may hold regarding role and distribution of ozone layer and ozone layer depletion. One way of dealing preservice science teachers' misconceptions about ozone and ozone layer could be investigating their mental models regarding ozone and ozone layer. For this purpose in this study, preservice science teachers' mental modes regarding ozone and ozone layer was investigated in terms of the issues considered in the next section.

### 1.3. Mental Models

Researcher stated that learners organize knowledge through cohesive mental models (Vosnidou and Brewer, 1992), fragmented knowledge when individuals possess disorganized information (diSessa, 1988) and a hybrid of the previous two models (Lawson, 1988). Lawson (1988) indicated that individuals develop concepts by how concepts are presented to them and naive beliefs about physical phenomena form the basis for cohesive models. These models can develop into more sophisticated models, and form hybrid models (Vosniadou & Brewer, 1992). Even

these models may further transform into scientific models with more information. As mentioned previously, ozone layer and its depletion are abstract concepts for students to learn meaningfully. According to Park (2006) most of the scientific concepts have an abstract nature, so students need analogues explanations and scientific models to understand the concepts. It was stated that scientific models are (functional) mental representations designed by users to represent aspects of the natural world in order to realize certain cognitive or practical goals (Ducheyne, 2008). Philip Johnson-Laird (1983) stated that mental representation deals with how humans interact with the external world by using their mental models. He distinguishes between three kinds of mental representations: propositional representations, i.e. verbal representations; mental models, i.e. structural analogues of the world; and mental images, i.e. perceptual correlates of the phenomenon being depicted.

Moreover, constructing cognitive representations are needed to understand scientific concepts. To meet this need putting up mental models can work like cognitive representations (Clement & Rea-Ramirez. 2008; Glynn & Duit, 1995, Nersessian, 1999, 2008; Norman, 1983). Also, research regarding misconceptions set up the mental model term in science education (Çepni & Keleş, 2006). "In order to being understood of scientific theory, construction of mental models is needed" (Greca & Moreiro, 2001, p.208). This study focuses on mental models of preservice science teachers about role and distribution of ozone layer and its depletion. In the next section, mental models were presented.

### 1.3.1. Nature of Mental Models

The term ‘mental model’ has been ascribed to the Scottish psychologist, Keeneith Craik. He mentioned that the mind constructs “small-scale models” of reality to foresee events, and construct explanations (Craik, 1943). Boulter and Gilbert (2000) explain that models are representations of an idea, object, event, and process. Mental models are special type of models and are described as cognitive structure of human (Finegold & Smit, 1995; Ritchie et al., 1997). Mental models are used to describe phenomena which cannot be attempted directly. In other words, these models represent our analogies about what it is observed externally. Thus, they are imaginary structures which are externally represented or perceived system which means the spatial arrangement of elements in the system and relationship among them (Anderson & Chiou, 2009).

As a research purpose mental models are difficult to investigate intrinsically. Gilbert et al. (2000) indicated that what researchers meet during interview are in fact participants’ expressed mental models. In other words, researchers may understand participants’ mental models as the way they explain their mental models to researcher. So, the analysis of these mental models can give us useful information about students’ perception, learning, and conceptual framework of specific scientific concepts (Coll & Treagust, 2003; Park, 2006).

The construction of mental models is a continuing process. There is a consensus that individual’s interactions with system in the social and cultural environment originate mental models and then these models are improved through

assimilations and accommodations, or conceptual changes (Brewer & Vosniadou, 1994; Clement, Nunez-Oviedo & Rea-Ramirez, 2008; Duit & Glynn, 1995). Moreover, mental models represent what is happening in mind and can be run to generate predictions and explanations, which are among the most important functions of mental models (Anderson & Chiou, 2009). A mental model can be "in conflict with" the correct scientific model and can be missing or non-existing mental model or an incomplete mental model (Chi, 2008). Chi (2000, 2008) also stated that a learner's mental model conflicts with the correct scientific model when it is flawed which means coherent but incorrect. Therefore, the accuracy of the flawed mental model can be validated by predicting and testing how the student will respond to additional questions (Chi, 2008).

At the present time, there are two approaches to development of mental models. One of them is that conceptions (comprehension of the concept), with mental models, are supposed to improve within a widespread theoretical framework, and to transform naïve mental model into ones that scientifically accepted, it is need to changes at the theory level (Carey & Wiser, 1983; Brewer & Vosniadou, 1992, 1994). The other one supposes that conceptions are constructed through phenomenological primitives which are allotted from one's experience, hence the process of conceptual changes together with mental models are gradual rearrangements of the available, existing p-prims (diSessa, 2008). diSessa (1993) notices students' explanations of phenomena as spontaneous constructions based on their existing knowledge which he calls phenomenological primitives (p-prims). Students use unconsciously these p-prims to explain phenomena or events (diSessa,

1993). Students may use different p-prims to explain phenomena or events, so p-prims are not mental models, however, they are isolated knowledge that students use to make sense of the world (Shepardson, Choi, Charusombat & Niyogi, 2009). In this study, out of these models we used conceptual mental models of Coll and Treagust (2003) because role and distribution of ozone layer and ozone layer depletion are abstract concepts.

Coll and Treagust (2003) divide mental models into two groups as physical mental models and conceptual mental models.

1) **Physical Mental Models:** It is people's imagination of physical properties. Arousal of body organs in mind can be given as an example.
2) **Conceptual Mental Models:** It is mental construction of concepts, models or abstraction. Mental models in atom topic are conceptual mental models. Abstract concepts are mentioned with these models.

Most recently researchers argued that conceptions of mental models may have relationships with ontological categorization. In other words individuals' conceptions of scientific concepts related to how they see that particular scientific entity. In light of recent research studies we believed that through determining ontological beliefs of pre- service science teachers, we may have better understanding of their mental models about role and distribution of ozone layer and ozone layer depletion. Vosniadou and Brewer (1994) claimed that children's mental models are built on their ontological beliefs. Moreover, Chi (2005) proposes that

learning some scientific concepts which includes emergent process is difficult because they perceive these concepts as direct process instead of emergent process. She classifies as direct and emergent process which are different two categories on the basis of ontological properties. When individual can comprehend the distinction between direct and emergent process, s/he can form the mental model and conception which are scientifically acceptable. The next session explains how ontology is operationalized and used to understand mental models in this study.

### 1.4. Ontology

The term ‘ontology’ originates from period of Aristoteles (Chi, 2003). Smith (2003) defines ontology as the science of what is, of the kinds and structures of objects, properties, events, processes and relations in every area of reality. Ontology interests in entities and categories to which they belong. Ontology also investigates in order to ensure precise and comprehensive categorization of entities (Smith, 2003). Moreover, Chi, Slotta, and de Leeuw, (1994) stated that there are three ontological categories of physical entities: matter (things), processes and mental states. Also, each ontological category has sub categories (Chi, 1997). All ontological categories and their subcategories are different from each other.

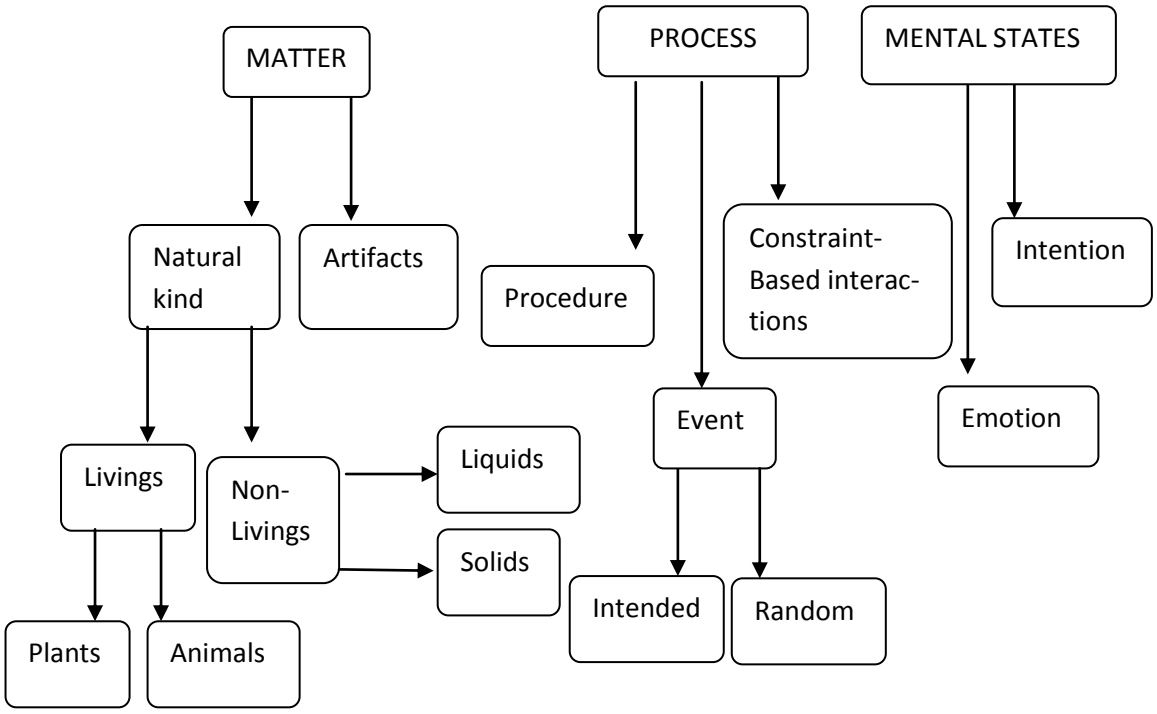



Figure 1.1: Three ontological categories and their sub categories which entities in the world can exist. Source: Chi, M. T. H. (1997)

Matter category has some ontological properties as volume, mass and color (Chi, 1992). For example, pencil and table belong to matter category because they have volume, mass, color etc. Matter category has two subcategories like natural kind and artifacts (Chi, 1997). Moreover, process category has properties like having initial point and final point. Physical property of process cannot be defined. For example, the concept 'heat' exists in process category. This concept does not have mass, volume, and color. Chi (2005) also stated that many scientific concepts are not only processes but they are actually a kind of process that is called emergent which is difficult for students to understand scientifically and direct which has usually an identifiable agent that causes some outcome in sequential and dependent sort of way

(Chi, 2008). In contrast, emergent process does not have identifiable causal agent and identifiable sequences of stages.

Chi (1992, 1997) stated that some misconceptions are robust due to changes in concepts' ontological nature. This means that people put concepts into different ontology (Keil, 1981). So, misconceptions are introduced because of belonging to an inappropriate ontological category (Chi, & Slotta, 2006). For example, Chiou and Anderson's (2009) study showed that undergraduate physics students assigned heat to incorrect ontological category. They assigned heat to 'matter' category instead 'process' category. Thus assigning to wrong ontological category resulted in having misconceptions in the understanding of that particular scientific concept. This misconception is reflected in their mental models. When concepts are assigned to correct ontological category, conceptual change is needed to be attained by these students to understand these concepts as scientifically accepted way. Thus, conceptual changes are reached when people change their ontological belief or mental model.

### 1.5. Grade Level and Achievement Level

Grade level and achievement level are important variables in most studies. Literature suggests that school-level factors such as grade-level configuration and achievement level may affect preservice science teachers' perceptions and practices, (Lai & Watman, 2008). This study examined these potential influences. In an extensive review of the literature, Graziano, DeGiovanni, and Garcia (1979) stated

that perception patterns appear to change with age, but that the changes are not in a simple linear relationship. Age differences, they concluded, are often hazard specific and frequently related to cognitive development. The age of participants plays a significant role in the field of environmental issues which has especially abstract nature. We were interested if this was also true for this study. Moreover, in the Science Education Program of the University, there is Environmental Science course in the third class. Therefore, preservice science teachers in the third and fourth grade level are supposed to be more knowledgeable about role and distribution of ozone layer and ozone layer depletion. Ontological knowledge also becomes more differentiated and hierarchically integrated as children become older (Gelman, 1990).

Moreover, in the literature research were generally about effects of factors on students' achievement. However, there were not research about effect of achievement level on students' perception of environmental issues. Hence, we were interested in if there was an effect of achievement level on preservice teachers' perception of role and distribution of ozone layer and ozone layer depletion. Preservice science teacher who are high achiever are supposed to be more knowledgeable about role and distribution of ozone layer and ozone layer depletion.

### 1.6. Relationship between Mental Models and Ontological Beliefs

Vosniadou and Ioannides (1998) describe some of the basic principles that seem to guide the process of acquiring knowledge about the physical world. Process of acquiring knowledge has constraints which is called framework theory.

Framework theories consist of ontological and epistemological presuppositions. *Ontological presuppositions* are presuppositions about the kinds of entities we assume to exist and the way they are categorized. *Epistemological presuppositions* are presuppositions that have to do with the nature of our knowledge. In this category it can be included presuppositions that have to do with the nature of explanation or with the nature of learning. In addition to framework theory, specific theories consist of a set of interrelated beliefs that describe the properties and behavior of physical objects. Beliefs are generated through observation or through information presented by the culture under the constraints of the framework theory Vosniadou and Ioannides (1998).

According to Vosniadou and Ioannides (1998), framework and specific theories provide the basis for generating situation specific representations of mental models. As a result, there are constraints which are ontological and epistemological presuppositions behind mental models. Also, according to Norman (1983), mental models can include knowledge or belief.

### 1.7. Research Questions

In this study preservice science teachers' mental models about the role and distribution of ozone layer and ozone layer depletion were examined regarding their ontological orientations. More specifically the research questions investigated in this study are:

1) What are preservice science teachers' mental models and ontological beliefs related to the role and distribution of ozone layer?
2) What are preservice science teachers' mental models and ontological beliefs related to ozone layer depletion?
3) How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different grade levels?
4) How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?
5) How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers change through different grade levels?
6) How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?

### 1.8. Significance of the Study

Past studies are mostly related to physics, biology, and chemistry. There are some studies about environmental issues like ozone layer depletion and global warming (Christidou & Koulaidis, 1997; Dove, 1996; Grima, Filho, & Pace, 2010; Groves & Pugh, 2002; Khalid, 2001; Papadimitriou, 2004; Pekel, 2005). Their

content is mostly perception of and misconception about these issues. However, a few research has been conducted to understand reasons of these misconceptions about environmental issues as compared with other science disciplines. This study argues that investigating preservice science teachers' mental models of distribution and role of ozone layer and its depletion can help us understand students' way of learning of environment. Hence, teacher educators can provide better understanding of environmental issues to preservice science teachers by integrating mental models and ontology into their lesson according to result of this study.

Also, this study determines the preservice science teachers' ontological beliefs about ozone layer and its depletion and it is aimed to determine causes underlying misconceptions through both mental models and ontological beliefs of preservice science teachers. According to Vosniadou and Ioannides (1998), behind the mental models there are ontological presuppositions. Preservice science teachers'mental models can include misconceptions. Hence, when we examine the mental models and ontological beliefs of preservice science teachers, we can understand cause of their misconceptions. Thus, this study is unique in terms of investigating mental models and ontological beliefs in environmental issues in Turkey.

Furthermore, this study reveals real knowledge about environmental concepts in depth, so it can provide information about how effective environmental education and different sources are integrated to lessons because preservice science teachers' knowledge generally comes from media. This study also can reveal additional misconceptions oriented towards Turkish culture.

## 1.9. Definitions of Terms

*Chlorofluorocarbons:* A chlorofluorocarbon (CFC) is an organic compound that contains carbon, chlorine, and fluorine, produced as a volatile derivative of methane and ethane.

*Mental models:* Mental models are special type of models and are described as cognitive structure of human (Finegold & Smit, 1995; Ritchie et al., 1997) used to describe phenomena which cannot be attempted directly.

*Misconception:* Because of the abstract nature of science, it entails an analogous explanation and scientific models to observe the phenomena (Park, 2006). Most of the time students understanding does not consisted with scientific models, so misconceptions occur. In this study, it is mentioned about misunderstanding of preservice teachers about ozone layer.

*Ozone:* The ozone molecule (O3) contains three atoms of oxygen and is mainly formed by the action of the UV rays of the sun on oxygen molecules in the upper part of Earth's atmosphere (called the stratosphere).

*Ozone Depleting substances:* Certain chemicals (such as chlorofluorocarbons, hydrochlorofluorocarbons and halons) are recognized as ozone-depleting substances (ODS) because they breakdown in the stratosphere and release chlorine or bromine, which destroy the stratospheric ozone layer (http://www.ene.gov.on.ca/environment/en/subject/ozone_depleting_substances/index.htm)

*Ozone layer:* About 90% of all ozone molecules are found in the stratosphere. Most of this ozone is found in the lower stratosphere in what is commonly known as the "ozone layer."

*Ozone layer depletion:* Destruction of the stratospheric ozone layer that protect the Earth from ultraviolet radiation (http://en.mimi.hu/environment/ozone_layer.html).

*Preservice teachers*: Teacher candidates who are registered in an undergraduate science teacher education program in the university in Black Sea Region.

*Scientific model:* Scientific models are (functional) mental representations designed by users to represent aspects of the natural world in order to realize certain cognitive or practical goals (Ducheyne, 2008).

*Stratosphere:* Stratosphere is the upper part of Earth's atmosphere.

*Troposphere:* The troposphere, which is the lowest region of the atmosphere, is between Earth's surface and the stratosphere.

# 2. LITERATURE REVIEW

This chapter of proposal is devoted to literature review. In this chapter, first studies of misconceptions about greenhouse effect and ozone layer are given. Then, mental models and ontology studies are presented and related to better understanding of role and distribution of ozone layer and its depletion.

## 2.1. Misconception Studies about Ozone Layer and Studies about Understanding Ozone Layer

During the last decade lots of studies have been conducted to understand students' and teachers' conceptions about global environmental issues, especially ozone layer depletion and greenhouse effect (Daskolia, Flogaitis, & Papageorgiou, 2006; Papadimitrou, 2004; Pekel, 2005). Ozone depletion is a complex and abstract environmental issue (Boyes et al., 1995; Dove, 1996; Leighton & Bisanz, 2003). Previous research have shown that students and teachers hold many misconceptions of this issue because of being abstract. These misconceptions are strongly held and persist even after instruction (Groves & Pugh, 2002). Major misconceptions are summarized in Khalid's (2001) study as ozone depletion and greenhouse effect are connected with each other; ozone layer has many functions which are controlling temperature, equilibrating the amount of atmosphere gases; the stratospheric ozone can be damaged by car and factory exhausts; one of the causes of ozone depletion is $CO_2$ and ozone depletion may increase Earth's temperature. Moreover,

Papadimitriou (2004) found that a few teachers mentioned ozone layer depletion other expressed their views as holes in the ozone layer.

Of these misconceptions associating ozone layer depletion with greenhouse effect was prevalent among participants (Boys et al., 1993; Papadimitriou, 2004). Majority of them think that holes allow the sun rays enter and lead to raise in the Earth's temperature (Boys et al., 1993; Groves & Pugh, 1999). Some of them think that global warming is the incoming solar radiation through the ozone "hole" and ignore any entrapment (Boys & Stanisstreet, 1993). Students think that ozone at ground level is a kind of pollution that destroys the ozone layer by allowing more sun rays to enter the Earth and then accelerate global warming (Grima, Filho, & Pace, 2010). Researchers argued that media can play an important source in having such these misconceptions (Boyes & Stanisstreet, 1995; Daskolia et al., 2006; Dove, 1996; Khalid, 2003).

There were some studies in the literature about teachers perception about their environmental knowledge. According to these studies result, teachers mainly perceived that their knowledge was adequate to effective teaching of environment. However, Ko and Lee (2003), and Marco (1997) claimed that teachers perceived their knowledge as inadequate. Teachers also emphasize that monetary fund, time, and instructional materials are barriers to effective environmental education in schools (Ko & Lee, 2003; Lane, Jennie, Wilke & Richard, 1994).

In the literature, preservice teachers' knowledge was found adequate (Ko & Lee, 2003; Marco, 1997). Preservice teachers had inadequate knowledge about ozone

layer depletion and greenhouse effect (Şahin, Cerrah, Saka & Şahin, 2004, Tahsin, 2003).

Michail, A. G. Stamou and Stamou (2007) study on the Greek primary school teachers' understanding of three current environmental issues: acid rain, the ozone layer depletion, and the greenhouse effect were examined. Questionnaire with three parts was implemented to participants. According to results, teachers thought that human activity is responsible for the formation of the ozone layer depletion, greenhouse effect and acid rain. This research again revealed misconception such as association of the ozone layer depletion with greenhouse effect as mentioned above. Research revealed that Greek teachers have more environmental knowledge gaps than their colleagues in other countries such as Australia and England. Moreover, the location of ozone layer was confused and Greek teachers did not know the ozone depleting substance. Teachers also said that in order to get information about the environment they used mass media.

Dove's (1996) study investigated 60 students' comprehension of greenhouse effect, ozone layer depletion, and acid rain. The researcher found that at normal levels ultraviolet radiation is essential for the synthesis of vitamin D, but at higher intensities it causes skin cancer; the ozone layer filters out some of these harmful rays and is therefore essential to life; the ozone layer is currently being depleted by CFCs, emissions from supersonic aircraft and nitrous oxides released from fertilisers. All the students realised that CFCs were responsible for ozone layer depletion. Students suggested that they knew this because of media coverage and warnings

about aerosol cans. Only one student referred to the role of chlorines in CFCs splitting the chemical structure of ozone.

Similarly Boyes et al. (1995) implemented questionnaire to 435 students to understand the ozone layer. Results revealed that students knew the function of the ozone layer (it filters the UV light), role of the CFCs in ozone layer depletion and harmful effects of its depletion. Above two studies participants had misconceptions like: exhaust from vehicles caused to ozone depletion. This misconception is related to misunderstanding or lack of scientific knowledge involved in the two phenomena. Moreover, Koulaidis et al. (1994) studied opinions of the five groups of primary education teachers about nature and process of ozone layer via interview.

Summers, Kruger, Childs, and Mant (2000) conducted a qualitative study to 12 practicing primary school teachers in order to explore the understanding and misconception about biodiversity, carbon cycle, ozone layer and global warming. The research findings revealed that a good number of teachers knew that the ozone layer is protective, which it has 'holes' in it, and that these were caused by man-made chemicals. Far fewer numbers of teachers were aware of recent increased ground-level ozone and those that were could not specify why this was 'bad' or how it was produced and teachers had common misconceptions with the literature. These were: The 'holes' cause global warming and ozone-depleting chemicals come from car exhausts.

## 2.2. Mental Models and Ontology Studies

Researchers not only studied the misconceptions about ozone layer depletion, but also studied reasoning behind them and models of students and teachers related to ozone layer depletion. Although there are studies about ozone layer and its depletion and misconception about it, there are fewer studies about how students and teachers understand topic, how they learn and how their cognitive representation of ozone layer and its depletion.

Learning occurs actively because learners construct their concepts and ideas based on their existing knowledge (Bruner, 1973). The learner, who is at the centre of control, chooses and converts information, sets hypothesis and make decisions depending on cognitive structure (Grima, Face, & Filho, 2010). Brewer and Vosniadou (1992) suggest that children and adults give reason to a topic through concepts to constitute 'mental models'. On the other hand, diSessa (1988) suggest that individuals firstly give reason to a topic with fragmented knowledge. According to latter notion, if there are not enough facts to support the meaningful knowledge construction, mental models do not come up (Bisanz & Leighton, 2003). Lawson (1988) propose hybrid of the previous two models: individuals develop concepts according to the ways these concepts are presented to them. Moreover, Brewer and Vosniadou (1992) stated that children's models develop as they gain experience with their environment. Children's mental models are shaped by their initial beliefs which contain misconceptions. However, they improve their model and form new one which Vosniadou and Brewer called 'synthetic models'. Instruction and experience,

synthetic models develop into scientific models as time passes (Brewer & Vosniadou, 1992). In 1992, Brewer and Vosniadou's study of mental models of children concentrate on concrete concepts such as Earth. As mentioned before, ozone layer and holes are abstract terms. Hence, their mental models have inadequacy to explain children and adults' knowledge about ozone layer depletion.

Furthermore, previous research show that children and adults generate different models about ozone layer and its depletion. For example, Bisanz & Leighton, (2003) studied with children and adults to understand the model of them about ozone layer and its depletion and they implemented interview. By children's and adults' responses, Leighton and Bisanz categorize them as having full model, a partial model or no model. If they describe structure of the hole in the ozone layer and answered interview questions consistently, they would have full model; if they do not explain the structure of the ozone hole and do not answer interview questions consistently, they would have no model; finally if they describe the structure of the ozone hole and answered most interview questions consistently, they would have partial model. The full models displayed by students fell into four categories: Geological/Physical model mentioned that ozone layer was in the ground; Atmospheric/Physical model mentioned that something had broken through the ozone layer; Atmospheric/Pollution model mentioned that all pollution harmed the ozone layer in the atmosphere; Atmospheric/Chemical model mentioned that chemicals harmed the ozone layer. Bisanz and Leighton (2003) found the categories of models which results from ontological beliefs. However, Christidis, Christidou and Koulaidis's (1997) research showed that students use metaphors which based on

ontological beliefs to understand and explain the ozone layer and its depletion. According to Christidis, Christidou and Koulaidis (1997), metaphorical thinking:

1. Can serve as a fundamental restructuring of knowledge and mechanism for the reinforcement by simplifying the construction of new models (Ortony & Vosniadou, 1989).
2. Have a significant role in comprehension, and science education can utilize it in order to help children put up sufficient models of various phenomena and then to assess them (Nersessian, 1984, 1994).

Moreover, Christidis, Christidou and Koulaidis (1997) studied with 40 primary school Greek pupils. Study was based on semi-structured and individual interviews. This study concerns the correlation between metaphor which is used by primary students and mental models they put up to comprehend role of the ozone layer and its depletion. The concepts introduced in metaphors classified as three categories which are objects, substances and persons. Object category is classified into 5: container, dividing surface, absorbing/reflecting surface, air/atmosphere and hole. Analysis of the categories and their relationship result in: How children represent the function and depletion of ozone is strongly associated with the types of metaphors they use while they are putting up their mental models. Christidis, Christidou and Koulaidis (1997) make conclusion that children use metaphors consistently to comprehend, describe and represent the function and distribution of ozone in the atmosphere and the depletion of it. And metaphors can be significant educational instrument in order to strength the representation of complex and abstract issues. However, use of inappropriate metaphors can lead to misconceptions.

Moreover, researchers used different types of term in order to explain ontological categories. In this study, ontological categories are used instead of metaphors.

From studies mentioned above ozone layer and its depletion is an important topic to consider. Generally participants confused ozone layer depletion with greenhouse effect. That is, students and teachers see these two concepts as they are related topics. Moreover, students and teachers have lots of misconceptions about them. In this study, mental models and ontological beliefs of preservice science teachers were studied. Previous research showed that ontological beliefs and mental models are related. Also, misconceptions occur because of inappropriate ontological categories.

# 3. METHOD

This chapter is devoted to the research approach, participants, instrument, data collection, and data analyses.

## 3.1. Research Approach

McMillan and Schumacher (1993, p. 479) defined qualitative research as, "primarily an inductive process of organizing data into categories and identifying patterns (relationships) among categories." Merriam (1998) describes the research design as basic or generic qualitative research approach. In this study, data were collected through semi structured interview based on qualitative study and the mental models of the preservice science teachers were analyzed through ontological beliefs and mental models participants used to comprehend the role and distribution of ozone and ozone layer depletion in the Christidis, Christidou and Koulaidis's (1997) study. For exploring the mental models and ontological beliefs about role and distribution of ozone layer and ozone layer depletion of the participants, content analysis was carried out on responses of the participants to the interview questions related to Sun, ultraviolet rays, atmosphere, role and distribution of ozone layer and ozone layer depletion.

Considering qualitative research philosophy, individuals form their realities (Merriam, 1998). Hence, this study investigates the individuals' own mental model and their ontological beliefs. People's or groups' beliefs, thoughts, attitudes and

values can be revealed by content analysis (Stemler, 2001). In order to comprehend preservice science teachers' mental models about role and distribution of ozone layer and its depletion, this study used semi structured interview to reveal their mental models. Mental models were used because the analysis of mental models can give us useful information about the understanding of students' perception and learning (Park, 2006). Also, mental models can offer valuable information about the learners' conceptual framework in science education (Coll & Treagust, 2003). In order to investigate participants' inner representations, interviews were conducted through process that we cannot see the participants' mental model directly and their internal cognitive representation and their ontological beliefs to comprehend participants' understanding role and distribution of ozone layer and its depletion which they describe and share information verbally (Norman, 1983).

During the research, studies which were explained below were done:

- Through literature review, studies which include mental models and ontological categories about environmental issues such as global warming, ozone layer depletion were examined.
- After literature review, it was decided that interview was used developed by Leighton and Bisanz (2003). Interview was translated into Turkish and pilot study was done. Afterwards, interview was got into its final version with an expert.
- Sample was chosen by convenience sampling according to their CGPA and then interview was applied to participants.

### 3.2. Participants

Mentioning population in this study is not meaningful because the purpose of the study is not generalization. Patton (1990) claims that there is no rule while deciding sample size in qualitative research. According to Patton (1990), sample size is based on:

- What you want to know
- Purpose of the study
- Things that are useful and advantageous
- Things that are valuable and significant
- What can be done according to available time and sources.

Participants in this study were twenty four preservice science teachers from Elementary Science Education Program of Education Faculty of one public university located in Central Anatolia to understand their mental models and ontological beliefs about role and distribution of ozone layer and its depletion. They were selected by convenience sampling. Convenience sampling is a sampling method which samples are accessible and easily applicable because of the limitations of money, time and labor.

In order to understand progress of preservice science teachers' mental models and ontological beliefs throughout their teacher education program, preservice teachers enrolled in different level of the program were selected. From each grade level six preservice science teachers were selected; two from low achiever, two from middle achiever and two from high achiever. Also, Elementary Science Education

program in this University contained Environmental Science course. In case of this course can affect preservice science teachers' understanding about the role and distribution of ozone layer and ozone layer depletion, syllabus of the course was given in Table 3-1.

Table 3-1 Syllabus of the Environmental Science Course

| **FB 306A** | **Environmental Science** | | | **Department of Primary School Education/Science Teacher Education Programme** | |
|---|---|---|---|---|---|
| **Semester** | **Teaching Methods** | | | **Credits** | |
| | **Lecture** | **Other** | **Total** | **Credit** | **ECTS Credit** |
| **3/2** | 42 | 83 | 125 | 3 | 3 |
| **Language** | In Turkish | | | | |
| **Compulsory / Elective** | Compulsory | | | | |
| **Prerequisites** | None | | | | |
| **Catalog Description** | Ecology, ecosystem and ecological cycles, environmental pollution, water pollution and control, solid wastes, air pollution, soil pollution, noise pollution, radioactive Pollution, natural pollutions. Environmental pollution control methodology, national and international environmental pollution policy. | | | | |
| **Course Objectives** | Understanding natural and artificial systems which we live and so; to understand the concept of Environmental pollution with all dimensions and help students have attitudes of protecting environment. | | | | |
| **Course Outcomes** | To know natural and artificial systems, to learn system, ecosystems, environment pollution, control ect. concepts. To learn the legal and politic concepts about environment. | | | | |
| **Textbook and /or References** | -Ekoloji ve Çevre Bilimleri, Berkes, F., Kıslalıoglu, M., Remzi Kitabevi, , 1993, Ankara<br>-Çevre Kirliligi "Çevre Biyolojisi", Akman, Y., Ketenoglu, O., Kurt, L., Evren, H,<br>Düzenli, S., Palme Yayıncılık, 2000, Ankara. | | | | |
| **Assessment Criteria** | **Number** | | | **%** | |
| **Midterm Exams** | 1 | | | 40 | |
| **Final Exam** | 1 | | | 60 | |

Table 3-1 Continued / 1

| WEEK | TOPICS |
|---|---|
| **1st week** | Introduction, explanation of the course content, references and sources |
| **2nd week** | Ecology, ecosystem and ecological cycles |
| **3rd week** | Definition of the environmental pollution |
| **4th week** | Water pollution and control |
| **5th week** | Solid wastes |
| **6th week** | Air pollution |
| **7th week** | Soil polluition |
| **8th week** | Noise pollution |
| **9th week** | Midterm exam |
| **10th week** | Radyoactive pollution |
| **11th week** | Natural pollutions |
| **12th week** | Environmental pollution control regulations and standarts |
| **13th week** | Legal and politic concepts about environment. |
| **14th week** | National and international environmental pollution policy |

Thinning down of the ozone layer was mentioned in the air pollution topic as part of the course. In the textbook of the Environmental Science course (Aslan et al., 2006) it was mentioned that:

> Ozone layer contains three oxygen atoms. Ozone which is found in every layer of the atmosphere is found intensively in the stratosphere. Ozone layer functions as protective layer by filtering harmful rays of Sun. Chlorofluorocarbon gases set chlorine atoms free with the effect of ultraviolet rays which is held by ozone layer. Chemical reactions start with competition of oxygen atoms and chlorine compounds. UV rays which have 200-300 nm wavelengths are absorbed by ozone layer. Chlorine, hydrogen, and nitrogen gases are responsible for the ozone layer depletion. These gases are found in spray and refrigerant (fridge, air conditioner). Moreover, exhaust gases, fertilizer, and pharmaceutical industry gases are harmful for ozone layer. Ozone layer depletion causes that more UV rays reach to the Earth. The excess of UV rays causes mutation, some eye disease, and skin cancer.

The number (N) of male and female participants, participants in each grade level and in each achievement level is presented in Table 3-2.

Table 3-2 Frequencies of the Male and Female Participants, Participants in Each Grade Level and Achievement Level

| | **Grade Level** | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | | **2** | | | **3** | | | 4 | | | |
| | **Achievement** | | | **Achievement** | | | **Achievement** | | | **Achievement** | | | |
| **Gender** | **LA** | **MA** | **HA** | **LA** | **MA** | **HA** | **LA** | **MA** | **HA** | **LA** | **MA** | **HA** | **Total** |
| **Male** | 1 | 1 | - | 1 | 1 | - | 1 | 2 | - | 2 | 1 | - | 10 |
| **Female** | 1 | 1 | 2 | 1 | 1 | 2 | 1 | - | 2 | - | 1 | 2 | 14 |
| **Total** | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 24 |

* Number in the table represents frequency.
* - represents the absence of participants

Low, middle and high achiever were decided according to their CGPA. As seen from the descriptive statistics presented below in the Table 3-3, low achievers were selected by subtracting one standard deviation from mean value; middle achievers whose CGPA were equal to mean value were selected; high achievers were selected by adding one standard deviation to mean value in all grades.

Table 3-3 Determination of Achievement Level according to CGPA

**Descriptive Statistics**

| | N | Minimum | Maximum | Mean | Std. Deviation |
|---|---|---|---|---|---|
| Secondgrade | 89 | ,64 | 3,63 | 2,6510 | ,60663 |
| Firstgrade | 93 | 1,45 | 3,92 | 2,7249 | ,54455 |
| Thirdgrade | 91 | 1,08 | 3,87 | 2,8557 | ,41803 |
| Fourthgrade | 88 | 1,10 | 3,67 | 2,9515 | ,43491 |
| Valid N (listwise) | 88 | | | | |

Each participant was coded and their actual names were not used. For example: participant who is the first interviewer, second grader, middle achiever and girl was coded like 1G2MAG. In this code 1 (1 to 24) represents ID number of the participant in the interview; G2 (G1 to G4) represents the grade level, MA (LA, MA, HA) represents the achievement level, finally G (G and B) represents the gender.

### 3.3. Instrument

To reveal the participants' mental models and ontological beliefs about role and distribution of ozone layer and its depletion, semi structured interview protocol was used. Semi structured interview was translated and adapted by the researcher with an expert from the structured interview used in the study of Leighton and Bisanz (2003). The interview protocol was used to understand preservice science teachers' thinking about what the ozone layer is and how its depletion occurs and throughout the interview the participants were encouraged to think aloud to while providing answers to interview questions.

Structured interview protocol was included a list of facts (see Appendix A) and this list was constructed from encyclopedia, newspaper, and magazine reports in order to be well informed about the ozone layer by Leighton and Bisanz (2003). The facts were classified into five categories which gives different information about ozone layer. These categories are the sun and adverse consequences, ultraviolet light (UV light), ultraviolet light and human behavior, ozone composition, and ozone destruction. From these facts structured interview protocol was constructed by these

researchers. The semi structured interview protocol consists of eleven questions and with five questions having multiple parts.

In this study, semi structured interview was used because preservice science teachers may have not explain some questions exactly and so probing questions were asked in order to understand them exactly (see Appendix B). Semi structured interview protocol was first used in a pilot study in order to evaluate to what degree the translated interview questions would work with Turkish students. Pilot study consisted of two preservice teachers. The researcher conducted a detailed interview by asking probing questions with the participant. Answers and responses obtained from the participants were used to eliminate redundant questions and clarify the confused parts.

Expert opinion was also taken before and after the pilot study to make necessary revision in the interview protocol. After an agreement was established between experts and the researcher, the final structure of the interview was formed.

### 3.4. Data Collection

Data collection was carried out in 2010- 2011 spring semester and was completed in two months. The researcher conducted the interviews and before each interview session, the researcher informed the participants about ethical procedures. In that before interview starts, the participants were informed that they are willing to participate and if they want to leave interview, they can leave. Each interview session was audio-taped by taking permission from the participants. At each data collection

site, the aim of the study was explained briefly to the preservice science teachers. In the interview, firstly warm up questions were asked and then questions in interview protocol were asked. The approximate time of interview was 30-45 minutes. In addition, in order to prevent location threat to internal validity of study, each interview was done at the same location. Furthermore, process of recording which participants give responses will be in two formats (verbalization: Participants are demanded to think vocally and drawings: The participants were asked to draw how they imagine the ozone layer and the process of ozone layer depletion) which reflect the participants' representations of their mental models. Needed materials such as paper and pencil were given to participant.

### 3.5. Analysis of Data

Qualitative data analysis methods were utilized in order to analyze the study's data. This study attempt to analyze and present data collected in order to examine preservice science teachers' mental models and ontological beliefs about role and distribution of ozone layer and ozone layer depletion from interview questions.

Data analysis and collection are iterative. In the qualitative data analysis, data must be organized and reduced (data classification and reduction). In this study, data were organized by coding. Descriptions of behavior, statements, feelings, thoughts, etc. were identified and coded. Wiersma (1995, p. 217) identifies three types of codes:

1) Setting or context codes: These codes describe the setting or context descriptors of the phenomenon under study. Given that copious field notes are taken, codes for specific or regularly occurring characteristics contribute to efficient and effective field note production.

2) Perception codes: These codes are used to accurately record subjects' reported perception, understanding, etc. about relevant people, circumstances, or things. This type of codes was used in the study.

3) Process codes: It is a given in qualitative research that naturally occurring systems change. These codes are used to note event or process evolution and factors which cause or contribute to said evolution.

In order to achieve perception coding first, participants' verbal reports were transcribed into text. In order to keep the data manageable, coding was done and collected data was reduced via document sheets prepared for each participant's interview transcripts. Text and drawings were used as materials for the data analysis.

Furthermore, for verbal data analysis, data analysis process follows the Chi's (1997) guidelines. According to Chi (1997):

The method of coding and analyzing verbal data consists of the following eight functional steps:

1. Reducing or sampling the protocols.

2. Segmenting the reduced or sampled protocols (sometimes optional).

3. Developing or choosing a coding scheme or formalism.

4. Operationalizing evidence in the coded protocols that constitutes a mapping to some chosen formalism.

5. Depicting the mapped formalism (optional).

6. Seeking pattern(s) in the mapped formalism.

7. Interpreting the pattern(s).

8. Repeating the whole process, perhaps coding at a different grain size (optional).

As a result of literature search, codes were taken from the study of Christidis, Christidou and Koulaidis (1997).

Table 3-4 was used for mental models and ontological beliefs about role and distribution of ozone layer. 'Ontological belief' term was used in order to represent how preservice science teacher saw the role and distribution of ozone layer and its depletion because Chiou and Anderson (2009) used also this term in order to represent how participants saw heat and heat conduction process.

Table 3-4 Codes for Mental Models about Role and Distribution of Ozone Layer

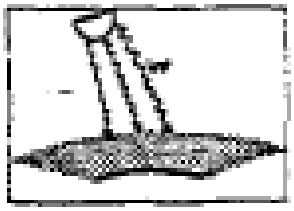
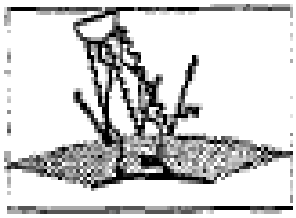
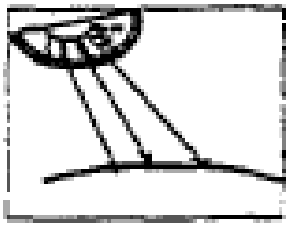
| **Mental Models** | **Christidis et al's drawing** | **Code Description** | **Ontological Beliefs** |
|---|---|---|---|
| **Model 1** |  | **Thin $0_3$ layer** around the Earth **blocking** UV | Person, container, dividing surface, absorbing/reflecting surface, air/atmosphere |
| **Model 2** |  | **Thin 03 layer** around the earth **reflecting** UV | Person, container, dividing surface, absorbing/reflecting surface, air/atmosphere |
| **Model 3** |  | **Uniformly distributed 03** around the Earth **blocking** UV | Person, container, dividing surface, absorbing/reflecting surface, air/atmosphere |

Table 3-4 Continued / 1

| | | | |
|---|---|---|---|
| **Model 4** |  | **Uniformly distributed 03** around the Earth **reflecting UV** | Person, container, dividing surface, absorbing/reflecting surface, air/atmosphere |
| **Model 5** |  | **Thin 03 layer** around the Sun, **blocking** UV | Person, container, dividing surface, absorbing/reflecting surface, air/atmosphere |

According to Christidis et al. (1997), generalized mental models were based on the identification of common characteristics of the detailed personal mental models of the students. These common characteristics were:

1) For generalized models of the role and distribution of ozone
    - Thickness of the ozone layer (thick versus thin)
    - The position of the ozone layer with respect to the Earth and Sun (surrounding the Earth versus surrounding the Sun)
2) For the generalized models of the ozone depletion process
    - The thickness of the ozone layer (thick versus thin)
    - The locality of ozone depletion (local versus general)
    - The degree of ozone depletion (total versus thinning down)

Similarly, in this study mental models were formed through common characteristics. These characteristics were:

1) For the mental models of the role and distribution of ozone layer

- Thickness of the ozone layer (thin versus uniformly distributed)
- The position of the ozone layer with respect to the Earth and atmosphere (surrounding the Earth versus surrounding the atmosphere)
- The role of ozone layer (absorbing UV versus reflecting UV)

2) For the mental models of the ozone depletion process

- The locality of ozone depletion (local versus general)
- The degree of ozone depletion (total versus thinning down)

An example of preservice science teacher's verbal responses and drawings, and a diagram of researcher were provided for each representative mental model. Researcher drew a diagram for each representative mental model determined by Christidis, Christidou and Koulaidis (1997) so that the differences between these representative mental model and preservice science teachers' drawings can be seen. In the result section of the study, mental models were shown like in Figure 3.1. Hence, an example to role and distribution mental models was presented below and how it was formed explained in detail.

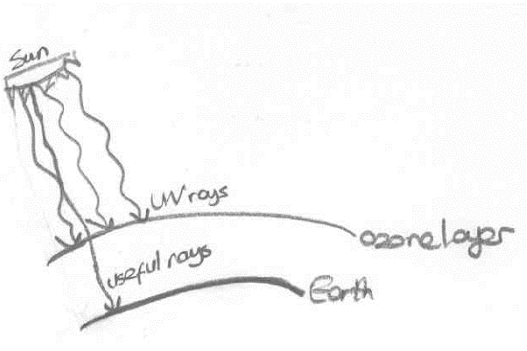
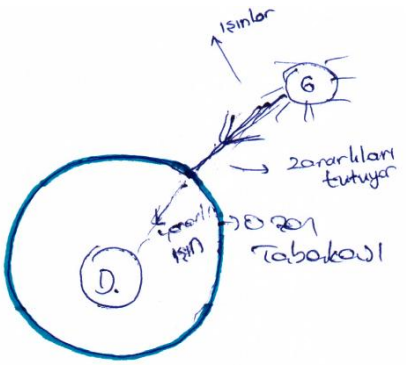
| | |
|---|---|
|  |  |
| Christidis et al.'s drawing | Preservice science teacher's drawing |

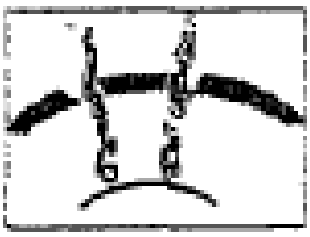
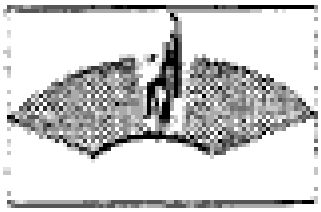
Figure 3.1 R&D Mental Model 1

Drawing which is seen on the left side was taken from Christidis et al.'s study (1997). However, researcher made difference like labeling of drawing. Also, the first, second, third, and fifth mental models about the role and distribution of ozone layer were taken from Christidis et al.'s study (1997). The remaining 6 mental models were modeled and labeled by researcher in order to make drawings more visual. Researcher modeled remaining 6 mental models by considering common characteristics which were mentioned above. Also, word groups 'thin $O_3$ layer', 'uniformly distributed $O_3$', 'absorbing', and 'reflecting' were written bold in order to represent distinction between mental models in Table 3-4.

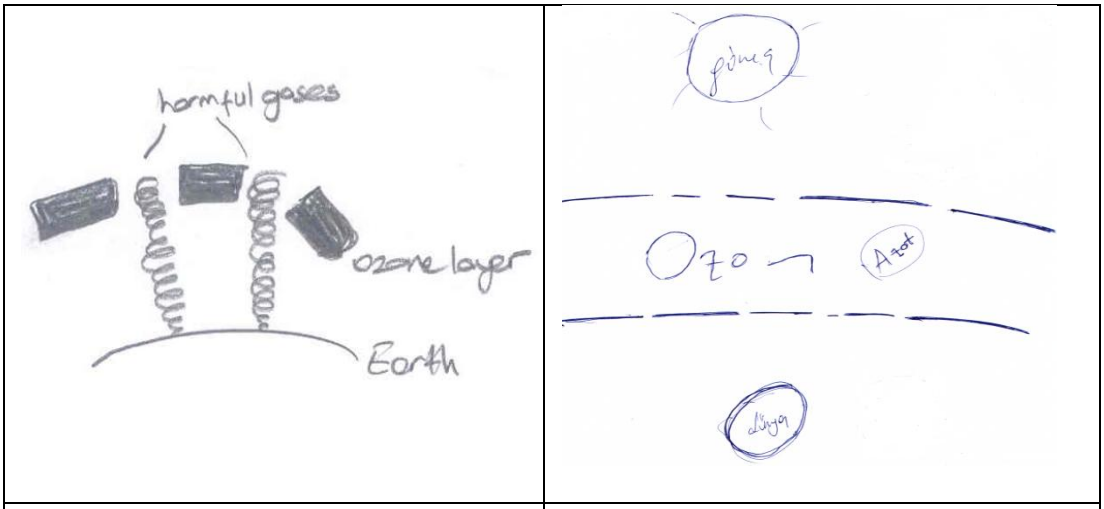
In this study similarly same distinction was considered while the remaining mental models were formed. At the right side preservice science teachers drawing is seen in Turkish, so researcher drew diagram in order to present drawings in English. Another reason why researcher drew diagram was to see how preservice science teacher reflected their ideas into drawings and whether their ideas were corresponded to their drawings or not.

Codes provided in below Table 3-5 were used for mental models and ontological beliefs about ozone layer depletion.

Table 3-5 Codes for Mental Models and Ontological Beliefs about Ozone Layer Depletion

| Mental Models | Christidis et al's drawing | Code Description | Ontological Beliefs |
|---|---|---|---|
| **Model 1** |  | Local but total destruction of the thin $0_3$ layer | Person, substance, container, hole, dividing surface |
| **Model 2** |  | Local decrease of $0_3$ alters atmosphere | Person, substance, container, hole, dividing surface |
| **Model 3** |  | Local thinning down of the $0_3$ layer | Person, substance, container, hole, dividing surface |

In the result section of the study, mental models were shown like in Figure 3.2. Hence, an example to ozone layer depletion mental models was presented below and how it was formed explained in detail.




| Christidis et al.'s drawing | Preservice science teacher's drawing |
|---|---|

Figure 3.2 D Mental Model 1

Drawing which is seen on the left side was taken from Christidis et al.'s study (1997). However, researcher made difference like labeling of drawing. Also, the first 3 mental models about the ozone layer depletion were taken from Christidis et al.'s study (1997). The remaining 2 mental models were modeled and labeled by researcher in order to make drawings more visual. Researcher modeled remaining 2 mental models by considering common characteristics which were mentioned before. At the right side preservice science teachers drawing is seen in Turkish, so researcher drew diagram in order to present drawings in English.

Participants' ontological beliefs were coded by using ontological beliefs of participants which were determined by Christidis, Christidou and Koulaidis (1997), in the study they categorized ontological beliefs into three: object (container, dividing surface, absorbing/reflecting surface, air/atmosphere, and hole), substance and person illustrated in Figure 3.3.

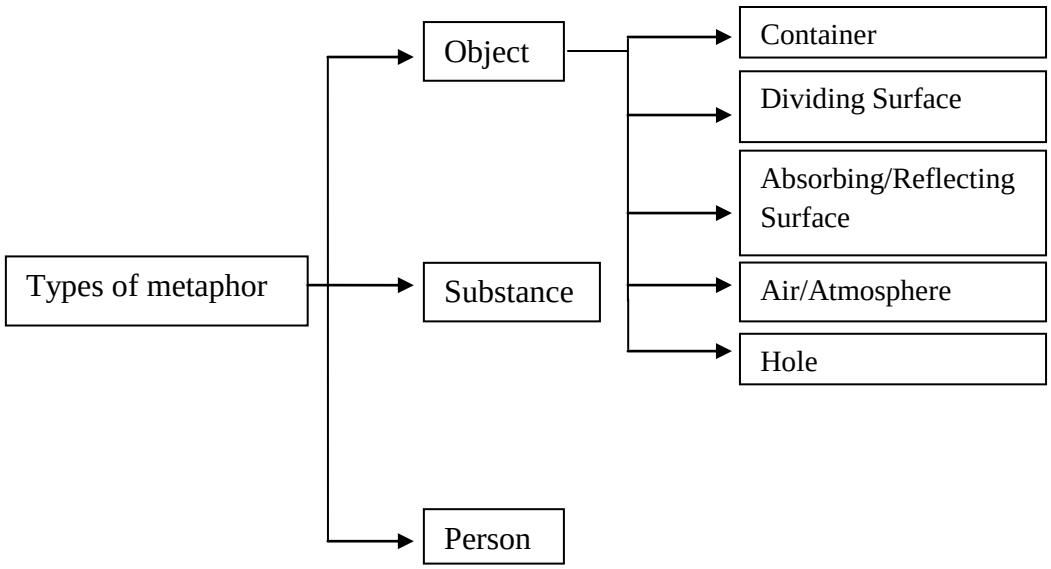



Figure 3.3 The categories of ontological beliefs used by pupils to explain the role and depletion of ozone layer. Source: Christidis, Christidou, & Koulaidis (1997).

Preservice science teachers' ontological beliefs about role and distribution of ozone layer:

***Objects:*** Preservice science teachers beliefs about dividing surface, absorbing/reflecting surface, and air/atmosphere were included in this category. An example reflecting this belief was given from the excerpt taken from 1G1MAB.

"Ozone layer is a cover over the Earth. It contains nitrogen, oxygen, carbon dioxide and slightly other gases. It is like air and is not observed by eyes".

***Dividing surface:*** In order to explain position of ozone layer and its role, dividing surface category was represented with these words: Cover, umbrella, and layer by preservice science teachers. An example reflecting this belief is given from the excerpt, taken from 18G1MAB.

"Ozone layer is like cloud or umbrella; it prevents Sun's harmful rays (UV rays and X-rays) to enter the Earth".

***Absorbing/Reflecting Surface:*** In order to explain role of ozone layer, preservice science teachers explained that ozone layer absorbs or reflects Sun's harmful rays. An example reflecting this belief is given from the excerpt, taken from respectively 19G2MAG, 9G4HAG.

19G2MAG*: "*Ozone layer which contains three oxygen atoms exists in the atmosphere. It absorbs the Sun's harmful rays and let useful rays pass and reach to Earth".

9G4HAG*: "*Ozone layer is the first layer which covers the Earth. It protects the Earth from Sun's harmful rays by reflecting them and let useful rays pass and reach to Earth".

***Air/Atmosphere:*** In order to describe the composition of ozone layer, preservice science teachers thought that ozone layer is like air and its composition is the same with atmosphere. An example reflecting this belief is given from the excerpt, taken from 23G1LAG.

"Ozone layer is the second layer in the atmosphere. It is like air and does not contain hydrogen gas, but contains carbon dioxide, oxygen, and nitrogen. Some Sun's harmful rays are reflected and some of them reach to earth by ozone layer. Useful rays also reach to Earth".

Preservice science teachers' ontological beliefs ozone layer depletion:

***Container:*** This category emphasizes that ozone layer has many compounds. An example reflecting this belief is given from the excerpt, taken from 3G3LAG.

> "Ozone layer includes not only ozone but also it includes sulfuric acid, nitrogen and carbon dioxide. Carbon dioxide holds ozone and ozone concentration decrease. It is thinning of the ozone layer; there is not a hole on it".

***Substance:*** Substance category represents that depletion means decrease in concentration of ozone or thinning of ozone layer. An example reflecting this belief is given from the excerpt, taken from 12G2HAG.

> "Chemicals which are found in perfume, air conditioner and fridge cause to thinning of ozone layer. These chemicals go up and they alter ozone layer by interacting with ozone layer gases".

***Hole:*** This category emphasizes that ozone layer has holes on it. Hole means that ozone has disappeared. An example reflecting this belief is given from the excerpt, taken from 24G2LAB.

> "I know that ozone layer has holes and this causes to global warming. Harmful gases such as carbon dioxide, carbon monoxide, and methane interact with ozone layer gases and they disappear".

***Person:*** Preservice science teachers gave some personal characteristic to ozone layer in order to explain ozone layer depletion in this ontological category. An example reflecting this belief is given from the excerpt, taken from 16G3LAB.

> "There are not any holes on ozone layer. Ozone layer depletion means that only particular area of ozone layer cannot decrease effects of harmful rays. Ozone layer holds these harmful rays with help of methane. If methane interacts with ozone layer, ozone layer loses its power".

Besides Christidis et al.'s (1997) study, in this study a series of strategies were also considered to improve the codes reliability and validity. In order to validate the mental models of participants, different researchers' definitions of mental models were examined (diSessa, 2002; Norman, 1983). Moreover, while coding the participants' ontological beliefs about ozone layer and its depletion, past studies (Bisanz & Leighton, 2003; Christidou & Koulaidis, 1997) were used to verify usability of categorization. In addition, validation of categorization of participants' mental models is provided by different types of data. In other words, triangulation which is the use of multiple data collection devices, sources, analysts, etc. to establish the validity of findings was used. Participants' verbal responses and drawings were used for further validation. Moreover, codes were checked by multiple researchers by actually coding of the data and different perceptions and code usage were resolved. Furthermore, consistency of the results of the categorization across participants' responses to questions and across different formats of data was constantly controlled to improve the reliability.

The qualitative researcher does not share the same level of concern for generalizability as does the quantitative researcher. Qualitative external validity concerns itself with comparability (i.e., the ability of other researchers to extend knowledge based on the "richness and depth" of the description) and translatability (i.e., the extent to which other researchers understand the results given the theory and procedures underlying the study.) (Gall, Borg, & Gall, J. P., 1996).

## 3.6. Trustworthiness of Study

Guba and Lincoln (1985) state that the goal of the trustworthiness of a qualitative research is to support the evidence that findings are worthy to attend. The main idea of trustworthiness is: How can investigator convince audiences that findings are valuable to consider if investigation is also worthy (Guba & Lincoln, 1985). Conducting a qualitative study requires four subject of trustworthiness (Guba & Lincoln, 1985). These subjects are credibility, applicability, dependability and confirmability (Sadler, 2003).

### 3.6.1. Credibility

According to Guba and Lincoln (1985), credibility means that interpretation of participants' data is trustworthy considering research findings. The triangulation strategy was used in order to ensure credibility. Triangulation is provided by using multiple sources of data and multiple investigators (Denzin, 1970). In this study,

triangulation of data collection and data analysis were used. In the data collection triangulation, audio recordings of preservice science teachers were triangulated with participants' drawings; in the data analysis triangulation participants' drawings was analyzed by two independent researchers in order to provide inter-rater consistency.

### 3.6.2. Applicability

According to Merriam (1998), applicability is being able to apply findings of study to different situations. In this study, applicability was addressed by giving preservice science teachers' descriptions such as undergraduate level, gender, and university clearly. Furthermore, for other qualitative researchers in order to be able to transfer this study's findings, data analysis documents were presented in detail.

### 3.6.3. Dependability

Dependability is the evaluation of the concurrency of data collection, data analysis and theory generation (Guba & Lincoln, 1985). In this study, consistency of data analysis was provided by inter-rater reliability. Reliability term used in quantitative research is generally analogous to dependability used in qualitative research and methods to achieve dependability and reliability are similar.

### 3.6.4. Confirmability

According to Guba and Lincoln (1985), confirmability is to what degree measure that collected data support study's findings. In this study, confirmation was provided through whom is expert in the field of elementary. Also, triangulation which was used to verify credibility of the study was utilized for verification of the study's confirmability because the techniques used to verify credibility are applicable to confirmability (Sadler, 2003).

## 3.7. Limitations of the Study

The study was subjected to the following limitations:

- This study was conducted with preservice science teachers from all grades. They were asked about environmental issues as ozone layer. However, in teacher education programs the lessons Environmental Science is given in the third year. Therefore, the freshmen and sophomore may not know the terms deeply related with the ozone layer.
- The subjects of the study were limited to preservice science teachers enrolled in one university. Therefore, more diverse samples are needed.
- Preservice science teachers' drawings may have not reflected their thoughts and mental models.

# 4. RESULTS

In this chapter, the presentation of the results was presented by comprising research questions which are:

1) What are preservice science teachers' mental models and ontological beliefs related to the role and distribution of ozone layer?
2) What are preservice science teachers' mental models and ontological beliefs related to ozone layer depletion?
3) How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different grade levels?
4) How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?
5) How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers change through different grade levels?
6) How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?

In addition to the research questions, in this chapter the presentation of the results is structured in four different parts which are:

1) Harmful and beneficial effects of sun rays

**2)** Location of the ozone layer concerning atmosphere

**3)** Materials and chemicals which are harmful for ozone layer

**4)** Misconceptions about ozone layer

## 4.1. What are preservice science teachers' mental models and ontological beliefs related to the role and distribution of ozone layer?

In this part, preservice science teachers' mental models, ontological beliefs, and reasons of developed mental models about role and distribution of ozone layer were explained below.

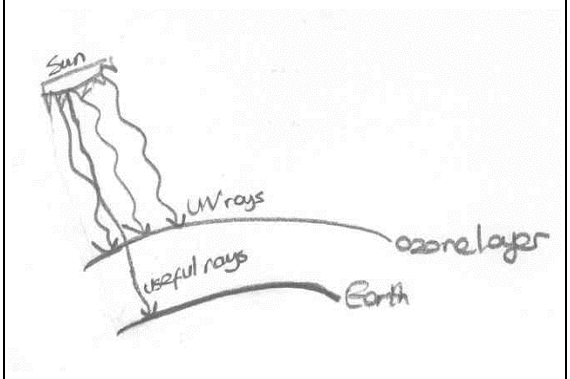
### 4.1.1. Mental Models of Preservice Science Teachers about the Role and Distribution of Ozone Layer

Ten distinct models were formed regarding role and distribution of ozone layer. Each of these models was presented below with its description, an example of preservice science teacher's verbal responses and drawings, and a diagram of researcher was also provided for each representative mental model.

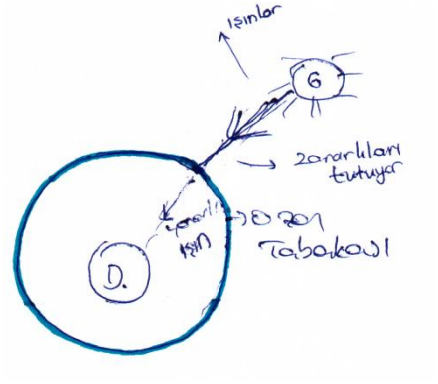
*Description of Model 1:* Ozone forms a thin layer above the Earth. This layer absorbs the ultraviolet rays (or the dangerous sun rays in general), thus preventing it from reaching the Earth, let useful rays pass and reach to Earth. A sample reflecting this model is given with below verbal excerpt and drawing taken from the participant

5G4MAG. One example was given to this mental model, however, 3 preservice science teachers formed this mental model.

> "Ozone layer is a thin layer which is above the Earth. It absorbs the Sun's harmful rays (UV rays), not reflects and it contains three oxygen atoms. It also lets Sun's useful rays pass and reach to Earth."




Christidis et al.'s drawing




Preservice science teacher's drawing

Figure 4.1 R&D Model 1

*Description of Model 2:* Ozone forms a thin layer above the Earth. The ozone layer reflects, or scatters the ultraviolet rays, thus preventing them from entering the earth, let useful rays pass and reach to Earth. A sample reflecting this model is given with below verbal excerpt and drawing taken from the participant 13G3HAG. One example was given to this mental model, however, 7 preservice science teachers formed this mental model.

> "Ozone is a gaseous layer which contains three oxygen atoms. It wraps the Earth and reflects the Sun's harmful rays (UV rays). It also let useful rays pass and reach to Earth".

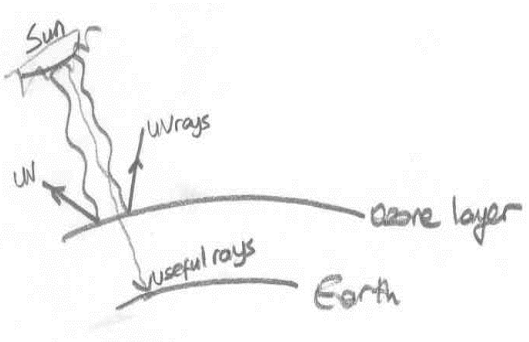
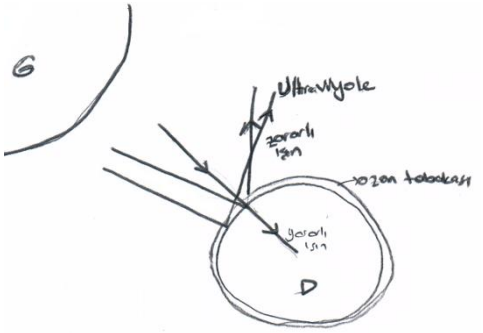
| | |
|---|---|
|  |  |
| Christidis et al.'s drawing | Preservice science teacher's drawing |

Figure 4.2 R&D Model 2

*Description of Model 3:* Ozone forms uniformly distributed layer above the Earth. This layer absorbs the ultraviolet rays (or the dangerous sun rays in general), thus preventing it from reaching the Earth, let useful rays pass and reach to Earth. A sample reflecting this model is given with below verbal excerpt and drawing taken from the participant 4G4HAG. One example was given to this mental model, however, 2 preservice science teachers formed this mental model.

> "Ozone is a gaseous layer which contains three oxygen atoms. It is on the stratosphere and is distributed evenly in the atmosphere. Its function is absorbing Sun's harmful rays (UV rays) and passing useful rays to Earth".

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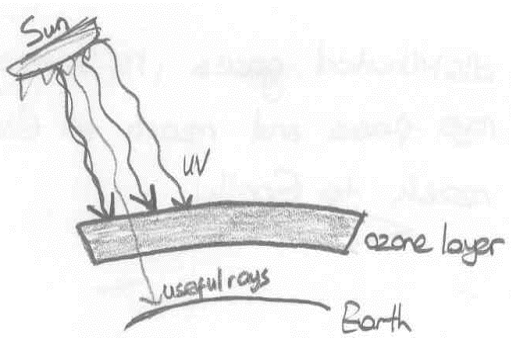
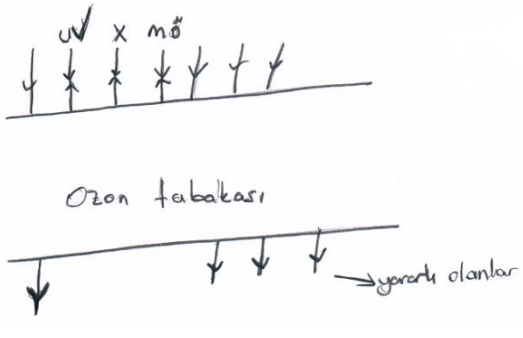
|---|---|
|  |  |
| Christidis et al.'s drawing | Preservice science teacher's drawing |

Figure 4.3 R&D Model 3

*Description of Model 4:* Ozone forms a uniformly distributed layer above the Earth. The ozone layer reflects, or scatters the ultraviolet rays, thus preventing them from entering the Earth, let useful rays pass and reach to Earth. A sample reflecting this model is given with below verbal excerpt and drawing taken from the participant 12G2HAG. One example was given to this mental model, however, 3 preservice science teachers formed this mental model.

> *"*Ozone layer is above the Earth and in the mesosphere which is the third layer of the atmosphere. It is distributed evenly in the atmosphere and contains three oxygen atoms. It is like a curtain. It protects Earth from Sun's harmful rays (UV rays) and useful rays pass from ozone layer to Earth*"*.

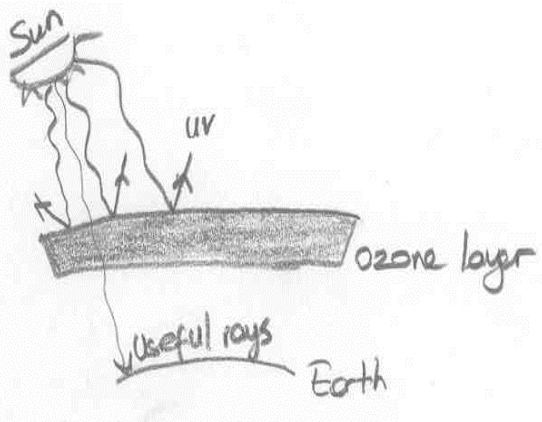
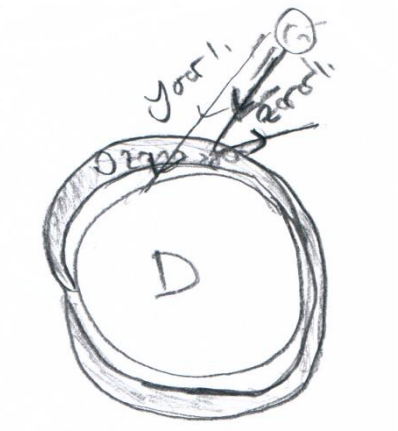
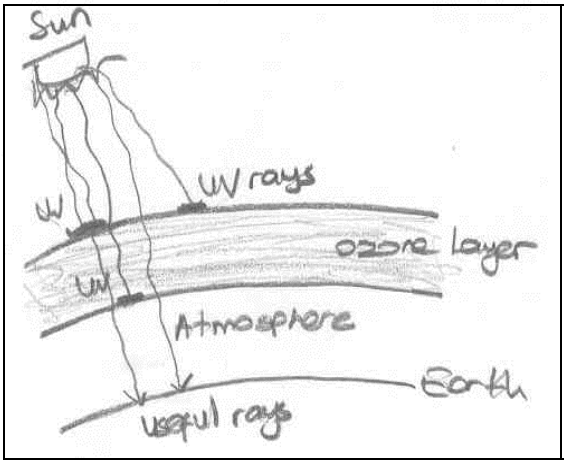
| | |
|---|---|
|  |  |
| Researcher's drawing | Preservice science teacher's drawing |

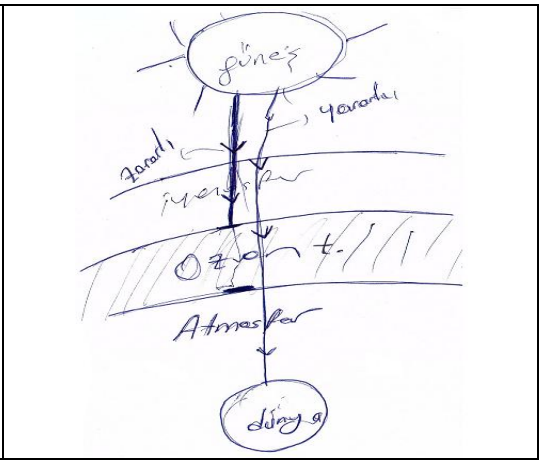
Figure 4.4 R&D Model 4

*Description of Model 5:* Ozone forms uniformly distributed layer around the atmosphere. This layer absorbs the ultraviolet rays (or the dangerous sun rays in general), thus preventing it from reaching the earth, let useful rays pass and reach to Earth. A sample reflecting this model is given from the excerpt, taken from 18G1MAB. One example was given to this mental model and only 1 preservice science teacher formed this mental model.

> "Atmosphere is in between Earth and ozone layer and contains nitrogen and other gases. It is like an umbrella because it protects the Earth from Sun's harmful rays by absorbing them. However, ozone layer lets useful rays pass and reach to Earth".




Christidis et al.'s drawing



Preservice science teacher's drawing

Figure 4.5 R&D Model 5

*Description of Model 6:* Ozone forms a thin layer around the atmosphere. The ozone layer reflects, or scatters the ultraviolet rays, thus preventing them from entering the Earth, let useful rays pass and reach to Earth. A sample reflecting this model is given from the excerpt, taken from 20G2MAG. One example was given to this mental model, however, 2 preservice science teachers formed this mental model.

> "Ozone layer is a thin gaseous layer which is out of the atmosphere. It contains chlorofluorocarbons and prevents Sun's harmful rays (UV rays) from entering to Earth's surface by scattering them. Useful rays pass to Earth through the ozone layer".

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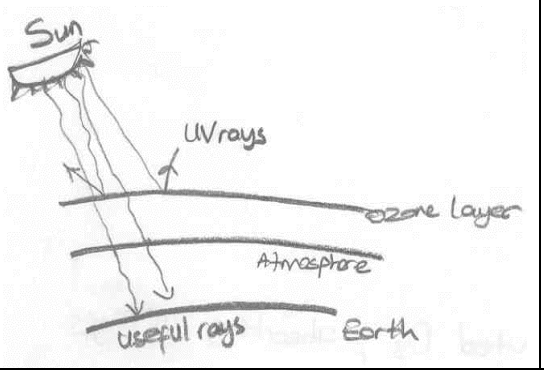
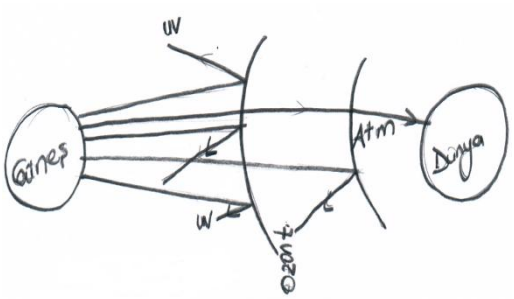
|---|---|
|  |  |
| Researcher's drawing | Preservice science teacher's drawing |

Figure 4.6 R&D Model 6

*Description of Model 7:* Ozone forms a uniformly distributed layer above the Earth. The ozone layer reflects, or scatters the some ultraviolet rays, and let some ultraviolet rays pass and reach to Earth, let useful rays pass and reach to Earth. A sample reflecting this model is given from the excerpt, taken from 3G3LAG. One example was given to this mental model, however, 2 preservice science teachers formed this mental model.

> *"*Ozone layer which is above the Earth and in the atmosphere is gaseous layer. It contains carbon dioxide, oxygen, and acids. It is like a membrane. Some harmful rays (UV rays) pass through the Earth; some is reflected by the ozone layer. However, infrared and alpha rays are come from the Sun and reach to the Earth".

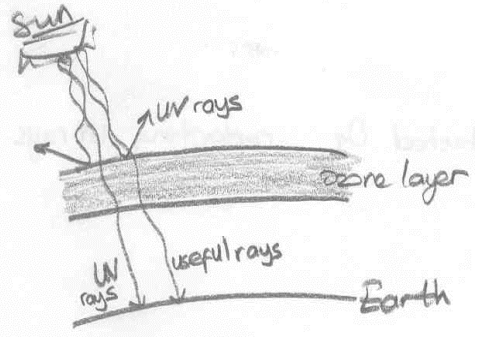
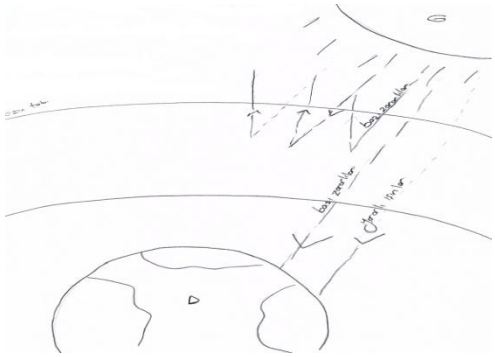
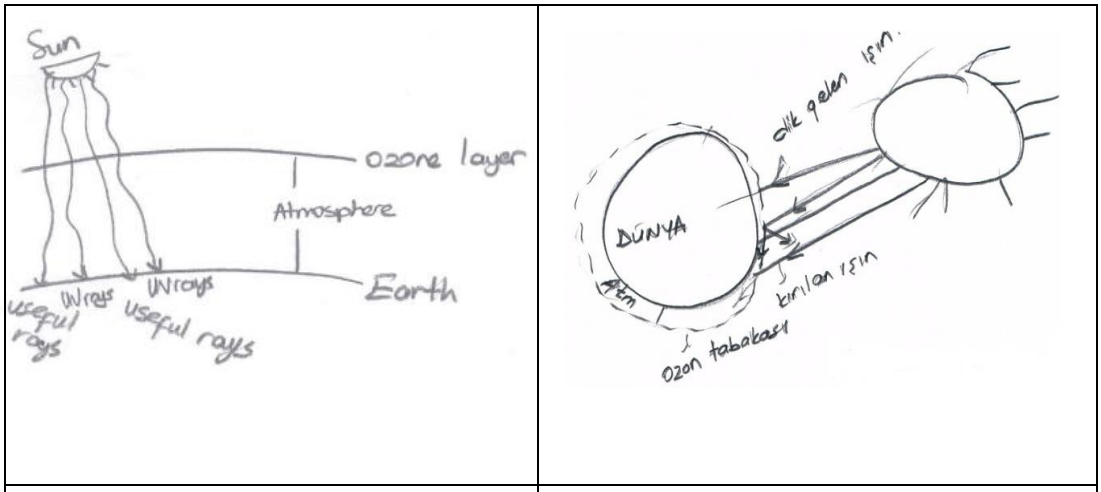
| | |
|---|---|
|  |  |
| Researcher's drawing | Preservice science teacher's drawing |

Figure 4.7 R&D Model 7

*Description of Model 8:* Ozone forms a thin layer around the atmosphere. The ozone layer let all sun rays pass and reach to Earth. A sample reflecting this model is given from the excerpt, taken from 17G2LAG. One example was given to this mental model, however, 2 preservice science teachers formed this mental model.

> "Ozone layer is inflammable because it contains oxygen. Atmosphere is in between Earth and ozone layer. It is like clothes of the Earth. All Sun's rays reach to earth by being broken or perpendicularly".




| Researcher's drawing | Preservice science teacher's drawing |
|---|---|

Figure 4.8 R&D Model 8

*Description of Model 9:* Ozone forms a thin layer above the Earth. The ozone layer absorbs the ultraviolet ray A and C, thus preventing them from entering the earth, let ultraviolet B and useful rays pass and reach to Earth. A sample reflecting this model is given from the excerpt, taken from 19G2MAG. One example was given to this mental model and only 1 preservice science teacher formed this mental model.

> "Ozone layer exists in the atmosphere and wraps the Earth. It contains methane, nitrogen and oxygen gases. Ultraviolet rays which is divided into three such as UV-A, UV-C (harmless) and UV- B (harmful). Ozone layer absorbs UV-A and UV-C. It is also let UV- B and useful rays pass and reach to Earth".

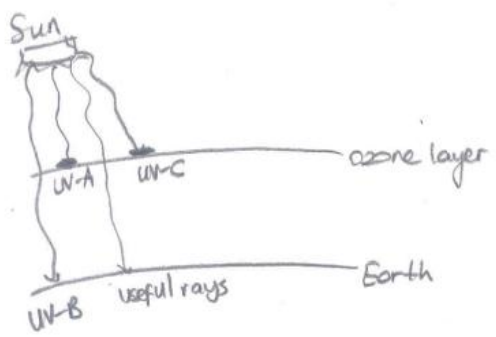
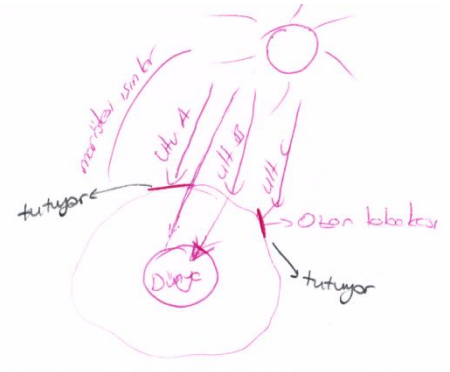
| | |
|---|---|
|  |  |
| Researcher's drawing | Preservice science teacher's drawing |

Figure 4.9 R&D Model 9

*Description of Model 10:* Ozone forms uniformly distributed layer around the atmosphere. This layer reflects some ultraviolet rays (or the dangerous sun rays in general), thus preventing it from reaching the Earth, let some ultraviolet rays and useful rays pass and reach to Earth. A sample reflecting this model is given from the excerpt, taken from 2G4MAB. One example was given to this mental model and only 1 preservice science teacher formed this mental model.

> "Atmosphere is in between the Earth and the ozone layer. It is gaseous layer and contains three oxygen atoms. Also, ozone layer reflects some harmful rays (UV rays, infrared, alpha, beta, and gamma); some of these rays reach to Earth and is reflected to the atmosphere again. Useful rays reach to the Earth".

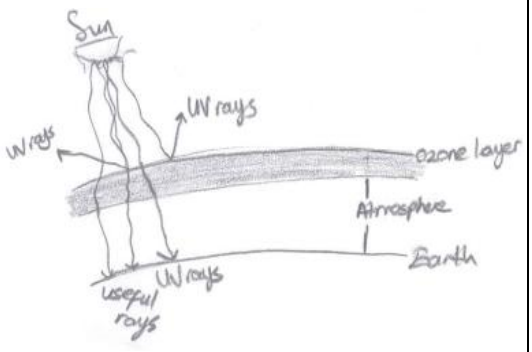
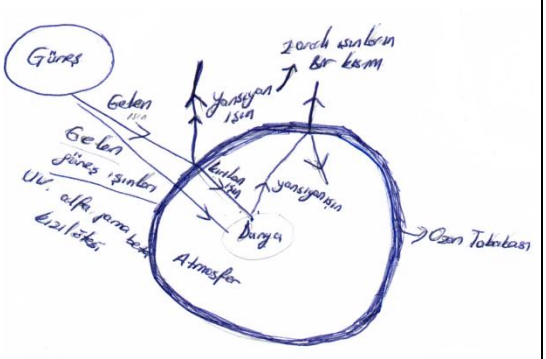
| | |
|---|---|
|  |  |
| Researcher's drawing | Preservice science teacher's drawing |

Figure 4.10 R&D Model 10

### 4.1.2. Ontological Beliefs of Preservice Science Teachers about the Role and Distribution of Ozone Layer

Ontological belief categories were taken from in the study of Christidis, Christidou, & Koulaidis (1997). In this study all of the ontological beliefs were found thus they are presented in the order of object, substance and person. The concepts introduced in ontological beliefs in this study involved three categories which are dividing surface, absorbing/reflecting surface, and air/atmosphere. Absorbing and reflecting surface was mostly seen ontological belief.

### 4.1.3. Reasons for Developing above Mental Models

Pre-service science teachers' models of role and distribution of ozone layer includes various alternative conceptions. In this study, reasons why they constructed

ten different mental models were explained. The reasons used by the participants were presented below (Christidou & Koulaidis, 1996):

**1)** ***Lack of Distinction between UV and Solar Radiation:*** Preservice science teachers did not make distinct conceptual differentiation between UV and other harmful solar radiation or Sun's rays. Models of role and distribution of ozone layer and ozone layer depletion were affected from this lack of distinction.

**2)** ***Lack of the Absorption Mechanism of UV by Ozone:*** Preservice science teachers who explain the role and distribution of ozone layer as reflecting harmful solar radiation was imperfect. Thus, they did not conceptualize that ozone layer can absorb UV rays.

**3)** ***Atmosphere Conceptualized as Entirely Homogeneous:*** Atmosphere was considered as entirely homogeneous mixture which includes ozone. Preservice science teachers saw ozone layer as uniformly distributed in the atmosphere.

**4)** ***Ozone Layer not Localized Around the Earth:*** This reason implies that ozone layer is thin, surrounds the atmosphere and filters Sun's harmful rays.

**5)** ***Ozone Hole not Interpreted as a Decrease in Ozone Concentration:*** Preservice science teachers considered decrease in ozone concentration as ozone hole. This reason caused misconceptions about depletion of ozone layer.

### 4.1.4. Relationship between Mental Models and Ontological Beliefs

Table 4-1 presents the frequencies of the types of ontological beliefs and reasons used for the models of the role and distribution.

Table 4-1 Frequencies of the Types of Ontological Beliefs Used for the Mental Models of the Role and Distribution of Ozone Layer

| Mental Model | Ontological Belief | | | Grade Level | | | | Achievement Level | | | R | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Dividing Surface | Abs.Ref. Surface | Air/ Atmosphere | 1 | 2 | 3 | 4 | Low | Middle | High | | |
| **Model 1** | | 3 | | | | 1 | 2 | 2 | 1 | | 1 | 3 |
| **Model 2** | | 6 | 1 | 3 | 1 | 2 | 1 | 1 | 2 | 4 | 1,2 | 7 |
| **Model 3** | | 2 | | | | 1 | 1 | | 1 | 1 | 1,2 | 2 |
| **Model 4** | | 3 | | | 2 | 1 | | 1 | | 2 | 1,2,3 | 3 |
| **Model 5** | 1 | | | 1 | | | | | 1 | | 1,3,4 | 1 |
| **Model 6** | 1 | 1 | | 1 | 1 | | | | 1 | 1 | 1,2,4 | 2 |
| **Model 7** | | 1 | 1 | 1 | | 1 | | 2 | | | 1,2,3 | 2 |
| **Model 8** | 1 | 1 | | | 1 | | 1 | 2 | | | 1,2,4 | 2 |
| **Model 9** | | 1 | | | 1 | | | | 1 | | 1 | 1 |
| **Model 10** | | 1 | | | | | 1 | | 1 | | 1,2,3,4 | 1 |
| **Total** | 3 | 19 | 2 | | | | 1 | 8 | 8 | 8 | | 24 |

* ‘R’ prefix represents reason for developing mental model.
* Number in the table represents frequency.

As tabulated in the above Table 4-1 preservice science teachers' responses were mostly seen as mental model 2 which is ozone layer is a layer around the Earth, thin, reflects UV rays, and let useful rays pass and reach to Earth. Moreover, absorbing and reflecting surface was mostly seen ontological belief. Lastly, all of the mental models were due to reason 1which is lack of distinction between UV and solar radiation. There was relationship between preservice science teachers' mental models and ontological beliefs.

In order to explain the role and distribution of ozone layer, the interpretations of this correlation were specifically:

**1.** Preservice science teachers who have R&D model 1, 2, 3, 4, 6, 7, 8, 9, and 10 prefer the ontological belief 'absorbing/reflecting surface'.

**2.** Preservice science teachers who have R&D model 2 and 7tend to consider the ontological belief 'air/atmosphere'.

**3.** Preservice science teachers who have R&D model 2 mostly tend to consider the ontological belief 'absorbing/reflecting surface'.

**4.** Preservice science teachers who have R&D model 5, 6, and 8 (included that ozone layer is a layer around the atmosphere) tend to consider the ontological belief 'dividing surface' (layer or umbrella).

In order to describe the role and distribution of ozone layer:

**1.** Preservice science teachers who have R&D model 5, 6, and 8 (included that ozone layer is a layer around the atmosphere) have low grade level (GL1 and 2).

**2.** Preservice science teachers who have R&D model 5, 6, and 8 (included that ozone layer is a layer around the atmosphere) are low and middle achiever.

More specifically;

- Preservice science teacher who has R&D model 2 and air/atmosphere ontological belief is freshman and middle achiever.
- Preservice science teacher who has R&D model 7and air/atmosphere ontological belief is freshman and low achiever.
- Preservice science teacher who has R&D model 5and dividing surface ontological belief is freshman and middle achiever.
- Preservice science teacher who has R&D model 6and dividing surface ontological belief is freshman and high achiever.
- Preservice science teacher who has R&D model 8and dividing surface ontological belief is sophomore and low achiever.
- Preservice science teachers who are high achievers tend to consider absorbing/reflecting ontological belief; only one of them considered dividing surface ontological belief.
- Preservice science teachers who are high achievers do not tend to consider air/atmosphere ontological belief.

### 4.2. What are preservice science teachers' mental models and ontological beliefs related to ozone layer depletion?

In this part, it is aimed to determine preservice science teachers' mental models, ontological beliefs, and reasons of developed mental models about ozone layer depletion.

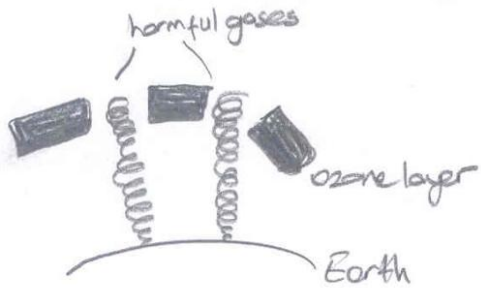
### 4.2.1. Mental Models of Preservice Science Teachers about Ozone Layer Depletion

Five distinct models were formed regarding ozone layer depletion. Each of these models was presented below with an example of preservice science teacher's response indicative of the respective models, and a diagram of researcher and preservice science teacher.

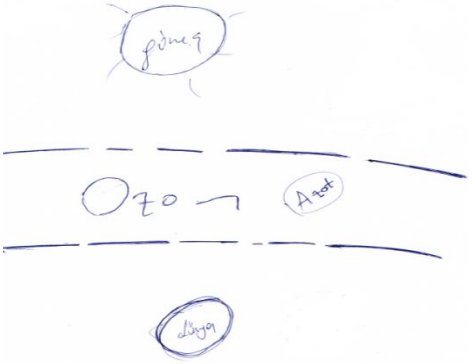
*Description of Model 1:*

Ozone layer depletion is local and there are holes on ozone layer. Ozone hole means that ozone has disappeared. A sample reflecting this model is given from the excerpt, taken from 9G4HAG. One example was given to this mental model, however, 6 preservice science teachers formed this mental model.

"Ozone layer depletion about which makes us worry today is important topic. This layer has holes in European countries and hole is gradually expanding. Chlorofluorocarbon, carbon dioxide, nitrogen and methane cause depletion. Hole means that there is no ozone in that region".




Christidis et al.'s drawing




Preservice science teacher's drawing

Figure 4.11 D Model 1

*Description of Model 2:*

Ozone layer consists of three oxygen atoms. Depletion of layer means that ozone concentration has decreased. A sample reflecting this model is given from the excerpt, taken from 1G1MAB. One example was given to this mental model, however, 8 preservice science teachers formed this mental model.

> "Greenhouse gases scatter gases which prevent harmful rays in ozone layer and ozone layer gases concentration decreases. So, depletion is greater in which greenhouse gases amount is much than in other places".

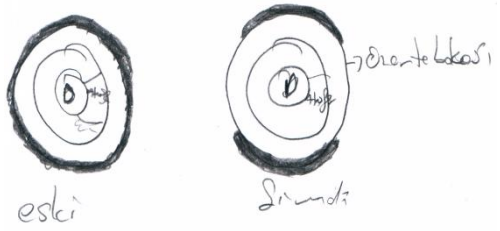
| | |
|---|---|
|  |  |
| Christidis et al.'s drawing | Preservice science teacher's drawing |

Figure 4.12 D Model 2

*Description of Model 3:*

Ozone layer depletion is local. Depletion means that ozone layer becomes thinner and thinner. A sample reflecting this model is given from the excerpt, taken from 15G2HAG. One example was given to this mental model, however, 3 preservice science teachers formed this mental model.

"Harmful gases like carbon dioxide and carbon monoxide go up to ozone layer and interact with ozone layer gases, so ozone layer gets thinner. Places where there is a lot of industrialization, ozone layer is thinner than where there are a lot of trees".

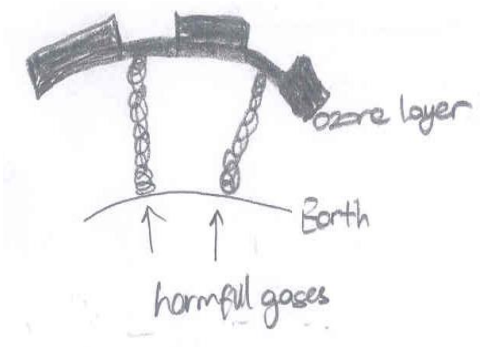
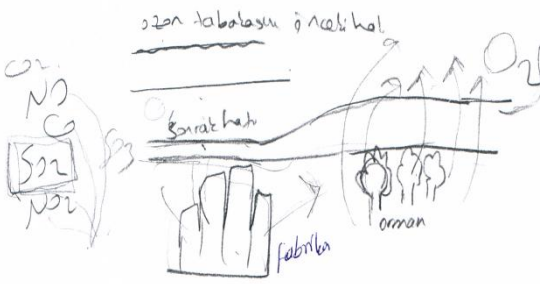
| | |
|---|---|
|  |  |
| Christidis et al.'s drawing | Preservice science teacher's drawing |

Figure 4.13 D Model 3

*Description of Model 4:*

Ozone layer depletion is same in everywhere, not local. Ozone layer is thinning all over the world. A sample reflecting this model is given from the excerpt, taken from 2G4MAB. One example was given to this mental model, however, 3 preservice science teachers formed this mental model.

"Harmful gases such as exhaust, perfume and factory gases; all gases which give harm to environment go up ozone layer and ozone layer gets thinner. Normally, ozone layer is thick, but it is thinning. I think that this thinning is general, not local".

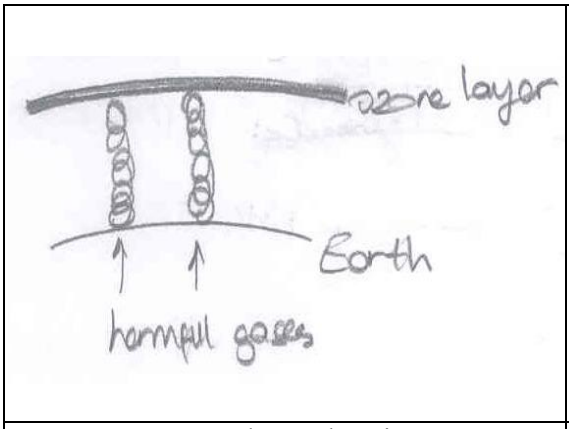
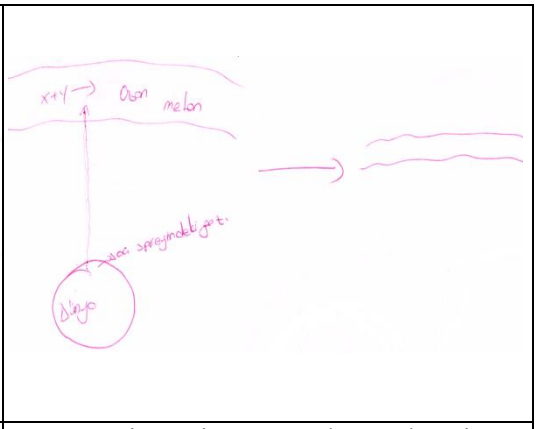
| | |
|---|---|
|   |  |
| Researcher's drawing | Preservice science teacher's drawing |

Figure 4.14 D Model 4

*Description of Model 5:*

Ozone layer is thinning all over the world and then it has holes on itself. A sample reflecting this model is given from the excerpt, taken from 7G3HAG. One example was given to this mental model, however, 4 preservice science teachers formed this mental model.

"Chlorofluorocarbon gases rise to ozone layer and then, $O_3$ molecules are disrupted. Ozone layer gets thinner and further it will has hole on it. Harmful gases pass through this hole".

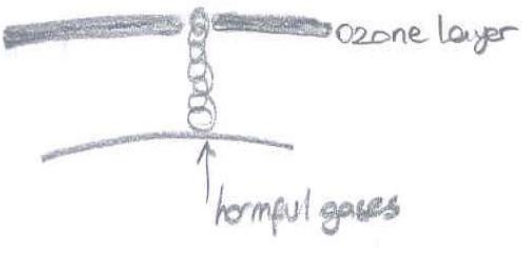
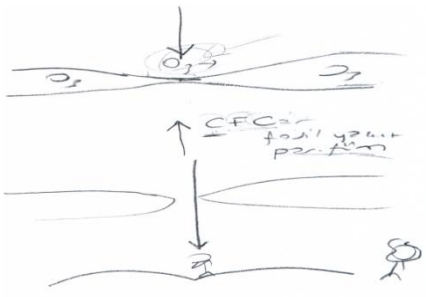
| | |
|---|---|
|   |  |
| Researcher's drawing | Preservice science teacher's drawing |

Figure 4.15 D Model 5

### 4.2.2. Ontological Beliefs of Science Teachers about Ozone Layer Depletion

The concepts introduced in ontological beliefs involved four categories which are container, substance, hole and person illustrated in Figure 3.3. Hole was mostly seen ontological belief.

### 4.2.3. Reasons for Developing above Mental Models

***Atmosphere Conceptualized as Entirely Homogeneous (R3):*** Atmosphere was considered as entirely homogeneous mixture which includes ozone. Preservice science teachers saw ozone layer as uniformly distributed in the atmosphere.

***Ozone Hole not Interpreted as a Decrease in Ozone Concentration (R5):*** Preservice science teachers considered decrease in ozone concentration as ozone hole. This reason caused misconceptions about depletion of ozone layer.

### 4.2.4. Relationship between Mental Models and Ontological Beliefs

Table 4-2 presents the frequencies of the types of ontological beliefs and reasons used for the models of ozone layer depletion.

Table 4-2 Frequencies of the Types of Ontological Beliefs Used for the Mental Models of the Ozone Layer Depletion

| Mental Model | Ontological Belief | | | | Grade Level | | | | Achievement Level | | | R | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Container | Substance | Hole | Person | 1 | 2 | 3 | 4 | Low | Middle | High | | |
| **Model 1** | | | 2 | | 2 | | | | 1 | 1 | | 5 | 6 |
| | | | 2 | | | 2 | | | 2 | | | | |
| | | | 2 | | | | | 2 | 1 | | 1 | | |
| **Model 2** | 1 | | | | 1 | | | | | 1 | | | |
| | | | | 1 | | | 1 | | 1 | | | 3 | 3 |
| | | | 1 | | | | | 1 | | 1 | | | |
| **Model 3** | 1 | 1 | | | 1 | 2 | 1 | | | | 4 | | |
| | 2 | 3 | | | | | | | | | | 3 | 8 |
| | | 1 | | | | 1 | 2 | 1 | | 4 | | | |
| **Model 4** | | | 1 | | 1 | | | | | | 1 | | |
| | 1 | | | | | | 1 | | 1 | | | - | 3 |
| | | 1 | | | | | | 1 | | 1 | | | |
| **Model 5** | | | 1 | | 1 | | | | 1 | | | | |
| | | | 1 | | | 1 | | | | 1 | | | |
| | | | 1 | | | | 1 | | | | 1 | 5 | 4 |
| | | | 1 | | | | | 1 | 1 | | | | |
| **Total** | 5 | 6 | 12 | 1 | 6 | 6 | 6 | 6 | 9 | 7 | 3 | | 24 |

* 'R' prefix represents reason for developed mental model
* Number in the table represents frequency.
*- represents the absence of reasons

As seen from the above table, preservice science teachers' responses especially second and third grade preservice teachers' were mostly seen as mental model 3 which is ozone layer depletion is local thinning down of the ozone layer. Moreover, hole was mostly seen ontological belief. Lastly, only third and fifth reasons were seen in ozone layer depletion models 1, 2 and 5. Mental models 3 and 4 were not related with any reasons. There was relationship between preservice science teachers' mental models and ontological beliefs.

In order to describe ozone layer depletion the interpretations of correlation between mental models and ontological beliefs were specifically:

**1.** Preservice science teachers who have D model 1 and 5 prefer the ontological belief 'hole'.

**2.** Preservice science teachers who have D model 4 tend to consider the ontological belief 'container', 'substance' and 'hole'.

**3.** Preservice science teachers who have D model 2 tend to consider the ontological belief 'container', 'hole' and 'person'.

**4.** Preservice science teachers who have D model 3 tend to consider the ontological belief 'container' and 'substance'.

**5.** Preservice science teachers who have D model 3 do not tend to consider the ontological belief 'hole' and 'person'.

**6.** Preservice science teacher who has the ontological belief 'person' tend to consider D model 2.

In order to describe ozone layer depletion:

- Preservice science teacher who has R&D model 2 and person ontological belief is junior and low achiever.
- Preservice science teachers who are sophomore do not tend to consider D model 2 and 4.
- Preservice science teachers who are junior do not tend to consider D model 1.
- Preservice science teachers who are high achievers mostly prefer D model 3.
- Preservice science teachers who are high achievers do not tend to consider D model 2.
- Preservice science teachers who are low achievers do not tend to consider D model 3.
- Preservice science teachers who have ontological belief 'hole' are mostly freshman, sophomore and senior; only one of the juniors has this belief.

### 4.3. How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different grade levels?

Preservice science teachers' responses were mostly seen as mental model 2 for role and distribution of ozone layer. 3$^{rd}$ and 4$^{th}$ grade preservice science teachers had different mental models, so grade level did not make difference among preservice science teachers' mental models about role and distribution of ozone

layer. Also, mental model 5, 6 and 8 which were about ozone layer around the atmosphere were seen in the 1st, 2nd, and 4th grade level preservice science teachers.

Preservice science teachers' responses especially second and third grade teachers' were mostly seen as mental model 3 which is ozone layer depletion is local thinning down of the ozone layer. Grade level did not make difference among preservice science teachers' mental models about ozone layer depletion.

### 4.4. How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?

Half of the high achievers formed mental model 2 for role and distribution of ozone layer. Achievement level did not make difference among preservice science teachers forming which type of mental models. Moreover, mental model 5, 6 and 8 which are layer around the atmosphere were formed by low achiever, middle achiever, and high achiever.

Any of low achievers formed mental model 3 for ozone layer depletion. Low achievers formed mental model 1 mostly and high achievers formed mental model 3 mostly. Achievement level made difference among preservice science teachers' mental models about ozone layer depletion.

### 4.5. How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers' change through different grade levels?

Absorbing /reflecting surface was mostly seen ontological belief for role and distribution of ozone layer. Specific examples of this type of ontological belief, that were frequently used during the interviews, include that ozone layer reflects and absorbs UV rays, and protects the Earth from the UV rays. While the grade level was increasing, the number of preservice science teachers who had absorbing/reflecting ontological belief also increased. Hence, grade level made difference among preservice science teachers' ontological beliefs about role and distribution of ozone layer. Moreover, hole was mostly seen ontological belief for ozone layer depletion. Preservice science teachers who had hole ontological belief were mostly freshman and senior. As a result, grade level did not make difference among preservice science teachers' ontological beliefs about ozone layer depletion.

### 4.6. How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?

Hole was mostly seen ontological belief for ozone layer depletion and absorbing and reflecting surface was mostly seen ontological belief for role and distribution of ozone layer. Approximately the same number of high achiever, middle achiever, and low achiever had absorbing/reflecting surface ontological belief.

Hence, achievement level did not make significant difference among preservice science teachers' ontological beliefs about role and distribution of ozone layer. However, hole ontological belief was seen mostly in low achiever. Achievement level made difference among preservice science teachers' ontological beliefs about ozone layer depletion.

## 4.7. Results of the Study Comprising Sun's Rays, Ozone layer Location and Misconceptions

### 4.7.1. Harmful and Beneficial Effects of Sun's Rays

***Harmful Effects of Sun's Rays:*** Before asking questions about ozone layer, warm up questions were asked to preservice science teachers. One of them was "Scientist say that you should wear sunscreen or suntan lotion when you are out in the sun. Why do you think they say that you should do this?" And the following question was "Why would it be bad for us to be burned by the Sun's rays?" Table 4-3 gives the descriptive information about harmful effects of Sun's rays.

Table 4-3 Harmful Effects of Sun's Rays

| | **Grade Level** | | | | **Achievement Level** | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **Low** | **Middle** | **High** | |
| Wound | 1 | | | | | 1 | | 1 |
| Sunburn | 4 | 2 | 1 | 3 | 2 | 5 | 3 | 10 |
| Skin Cancer | 5 | 6 | 5 | 3 | 7 | 6 | 6 | 19 |
| Skin Spot | | 3 | | | 1 | 2 | | 3 |

Table 4.3 Continued / 1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Cataract | | 1 | | | | 1 | | 1 |
| Allergy | | 1 | 1 | | | 1 | 1 | 2 |
| Hereditary Disease | | 1 | | | | 1 | | 1 |
| Immune System Disease | | 1 | | | | | 1 | 1 |
| Infertility | | | 1 | | | | 1 | 1 |
| Headache | | | | 1 | 1 | | | 1 |
| Mutation | 1 | | | 1 | 1 | | 1 | 2 |
| Sun Palpitation | | | 1 | 2 | 3 | | | 3 |
| Eye Disease | | 1 | 2 | | 1 | 1 | 1 | 3 |
| Nose bleeding | | | | 1 | | 1 | | 1 |
| Drowsiness | | | | 1 | | 1 | | 1 |
| Vomitus | | | | 1 | | 1 | | 1 |
| Fainting | | | | 1 | | 1 | | 1 |
| **Total** | 11 | 16 | 11 | 14 | 16 | 22 | 14 | 52 |

* Number in the table represents frequency.

As mentioned in the introduction chapter, harmful effects of ultraviolet rays are skin cancer, sunburn, skin spot, cataract, and immune system diseases (Mutlu, Şen, & Toros, 2003; İmal, İnan, & Onat, 2004)

As tabulated in the above table, preservice science teachers' responses were mostly seen as skin cancer and sunburn. Some of the preservice science teachers from each grade level considered skin cancer and sunburn. Only some of sophomores mentioned about cataract, skin spot and immune system disease while one freshman and senior mentioned about mutation. Therefore, grade level did not make difference among preservice science teachers' responses. Moreover, frequency of low achiever who considers harmful rays cause to skin cancer was slightly higher than the middle

and high achiever; frequency of middle achiever who considers harmful rays cause to sunburn was higher than the low and high achiever. Preservice science teacher who mentioned cataract was middle achiever; who mentioned immune system was high achiever; who mentioned mutation were low and high achiever and finally who mentioned eye disease were low, middle and high achiever as harmful effects. Hence, achievement level did not make difference among preservice science teachers' responses.

***Beneficial Effects of Sun's Rays:*** As mentioned in the introduction chapter, there are beneficial effects of Sun's rays such as photosynthesis, sense of seeing, and help people to secrete vitamin D (Mutlu, Şen, & Toros, 2003). Preservice science teachers think that Sun has useful rays. According to their responses the following question was asked: "What are the beneficial effects of useful Sun rays?" Table 4-4 gives the descriptive information about beneficial effects of Sun rays.

Table 4-4 Beneficial Effects of Sun's Rays

| | **Grade Level** | | | | **Achievement Level** | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **Low** | **Middle** | **High** | |
| Activation of vitamin D | 3 | 3 | 3 | 2 | 3 | 4 | 4 | 11 |
| Activation of vitamin E | 1 | | | | 1 | | | 1 |
| Photosynthesis of plants | 3 | 3 | 2 | 1 | 3 | 3 | 3 | 9 |
| Bone growing | 3 | | 1 | 2 | 2 | 3 | 1 | 6 |
| Heat source | | 1 | 2 | | 2 | | 1 | 3 |
| Suntanning | | | | 1 | 1 | | | 1 |
| **Total** | 10 | 7 | 8 | 6 | 12 | 10 | 9 | 31 |

* Number in the table represents frequency.

As tabulated in the above table, preservice science teachers' responses were mostly seen as activation vitamin D and photosynthesis of plants. Some of the preservice science teachers from each grade level considered activation of vitamin D and photosynthesis of plants as beneficial effects. Therefore, grade level did not make difference among preservice science teachers' responses. Moreover, frequency of middle achiever and high achiever who considers useful rays activate vitamin D was higher than the low achiever; frequency of low, middle, and high achiever who considers useful rays have roles in photosynthesis of plants was the same. Achievement level did not make difference among preservice science teachers' responses.

### 4.7.2. Location of Ozone Layer Concerning Atmosphere

In order to examine the preservice science teachers' knowledge about location of ozone layer, they are asked to draw atmosphere. Table 4.3 gives descriptive information about location of ozone layer in the atmosphere.

Table 4-5 Location of Ozone Layer Concerning Atmosphere

| | **Grade Level** | | | | **Achievement Level** | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **Low** | **Middle** | **High** | |
| Ozone is in the atmosphere | 4 | 3 | 5 | 1 | 5 | 4 | 4 | 13 |
| Ozone is out of the atmosphere | 2 | 3 | 1 | 5 | 3 | 4 | 4 | 11 |
| **Total** | 6 | 6 | 6 | 6 | 8 | 8 | 8 | 24 |

* Number in the table represents frequency.

As seen from the above table, approximately half of preservice science teachers thought that ozone layer exists in the atmosphere whereas; other half thought that ozone layer exists out of the atmosphere. In addition, frequency of third grade level preservice science teacher who said that ozone layer is situated in the atmosphere was more than other grade levels. However, except from one senior, other seniors considered ozone layer as out of the atmosphere. Hence grade level did not make difference among preservice science teachers' responses. Moreover, there is no difference among low, middle and high achiever while considering location of ozone layer. Lastly, preservice science teachers generally said that ozone layer is middle layer of atmosphere and only two of them mentioned about the exact location of ozone layer as stratosphere (4G4HAG, 14G3MAB).

### 4.7.3. Materials and Chemicals Hazardous to Ozone Layer

All preservice science teachers concerned about ozone layer depletion. When they are asked interview question 6 which is: "Is there something about the ozone layer that makes us worry today?" Responses were thinning down of ozone layer or hole in the ozone layer.

Table 4-6 Materials Hazardous to Ozone Layer

| | **Grade Level** | | | | **Achievement Level** | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **Low** | **Middle** | **High** | |
| Stove | 1 | 1 | 1 | | 1 | 1 | 1 | 3 |
| Coal | 1 | 1 | 1 | 1 | 3 | 1 | | 4 |
| Car | 2 | 3 | 2 | 3 | 4 | 5 | 1 | 10 |
| Perfume | 5 | 3 | 4 | 4 | 5 | 7 | 4 | 16 |

Table 4-6 Continued / 1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Deodorant | 2 | 2 | 5 | 5 | 7 | 4 | 3 | 14 |
| Fridge | | 2 | 1 | 1 | 1 | | 3 | 4 |
| Spray | 2 | 2 | 2 | 1 | 1 | 3 | 3 | 7 |
| Mobile phone | | 1 | 1 | 1 | 2 | 1 | | 3 |
| Computer | | 1 | 1 | 1 | 2 | 1 | | 3 |
| Air conditioner | | 1 | 1 | 1 | 1 | | 2 | 3 |
| Cabin heater | | 1 | | | | | 1 | 1 |
| Feeding bottle | | | 1 | | | | 1 | 1 |
| Microwave oven | | | 1 | | 1 | | | 1 |
| Cigarette | 1 | | | 1 | 1 | 1 | | 2 |
| Hair drier | | | 1 | | 1 | | | 1 |
| Factory | | | 1 | 2 | | 3 | | 3 |
| Nuclear plant | | | | 1 | | 1 | | 1 |
| **Total** | 14 | 18 | 23 | 22 | 30 | 28 | 19 | 77 |

* Number in the table represents frequency.

Table 4-6 presents the materials that cause to this thinning down of or hole in the ozone layer. As seen from the table, preservice science teachers' responses were mostly seen as perfume, deodorant, car, and spray as harmful materials. Materials that cause to global warming were confused with materials that cause to ozone layer depletion. Generally, materials which contain carbon were considered as a cause of depletion. Although there was not an evident tendency of increasing knowledge about materials as the grade level of the participants increased, statements given by higher graders were observed to be more comprehensive. There was also not an evident tendency of increasing knowledge about materials as the achievement level of the participants increased. Moreover, Table 4-7 presents the chemicals that cause to ozone layer depletion.

Table 4-7 Chemicals Hazardous to Ozone Layer

| | Grade Level | | | | Achievement Level | | | Total |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **Low** | **Middle** | **High** | |
| Cyanide | 1 | | | | 1 | | | 1 |
| Plastic | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 4 |
| Methane | | 2 | 1 | 1 | 1 | 3 | | 4 |
| Ozone | | 1 | | | | 1 | | 1 |
| Chlorine | | | | 1 | | | 1 | 1 |
| Chlorofluorocarbon | | | 5 | 4 | 2 | 3 | 4 | 9 |
| Hydro chlorofluorocarbon | | | | 1 | | | 1 | 1 |
| Methyl bromide | | | | 1 | | | 1 | 1 |
| Carbon monoxide | | 4 | 3 | 3 | 4 | 4 | 2 | 10 |
| Carbon dioxide | 1 | 2 | 3 | 3 | 5 | 3 | 1 | 9 |
| Nitrogen | 1 | | | | | 1 | | 1 |
| Nitrate | | | 1 | | 1 | | | 1 |
| Nitrogen dioxide | | 1 | | 1 | 1 | | 1 | 2 |
| Sulphur | 1 | | 1 | | | 2 | | 2 |
| Sulphur dioxide | | 1 | | | | | 1 | 1 |
| Sulphur trioxide | | 1 | | | | | 1 | 1 |
| Sulfuric acid | | | 1 | | 1 | | | 1 |
| Agrochemicals | | 1 | | | | | 1 | 1 |
| Pesticide | 1 | 1 | | | | | 2 | 2 |
| Petroleum | 1 | | | | 1 | | | 1 |
| Factory gases | | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| Exhaust gases | | 3 | 1 | 1 | 2 | 2 | 1 | 5 |
| Fossil fuel gases | | | 2 | | 1 | | 1 | 2 |
| Radioactive gases | | | | 1 | | 1 | | 1 |
| **Total** | 7 | 19 | 2 | 19 | 22 | 22 | 21 | 65 |

* Number in the table represents frequency.

Analyses revealed that chlorofluorocarbon, carbon monoxide, and carbon-dioxide were the most seen responses. It is also seen from the table,

chlorofluorocarbon was mentioned by higher graders. Hydro chlorofluorocarbon, methyl bromide, and chlorine which cause to thinning down of the ozone layer were mentioned by only one participant who was senior and high achiever (4G4HAG). There was also not an evident tendency of increasing knowledge about chemical as the achievement level of the participants increased. Moreover, greenhouse gases (e.g. carbon dioxide, methane) were confused with gases that cause to ozone layer depletion. Finally, nitrogen dioxide and sulphur dioxide gases which cause to acid rain were confused with gases that cause to ozone layer depletion.

### 4.7.4. Misconceptions about Sun's Rays and Ozone Layer

In this study, similar misconceptions were found when compared with past studies. These misconceptions are: Preservice teachers think that ozone holes causes global warming. They think that holes allow the sun rays enter and lead to raise in the Earth's temperature (Boys & Stanisstreet, 1993; Groves & Pugh, 1999). Some of them think that global warming is the incoming solar radiation through the ozone "hole" and ignore any entrapment (Boys & Stanisstreet, 1993). Moreover, some of them think that ozone layer as if it is consisted of many compounds and they believe that there exist one or more "holes" (Papadimitriou, 2004). Khalid's (2003) study revealed other misconceptions. These are ozone depletion and greenhouse effects are connected with each other; the stratospheric ozone can be damaged by car and factory exhausts; one of the causes of ozone depletion is $CO_2$ and ozone depletion may increase Earth's temperature.

Furthermore, different misconceptions were found in the study. These are: Sun's harmful rays cause to global warming; Sun has useful and harmful rays; UV rays are alpha, beta, and gamma rays; UV rays are infrared rays; atmosphere is between Earth and ozone layer; greenhouse gases cause to ozone layer depletion; global warming cause to holes in the ozone layer; acid rains ruin the structure of ozone layer; ozone layer depletion cause to global warming; hole in the ozone layer cause to acid rain; place where there are a lot of trees does not cause to ozone layer depletion and place where there are a lot of industrialization cause to more thinning down of ozone layer. All of these misconceptions were represented in Table 4-8.

Table 4-8 Misconceptions about Sun's Rays and Ozone Layer

| | **Grade Level** | | | | **Achievement Level** | | | **Total** |
|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **Low** | **Middle** | **High** | |
| Sun's harmful rays cause to global warming | | 1 | | | | | 1 | 1 |
| Sun has useful and harmful rays | 6 | 6 | 6 | 6 | 8 | 8 | 8 | 24 |
| UV rays are alpha, beta, and gamma rays | | | | 1 | 1 | | | 1 |
| UV rays are infrared rays | | | | 1 | 1 | | | 1 |
| Atmosphere is between Earth and ozone layer | | 1 | | | 1 | | | 1 |
| Greenhouse gases cause to ozone layer depletion | 1 | | | | | 1 | | 1 |
| Global warming cause to holes in the ozone layer | | | 1 | | 1 | | | 1 |
| Acid rains ruin the structure of ozone layer | | | 1 | | 1 | | | 1 |

Table 4-8 Continued / 1

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ozone layer depletion cause to global warming | 1 | 1 | 2 | | 2 | 1 | 1 | 4 |
| Hole in the ozone layer cause to acid rain | 1 | | | 1 | | 1 | 1 | 2 |
| Place where there are a lot of trees does not cause to ozone layer depletion | 1 | 1 | | | 1 | | 1 | 2 |
| Place where there are a lot of industrialization cause to more thinning down of ozone layer | | 1 | | | 1 | | | 1 |
| Total | 10 | 11 | 10 | 9 | 17 | 11 | 12 | 40 |

* Number in the table represents frequency.

All of the preservice science teachers divided Sun's rays into two: Harmful rays and useful rays. They were also connected ozone layer depletion with global warming and acid rain. These environmental issues have causal relationship (Khalid, 2001). In this study, it is found that language cause to misconceptions. Preservice science teachers knew ultraviolet rays as purple and beyond rays in Turkish translation. They supposed these terms alike. Moreover, they confused component of ozone layer and atmosphere. They believed that ozone layer contains oxygen, carbon dioxide, nitrogen, and low portions of other gases.

# 5. DISCUSSION

In this chapter, summary of the study, conclusions and discussions of its findings as well as its implications and recommendations for further research are presented.

## 5.1. Summary of the Study

In order to investigate previously explained purposes of this qualitative study, a convenience sample of 24 preservice science teachers who were enrolled in Elementary Science Education Program of Education Faculty of one public university located in Central Anatolia participated in this study. In addition, interview which contains 11 questions with sub questions were carried out in order to determine participants' mental models and ontological beliefs about role and distribution of ozone layer and its depletion. Data collection was realized over 2010-2011 Spring semesters and was completed after two months. Interviews were transcribed and analyzed qualitatively to bring out the participants' mental models and ontological beliefs about role and distribution of ozone layer and its depletion.

## 5.2. Discussions

The purpose of this study was to determine the preservice science teachers' mental models and ontological beliefs about role and distribution of ozone layer and

its depletion. In the light of this purpose this research study attempted to answer the following research questions:

1) What are preservice science teachers' mental models and ontological beliefs related to the role and distribution of ozone layer?
2) What are preservice science teachers' mental models and ontological beliefs related to ozone layer depletion?
3) How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different grade levels?
4) How do mental models about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?
5) How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers change through different grade levels?
6) How do ontological beliefs about the role and distribution of ozone layer and its depletion of preservice science teachers change through different achievement levels?

In the following parts of the study, results of the study considering harmful and beneficial effects of Sun's rays, location of the ozone layer considering atmosphere, materials and chemicals which are harmful for ozone layer, and misconceptions about ozone layer; results of the study considering above research questions were discussed.

### 5.2.1. Harmful and Beneficial Effects of Sun Rays

All of the preservice science teachers divided sun rays into two categories: Harmful rays and beneficial rays. However, in the literature it is mentioned that there are harmful and beneficial effects of Sun rays. Preservice science teachers consider harmful effects as harmful rays and beneficial effects as beneficial rays. They may give reason by plain logic. Moreover, skin cancer and sun burn were mostly seen responses to harmful effects. Only some of sophomores mentioned about cataract, skin spot and immune system disease. However, juniors and seniors were supposed to mention about these effects because they took Environmental Science course in $6^{th}$ semester. They may have forgotten content of the lesson due to memorization. Content of the textbook was given in the Table 3-1 Syllabus of the Environmental Science Course. It was mentioned about ozone layer tangentially in the textbook. In addition, there was no difference among low, middle and high achievers' responses to harmful effects of Sun rays while we were supposed that high achievers will have been more knowledgeable about the harmful effects of Sun's rays.

Activation vitamin D and photosynthesis of plants were the mostly seen responses to beneficial effects. They were the most known responses. This may be cause of daily life experience. Adults always say that babies sometimes should stay under Sun because Sun helps bond grow up. Moreover, there was no difference among low, middle and high achievers' responses. There was also no difference among different grade level students' responses. The reason for participants' responses not changing through different achievement level and grade level may be topics being general. Also, ozone layer is abstract in nature, so preservice science

teachers cannot internalize ozone layer and its depletion. Moreover, at each level according to preservice science teachers interesting, they can read these topics from internet, books or science journal and watch from TV. At the end of the interview, when researcher asked that where did you get information about ozone layer, they generally said that I read from newspaper and especially watch from the TV.

### 5.2.2. Location of the Ozone Layer Concerning Atmosphere

Frequency of juniors who said that ozone layer is situated in the atmosphere was more than other grade levels because they were taking Environmental Science course during fifth semester when they participated to interview. However, seniors who also took this course could not response correctly. Most of them said that ozone layer is out of atmosphere. They also confused the layers of atmosphere and layers of Earth. They may have forgotten content of the course within one year. This means that they memorize the topics. Moreover, they were preparing to KPSS (Public Staff Selection Test). Approximately all of the preservice science teachers were motivated to achieve this test in order to be a teacher. Therefore, they did not noticed anything except from their must course.

Moreover, there was no difference among low, middle and high achievers while considering location of ozone layer. All of the preservice science teachers may not be interested in ozone layer topic evenly. Hence, low achievers may be more knowledgeable about ozone layer and its location. Lastly, preservice science teachers generally said that ozone layer is middle layer of atmosphere and only two of them mentioned about the exact location of ozone layer as stratosphere (4G4HAG,

14G3MAB). They were junior and senior, so they may have known topic from the Environmental Science course.

### 5.2.3. Materials and Chemicals which are Harmful for Ozone Layer

Preservice science teachers' responses were mostly seen as perfume, deodorant, car, and spray as harmful materials. Materials that cause to global warming were confused with materials that cause to ozone layer depletion. This confusion may be due to the TV, media and misuse of the internet. Generally, materials which contain carbon were considered as a cause of depletion. Although there was not an evident tendency of increasing knowledge about materials as the grade level of the participants increased, statements given by higher graders were observed to be more comprehensive. There was also not an evident tendency of increasing knowledge about materials as the achievement level of the participants increased.

Analyses revealed that chlorofluorocarbon, carbon monoxide, and carbon-dioxide were the most seen responses. It is also seen from the table, chlorofluorocarbon was mentioned by higher graders because in the Science Education Program there is an Environmental Science course which includes ozone layer topic in the fifth semester. Hydro chlorofluorocarbon, methyl bromide, and chlorine which cause to thinning of ozone layer were mentioned by only one participant, 4G4HAG. Moreover, greenhouse gases were confused with gases that cause to ozone layer depletion. Preservice science teachers generally get information from TV or media. These sources may not be reliable; however, they trust these

sources without questioning. As the literature has shown, in the learning process environmental issues are constructed from out-of-school sources. Global environmental problems have been learned by receiving knowledge from the media and other informal sources. Lee (2008) found that African American college students' major sources of information about environmental issues were television and internet. Similarly, Chan (1998) found that major sources of environmental information were television, school, and newspaper. Hence, they obtain wrong and inadequate knowledge. Their responses may be inadequate or wrong due to this situation and memorization of the knowledge. Preservice science teachers who are in higher grade level could not know ozone layer topic in detailed although they were taking course concerned this topic. We thought that content of course was not sufficient and detailed, topics were mentioned tangentially.

### 5.2.4. Misconceptions about Ozone Layer

Misconceptions found in this study are confirmatory to a number of research found in the literature. Different misconceptions were also found in the study. Preservice science teachers were connected ozone layer depletion with global warming and acid rain. These environmental issues have causal relationship (Khalid, 2001). While Environmental Science course book was being examined, it was found that only tropospheric ozone was mentioned. Moreover, it was said that 3-7 % ozone gases cause to greenhouse effect, so preservice science teachers may thought that ozone layer depletion cause to global warming.

In this study, it is also found that language cause to misconceptions. Preservice science teachers knew ultraviolet rays as purple and beyond rays in Turkish translation. Moreover, they believed that ozone layer contains oxygen, carbon dioxide, nitrogen, and low portions of other gases as atmosphere contains. One reason for all of these misconceptions may be instructor having misconceptions. Another reason may be having beliefs to all knowledge from media and in the internet without questioning (see Appendix C). Finally, textbooks may also have misconceptions which are transformed to reader directly.

### 5.2.5. Mental models and ontological beliefs of preservice science teachers about the role and distribution of ozone layer and reasons for developing mental models

Ten distinct models were formed regarding role and distribution of ozone layer. Preservice science teachers' responses were mostly seen as mental model 2. This model explains that ozone layer is a thin layer around the Earth, reflects UV rays, and lets useful rays pass and reach to Earth. All of the mental models include that ozone layer reflects or absorbs UV rays and lets useful rays pass and reach to Earth. Most of them think that UV rays does not pass and reach to Earth. Only one preservice science teacher (19G2MAG) mentioned types of UV rays. When Environmental Science course textbook was examined, it was found that types ofUV-rays were not mentioned, so juniors and seniors who took this course were also not supposed to know types of UV rays. In addition to UV rays, they did not know absorption mechanism of ozone layer. One reason for not knowing something

about UV rays and absorption mechanism may be that they memorize topics, do not make research, and are not interested in environmental topics. They are contended with things heard from media. Finally, in the Science Education program environmental topics were not given place sufficiently. Moreover, half of the high achievers formed this mental model for role and distribution of ozone layer. Achievement level did not make difference among preservice science teachers forming which type of mental models. High achievers may have high GPA due to memorization, so it does not make difference. Furthermore, absorbing and reflecting surface was mostly seen ontological belief. Specific examples of this type of ontological belief, that were frequently used during the interviews, include that ozone layer reflects or absorbs UV rays, and protects the Earth from the UV rays. Lastly, all of the mental models contained reason 1 which is preservice science teachers being lack of distinction between UV and Solar radiation. Preservice science teachers did not make distinct conceptual differentiation between UV and other harmful solar radiation or Sun's rays. Models of role and distribution of ozone layer and ozone layer depletion were affected from this lack of distinction.

### 5.2.6. Mental models and ontological beliefs of preservice science teachers about ozone layer depletion and reasons for developing mental models

Five distinct models were formed regarding ozone layer depletion. Preservice science teachers' responses especially second and third grade teachers' were mostly seen as mental model 3 which is ozone layer depletion is local thinning down of the

ozone layer. Any of low achievers formed this mental model. Low achievers formed mental model 1 mostly and high achievers formed mental model 3 mostly. Hence, we can say that high achievers are most knowledgeable than low achievers considering ozone layer depletion. Participants generally had an idea about depletion of ozone layer but they did not know the place and role of ozone layer exactly. This may because of the fact that ozone layer depletion rather than role and distribution of ozone layer is the most spoken environmental issue in the lesson or on media.

In addition, participants whose ontological belief was either substance or container formed mental model 3. Another mental model which was seen mostly is model 2 (Local but total destruction of ozone layer; Ozone hole: Ozone has disappeared). As seen from the results, some of the participants thought that ozone layer had hole on it because they heard from TV and read from unreliable sources (see Appendix C). Some of the participants thought that ozone layer is thinning down because they read from scientific sources or their teacher said them.

Moreover, hole was mostly seen ontological belief. When a preservice science teacher understands the depletion of the thin ozone layer as a local decrease in its concentration, or as a decrease in its thickness, (s)he prefers the category of a substance or container rather than that of a hole (which could imply the local but total destruction or the complete absence of ozone) to explain it. Moreover, participants, whose mental models were 1 and 5, had ontological belief 'hole'. They may have ontological belief hole because they do not read scientific articles and journals; do not make research about environmental topics. They are contended with things heard from TV and internet. We live in society which is not researcher and curious.

Lastly, only third and fifth reasons were seen in ozone layer depletion models 1, 2 and 5. Mental model 3 and 4 do not include hole in the ozone layer and do not see ozone layer as uniformly distributed in the atmosphere; so there was no reason in mental models 3 and 4.

### 5.3. Implications of the Study

Human beings have a struggle with the environment and this causes certain environmental problems. In solving such problems having conscious individuals is very important. This may be possible with an effective environmental education. Environmental education can be defined as development of environmental consciousness in all society; gaining positive and permanent changes in behavior; protecting natural, cultural, historical and socio-aesthetic values; be assigned in solutions of problems. Environmental Education holds a unique place in formal public education (Campbell, Jerez, Erdoğan & Zhang, 2010). Moreover, environmental education is an interdisciplinary, that is, it focuses more discipline of science (i.e. chemistry, biology, physics and earth science). As a consequence, environmental education has been integrated into the school curriculum so that students have necessary environmental knowledge and can show environmentally responsible behavior.

This study has revealed some implications that should be taken into consideration by instructor and researchers who deal with environmental education programs. Environmental education courses should not only supply environmental

knowledge but also should supply that people can develop environmental responsibility.

Preservice science teachers use ontological beliefs in a consistent way in order to represent their mental models about role and distribution of ozone layer and ozone layer depletion. Hence, ontological beliefs can be valuable in order to represent abstract nature of ozone layer. However, inappropriate ontological beliefs can cause deficient mental model. There are reasons for developing incomplete models. These reasons could provide guidelines to teachers in order to help students detach their thinking from their alternative conceptions, so they can be valuable educational tool if they appropriately used in teaching.

The widely used ontological belief 'hole' seems to be valuable and helpful so as to understand the ozone layer and ozone layer depletion. Moreover, according to results, ontological belief 'air/atmosphere' which cause to construction of inadequate model should be avoided while explaining the role and distribution of ozone layer. Introduction of 'absorbing surface' ontological belief could lead to construction of more complete models regarding role and distribution of ozone layer. Preservice science teachers preferred ontological belief 'hole' which is interpreted ozone layer depletion as complete but local destruction of ozone (D model 1). Their thoughts about ozone layer depletion are limited that ozone layer depletion is not seemed as decrease in concentration. Based on the results, ontological belief 'substance' can be useful for constructing more adequate model which represents ozone layer depletion as a decrease in ozone concentration. Hence, ontological belief 'substance' can be beneficial and helpful educational tool for teaching ozone layer depletion. On the

other hand, ontological belief ‘hole’ should strictly be avoided in order not to cause misunderstanding. As a result, this study can be extremely valuable in determining preservice science teachers’ alternative conceptions and where teaching should focus in order to cope with these conceptions. Teaching materials could be beneficial for constructing more adequate models about the role and distribution of ozone layer and its depletion.

Giving an effective environmental education in education faculties possesses additional importance because teachers affect students in many topics. Therefore, environmental education program should be applied to all levels of education in all grade levels.

Interviews with the participants showed that environmental concerns are affected by the use of media. Therefore, environmental issues in media such as television, internet and newspapers should be enhanced and presented properly.

### 5.4. Recommendations for Further Research

Based on the findings of this study and previous research, following recommendations can be offered for further research:

In order to generalize results, larger sample which includes preservice science teachers from different universities, departments and regions of the country, can be used. Furthermore, future research can be expanded to primary and secondary education.

According to the findings, contents of environmental science courses may be reorganized and should include detailed information about current environmental problems. As mentioned previously, preservice science teachers should be teached about using reliable sources while getting information from internet. Moreover, the reason for not finding any difference in mental models and ontological beliefs of participants may be due to the characteristics of the sample. Thus, there is need to research with more diverse sample.

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## APPENDIX A

List of 57 ozone facts grouped under corresponding categories

### A. The Sun and Adverse Consequences

**1)** The sun rays contain ultraviolet radiation.

**2)** Ultraviolet light is harmful to life on earth.

**3)** Ultraviolet light decreases plant crop yield (plant growth) by interfering with photosynthesis.

**4)** The sun can burn you.

**5)** Ultraviolet light can cause diseases/pain/hurt in humans.

**6)** Ultraviolet light can cause diseases/pain/hurt in land animals.

**7)** Ultraviolet light causes skin aging/wrinkling.

**8)** Ultraviolet light causes cataracts.

**9)** Ultraviolet light causes some forms of (skin) cancer.

**10)** Ultraviolet light causes immune system suppression.

**11)** Ultraviolet light reduces aquatic life, kills phytoplankton, and kills krill.

### B. Ultraviolet Light

**1)** Ultraviolet light is the harmful part of the sun's rays.

**2)** There are many types of ultraviolet light. The most harmful types are UVA and UVB.

**3)** Ultraviolet light cannot be seen because it surpasses the violet in the color spectrum.

**C. Ultraviolet Light and Human Behavior**

**1)** Skin can be protected by wearing clothing such as a long-sleeved shirt, long pants, and a wide-brimmed hat.

**2)** Skin can be protected by wearing sunscreen with a sun-protection factor of at least 15–20.

**3)** Eyes can be protected by wearing sunglasses that absorb ultraviolet light.

**4)** Time spent in the sun should be minimized from 10.00 hours to 15.00 hours.

**5)** If behavior changes accordingly then diseases associated with ozone depletion will be reduced.

**D. Ozone Composition**

**1)** The earth is surrounded by an atmosphere.

**2)** The atmosphere is composed of a mixture of gases.

**3)** Oxygen is a gas in the atmosphere.

**4)** Ozone is a gas in the atmosphere.

**5)** Ozone is composed of three oxygen atoms.

**6)** One of the three oxygen atoms is loosely attached.

**7)** Ozone blocks ultraviolet light by absorbing ultraviolet light with short wave lengths.

**8)** Ozone is created naturally in the earth's atmosphere when ultraviolet light splits oxygen molecules which recombine.

**9)** Ozone is destroyed naturally in the earth's atmosphere when naturally occurring catalysts break down ozone molecules.

**10)** Ozone creation and destruction are balanced naturally.

**11)** Ozone can be destroyed by contact with industrial/special/harmful chemicals.

**E. Ozone Destruction**

**1)** Human beings have disrupted the natural balance of ozone creation and destruction.

**2)** Human beings have increased the amount of industrial chemicals in the atmosphere.

**3)** Industrial/special/harmful chemicals rise slowly in the atmosphere.

**4)** Industrial/special/harmful chemicals are discharged by aircraft into the atmosphere.

**5)** Some of these industrial/special/harmful chemicals contain catalysts that break down ozone.

**6)** Chlorine is a catalyst that breaks down ozone.

**7)** Chlorofluorocarbons are industrial/special/harmful chemicals.

**8)** Chlorofluorocarbons are propellants in some aerosol cans.

**9)** Chlorofluorocarbons are coolants in refrigerators.

**10)** Chlorofluorocarbons are coolants in air conditioners.

**11)** Chlorofluorocarbons are in blowing agents in some foam/styrofoam products.

**12)** Chlorofluorocarbons are used to produce some cleaning agents.

**13)** Chlorofluorocarbons collect at the poles (north & south poles).

**14)** Chlorofluorocarbons are swept up by the polar vortex from the industrialized countries.

**15)** Chlorofluorocarbons are broken up by the sun's rays.

**16)** Chlorine atoms are released when chlorofluorocarbons are broken up by the sun's rays.

**17)** Chlorine atoms capture the loose oxygen atom from the ozone molecule.

**18)** Chlorine atoms and the loose oxygen atoms form Chlorine Monoxide.

**19)** Chlorine Monoxide releases the chlorine atom when new oxygen atoms are formed in the presence of heat.

**20)** Released chlorine atoms break up more ozone.

**21)** The breakdown of ozone molecules can cause holes in the ozone layer.

**22)** The first ozone hole was detected over Antarctica.

**23)** New ozone holes are predicted to appear over other parts of the world.

**24)** Holes in the ozone layer will result in increased exposure to ultraviolet light.

**25)** Ozone hole/depletion causes public fear of disease.

**26)** Public fear of diseases necessitates behavior change outdoors.

**27)** Ozone hole/depletion has led to international agreements to reduce use of these industrial/special/harmful chemicals.

## APPENDIX B

## GÖRÜŞME SORULARI

**1)** Güneş insanlara, hayvanlara ve bitkilere yararlı olan ışık ve enerjiyi verir. Güneş ışığı olmadan bu gezegende yaşayamayız. Bazı bilim adamları güneş ışınlarına maruz kaldığımız zamanlarda güneş yanığı losyonu ya da güneş kremi sürmemiz gerektiğini söylemektedirler. Neden böyle yapmamız gerektiğini hakkında ne düşünüyorsunuz?

- Bizim için zararlı güneş ışınlarına maruz kalmamız neden kötü olurdu?

**2)** Bütün güneş ışınları mı zararlıdır?

**3)** Güneşin zararlı ışınlarının adlarını biliyor musunuz?

- Ultraviyole ışını nedir?
- Ultraviyole ışını hakkında daha başka söyleyeceğiniz bir şeyler var mı?

**4)** Atmosfer nedir?

- Atmosferin tabakaları nelerdir?
- Tabakaların sıralaması nasıldır?
- Bu tabakaları çizimle gösterebilir misiniz?
- Atmosfer hakkında daha başka söyleyeceğiniz bir şeyler var mı?

**5)** Güneş ve gezegenimiz arasında bizi güneşin zararlı ışınlarına karşı koruyan herhangi bir şey var mı?

- Ozon tabakası nedir?
- Ozon tabakası nerede bulunur, çizimle gösterebilir misin?
- Ozon tabakasının görevleri nelerdir, çizimle gösterbilir misin?

- Ozon tabakası hakkında daha başka söyleyeceğiniz bir şeyler var mı?

**6)** Günümüzde ozon tabakası ile ilgili bizi endişelendirecek şeyler var mı?

- Ozon tabakası incelmesi nedir, çizimle gösterebilir misin?
- Ozon tabakası incelmesi hakkında daha başka söyleyeceğiniz bir şeyler var mı?

**7)** Tüm dünyayı düşünürsek atmosferin tamamı mı incelmiştir yoksa belirli kısımları mı incelmiştir?

**8)** Ozon tabakası incelmesi neden başladı?

**9)** İnsanların kullandığı ve ozon tabakasına zarar verdiği düşünülen eşyaların (malzemelerin) neler olduğunu söyleyebilir misiniz?

**10)** Ozon tabakasına zarar veren kimyasal maddelerin ne olduğu hakkında bilgi verebilir misiniz?

- Kloroflorokarbon gazı nedir?
- Kloroflorokarbon gazı hakkında daha başka söyleyeceğiniz bir şeyler var mı?

**11)** Ozon tabakası incelmesinden kendisini koruması gerekenler sadece biz insanlar mıyız? Yoksa gezegenimizde korunması gereken daha başka şeyler var mı?

# APPENDIX C

**Ozon Tabakasında Endişelendiren Delik**

02 Ekim 2011 22:00

Kuzey Kutbu üzerindeki ozon tabakasında açılan ve Almanya'nın beş katı büyüklüğündeki delik bilimadamlarını endişelendiriyor. Amerikan Havacılık ve Uzay Dairesinin (NASA) internet sitesinde yer alan ve Nature dergisinde yayımlanan makalede, Kuzey Kutbu'nda görülmedik bir soğuğa yol açan bu rekor büyüklükteki deliğin geçen nisanda 15 gün kadar Doğu Avrupa, Rusya ve Moğolistan üzerinde dolaştığı, deliğin bu bölgelerde yaşayan insanların yüksek derecelerde ultraviyole (morötesi) ışınlara maruz kalmalarına yol açtığı kaydedildi. 3 atom oksijeninden oluşan ozon molekülü, özellikle bitki örtüsüne zarar veren ve cilt kanserine ya da katarakta yol açabilen ultraviyole ışınlarının zararlarından dünyayı koruyor. Dünyanın bu doğal kalkanı kışları ve ilkbaharları, soğutma sistemleri ve aerosollarda kullanılan ve 1985'ten beri üretimi yasak olan kloroflorokarbon (CFC) gazları yüzünden inceliyor. Bilimadamları, Kuzey Kutbu'ndaki bu rekor büyüklükteki ozon tabakası deliğinin sorumlusunun kışları kuzey kutup stratosfer tabakasında oluşan dev kasırga "kutup girdabı" olduğunu belirterek, bu doğa olayının geçen kış çok soğuk bir ortamda oluşmasının ozon tabakasına çok daha fazla zarar verdiğinin altını çiziyorlar.

# APPENDIX D


## TEZ FOTOKOPİ İZİN FORMU

**ENSTİTÜ**

| | |
|---|---|
| Fen Bilimleri Enstitüsü | |
| Sosyal Bilimler Enstitüsü | X |
| Uygulamalı Matematik Enstitüsü | |
| Enformatik Enstitüsü | |
| Deniz Bilimleri Enstitüsü | |

**YAZARIN**

Soyadı: Yanış
Adı: Hilal
Bölümü: İlköğretim Fen ve Matematik Eğitimi

**TEZİN ADI:** Investigating Preservice Science Teachers' Understanding of Role and Distribution of Ozone Layer and Ozone Layer Depletion through Mental Models and Ontological Beliefs.

**TEZİN TÜRÜ:** Yüksek Lisans [X] Doktora [ ]

1. Tezimin tamamı dünya çapında erişime açılsın ve kaynak gösterilmek şartıyla tezimin bir kısmı veya tamamının fotokopisi alınsın. [ ]
2. Tezimin tamamı yalnızca Orta Doğu Teknik Üniversitesi kullanıcılarının erişimine açılsın. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [ ]
3. Tezim bir (1) yıl süreyle erişime kapalı olsun. (Bu seçenekle tezinizin fotokopisi ya da elektronik kopyası Kütüphane aracılığı ile ODTÜ dışına dağıtılmayacaktır.) [X]

Yazarın imzası: Tarih: