INVESTIGATING PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDINGS AND USE OF MODELS

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

AYŞE YENİLMEZ TÜRKOĞLU

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT OF ELEMENTARY EDUCATION

MARCH 2013

Approval of the Graduate School of Social Sciences

Prof. Dr. Meliha Altunışık
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy.

Prof. Dr. Jale Çakıroğlu
Head of Department

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 Doctor of Philosophy.

Prof. Dr. Ceren Öztekin
Supervisor

Examining Committee Members

Prof.Dr. Ömer Geban	(METU, SSME)	
Prof.Dr. Ceren Öztekin	(METU, ELE)	
Assoc.Prof.Dr. Semra Sungur Vural	(METU, ELE)	
Assist.Prof.Dr. Ömer Faruk Özdemir	(METU, SSME)	
Dr. Şule Özkan Kaşker	(Ulusal Ajans)	

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : Ayşe Yenilmez Türkoğlu

Signature :

ABSTRACT

INVESTIGATING PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDINGS AND USE OF MODELS

Yenilmez Türkoğlu, Ayşe
Ph.D., Department of Elementary Education
Supervisor : Prof. Dr. Ceren Öztekin

March 2013, 286 pages

To gain a better understanding of pre-service science teachers' (PSTs') views of models, a case study was conducted with fourteen PSTs in a large public university in Ankara. The study aims to provide an answer to the research question, 'What understandings do PSTs possess about scientific models and the models used in science education?' and to explore how they use these models in their classroom practices. Data were collected using an open-item instrument, semi-structured interviews, class observations, and lesson plans; and were analyzed using qualitative data analyses methods, where transcriptions from the instrument and interviews were repeatedly examined for the purpose of revealing the codes and categories about PSTs' understandings of models, while lesson plans and class observations were examined in terms of their use of models in classroom practices. Findings showed that PSTs held *fragmented* views of models by having informed views in some aspects while having naïve views on other aspects. While they displayed a 'constructivist orientation' by acknowledging the presence of multiple models for the same phenomenon depending on scientists' perspective or creativity involved in the production of scientific knowledge, the PSTs also expressed 'logical positivist' views by believing that models should be close to the real phenomena. Further, although PSTs perceived models as useful tools for teaching science and showed strong willingness towards using them, they had difficulties in integrating them in their classroom practices. These findings evidenced the intention-practice gap and the need to support PSTs in terms of pedagogical content knowledge about models.

Keywords: Scientific Models, Teaching Models, Nature of Models, VOMMS, Pre-Service Science Teachers, Science Education

ÖZ

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ MODELLER HAKKINDAKİ ANLAYIŞLARI VE MODEL KULLANIMLARININ İNCELENMESİ

Yenilmez Türkoğlu, Ayşe
Doktora, İlköğretim Bölümü
Tez Yöneticisi : Prof. Dr. Ceren Öztekin

Mart 2013, 286 sayfa

Bu çalışmanın amacı, fen bilgisi öğretmen adaylarının, bilimsel modeller hakkındaki anlayışlarını ve modelleri sınıf ortamlarında nasıl kullandıklarını araştırmaktır. Bu amaçla, Ankara'da büyük bir üniversitede son sınıf öğrencisi olarak öğrenim gören ve 'İlköğretimde Öğretmenlik Uygulamaları' dersine kayıtlı olan on dört fen bilgisi öğretmen adayıyla bir durum çalışması gerçekleştirilmiştir. Araştırmanın verileri, açık uçlu bir ölçek (VOMMS), yarı yapılandırılmış görüşmeler, ders planları ve sınıf gözlemleriyle toplanmış olup, nitel veri analizi yöntemleriyle analiz edilmiştir. VOMMS ölçeğinden elde edilen bulgularla görüşme kayıtlarının yazılı dökümleri, öğretmen adaylarının modeller hakkındaki anlayışlarını gösteren kodlar ve temaları ortaya çıkaracak şekilde analiz edilirken; ders planları ve sınıf gözlemleri ise, öğretmen adaylarının öğretmenlik uygulamalarında modelleri nasıl kullandıklarını araştırmak amacıyla incelenmiştir. Bulgular, öğretmen adaylarının modeller ile ilgili olarak bazı alanlarda bilgili iken diğerlerinde sınırlı anlayışlara sahip olduklarını göstermiştir. Örneğin, öğretmen adayları, bilim adamlarının bakış açısı ve bilimsel bilginin oluşturulmasında yaratıcılığın etkisine bağlı olarak bir olgu için birden fazla model oluşturulabileceğinin farkındayken, aynı zamanda, modellerin gerçek olguya benzemesi gerektiğini görüşünü de savunmuşlardır. Ayrıca, öğretmen adayları, modellerin fen eğitiminde önemli bir yere sahip olduklarını düşünüp, sınıf uygulamalarında model kullanmaya çok istekli olduklarını belirtirken, derslerine modelleri entegre etmekte zorluk yaşamışlardır. Bu bulgular, öğretmen adaylarının modelleri kullanma konusundaki niyetleri ile sınıf uygulamalarındaki farklılıkları göstermiş ve öğretmen adaylarının modeller hakkında pedagojik alan bilgisine olan ihtiyaçlarını ortaya koymuştur.

Anahtar Kelimeler: Bilimsel Modeller, Öğretim Modelleri, Modellerin Doğası, VOMMS, Öğretmen Adayları, Fen Eğitimi

To My Little Daughter Çağla

ACKNOWLEDGEMENTS

First and foremost, I would like to express my sincere appreciation to my supervisor Prof. Dr. Ceren Öztekin for her guidance, valuable contributions, suggestions, constructive criticism, encouragements and patience throughout this study.

I would also like to thank Assist. Prof. Dr. Ömer Faruk Özdemir for the suggestions and comments he provided about the analyses of the data. I extend my thanks to the committee members Prof. Dr. Ömer Geban, Assoc. Prof. Dr. Semra Sungur Vural, and Dr. Şule Özkan Kaşker for their valuable contributions to my dissertation.

I am also grateful to my friends Kader Bilican and Erdinç İşbilir for their valuable help in the analyses of data. I would also like to thank to my dear friends, Dilek Karışan, Deniz Kahriman and Özlen Demircan, not only for their emotional support but also encouragements and friendship.

My special thanks go to my mother for taking care of my daughter and showing endless patience in the sleepless nights. If it was not for her, I would never be able to complete this dissertation. I am also grateful to my family for their encouragement, patience, and love.

I am further grateful to the participants of this study for the valuable data they provided by sharing their opinions and devoting their valuable time for this study.

Finally, I would also like to express my gratitude to the Scientific and Technological Research Council of Turkey (TUBITAK) for supporting me with the 'National PhD Scholarship'.

TABLE OF CONTENTS

LIST OF TABLES

TABLES

LIST OF FIGURES

FIGURES

LIST OF ABBREVIATIONS

PST	Pre-Service Science Teacher
VOMMS	My Views of Models and Modeling
ESE	Elementary Science Education
PCK	Pedagogical Content Knowledge

CHAPTER I

INTRODUCTION

This chapter provides an introduction to the study, which explores how a group of pre-service science teachers (PSTs) understand scientific models, and how they perceive the use of models in science education. The chapter includes the background of the study, the purpose of the study, the research questions, the significance of the study, and the definitions of important terms.

1.1. Background of the Study

Teaching science depends on a number of scientific models since several scientific concepts, such as the atom, the cell and DNA depend on models for their conceptualization. These concepts, by their nature, are usually inaccessible or abstract, and models serve as abstractions or simplifications of these systems to make their features explicit and visible, and allow scientists, teachers or students generate explanations or make predictions about them (Harrison & Treagust, 2000b). In other words, models test or predict about the attributes of scientific phenomena, and they also function as objects or ideas that provide and suggest explanations or descriptions about the phenomena (Aktan, 2005). According to Hestenes (1996), the structure of scientific knowledge can be made more explicit for students by organizing course content around a number of models. With the use of a globe (the physical model for the Earth), for example, the Earth is represented, and several concepts about the Earth such as, the shape, continents, axial tilt, etc. are made clearer. Several scientific concepts can be easily explained not only with physical models but also through multiple representational forms like structural (solar system, DNA), functional (moon phases, chemical reactions), or analogical (billiard ball model of a gas, liquid drop model of the nucleus) models (Schwartz & Skjold, 2012). The use of such models in classroom settings can improve students' understanding in the development of scientific ideas and the development of a better understanding of the scientific concepts (Treagust, Chittleborough & Mamiala, 2002). Besides scientific models, teachers may also make use of *teaching models* to facilitate understanding of scientific concepts (Gobert & Buckley, 2000). Teaching models are "specially constructed models used by teachers to aid the understanding of a scientific concept" (Cittleborough, Treagust, Mamiala, & Mocerino, 2005, p. 196). Among the most common teaching models are drawings, simulations, analogies, and concrete models (Justi &

Van Driel, 2005b), and two-dimensional textbook models like diagrams, three-dimensional models like scaled miniatures, and visual and verbal metaphors and analogies (Coll, France & Taylor, 2005). These models are developed for simplifying, visualizing or materializing scientific topics in order to promote learning (Falcao, Colinvaux, Krapas, Querioz, Alves, Cazelli, Valente & Gouvea, 2004), and if they are easily understood and remembered by students, they act as aids to memory, explanatory tools and learning devices (Harrison & Treagust, 1998, 2000b).

According to Chittleborough et al. (2005), scientific models and teaching models provide input into students' learning. Figure 1.1 presents the process that relates scientific models and teaching models, and their role in learning process.

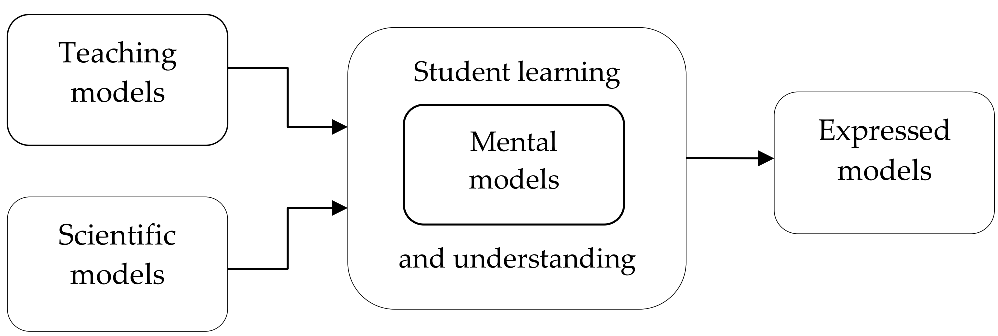


Figure 1.1. A theoretical framework of models in learning (Chittleborough et al., 2005, p.197)

Chittleborough and her colleagues (2005) describe learning as the construction of mental models where scientific and teaching models provide input into students' understanding. Mental models in this process are the product of students' learning, which can be regarded as output. Expressed models, on the other hand, are students' expressions of their mental models through action, speech or writing. Understanding a new concept, students look for similarities with their prior knowledge and are able to construct their personal mental models. Chittleborough (2004) claims that the construction of mental models is consistent with constructivist approach. Several other researchers also base the theoretical foundation of their designs on constructivist views of learning and teaching (Byrne, 2011; Crawford & Cullin, 2005; Harrison & Treagust, 2000a; Treagust, Chittleborough & Mamiala, 2002). According to the constructivist view, learning in science requires students to own an idea or concept, reconstruct and internalize it, and be able to explain or communicate it with others; and models may serve as very useful tools in this process (Treagust, Chittleborough & Mamiala, 2002). Models may be regarded as an important constructivist teaching strategy since they include the construction of personal representations (mental models) of the phenomena experienced. Moreover, models (together with analogies and metaphors) are used to provide links to familiar concepts and provide a foundation on which students can build new ideas (Chittleborough, 2004). When new ideas are accepted and are connected to existing ideas, learning occurs by extending and sophisticating the learner's mental model (Byrne, 2011). Since a model may provide a physical appearance, and an analogy and a metaphor may describe the novel phenomena by stating a likeness (similarity) with the thing that students already know about (Taber, 2001), the use of them can be said to be consistent with constructivist approach, in which students' prior knowledge is the foundation on which to build further knowledge (Yager, 1991, as cited in Chittleborough, 2004).

The theoretical framework of models in learning presented in Figure 1.1 suggests that it is important to uncover understandings about scientific and teaching models since they take part in the process of learning. Construction of feasible mental models of scientific concepts is important in learning these concepts meaningfully, because we understand, reason, and make inferences through these mental models. Not only the feasible construction of mental models, but also the appropriate use of scientific and teaching models in science lessons, which also support the constructivist learning strategies, may be effective instructional strategies that aim conceptual understanding. When all these ideas are considered, it may be appropriate to suggest that we should look for ways for students to have opportunities to construct feasible mental models and to use models effectively. Therefore, as Norman (1983) suggests, it should be their developers' aim to build instructional materials that aid users to construct more coherent mental models; and, it should be scientists' aim to develop appropriate ways to construct good mental models and understand the incomplete and unclear structures that people actually have; and, it should be teachers' goal to develop teaching models that aid students to develop appropriate mental models. So, it is important that teachers (both in-service and pre-service) not only should have a sound understanding of important models used in science, but should also have a sound understanding about models (Danusso, Testa & Vicentini, 2010). Stated differently, they should be aware of the role of models in the process of constructing the scientific body of knowledge, and modeling as a key support to conceptual understanding of scientific concepts (Danusso, Testa & Vicentini, 2010). In order to promote their knowledge and teaching practice around this authentic scientific practice, first, science teacher educators need to understand their strengths and limitations related to models (Davis, Nelson, Hug, Kenyon, Cotterman, Teo & Reiser, 2010). From this point of view, the need to investigate PSTs' understandings of scientific emerges, which frames the purpose of the current study.

1.2. Purpose of the Study

The current study attempted to address the understandings that PSTs possess about scientific models and their perceptions about the use of models in science education. More specifically, the findings would reveal PSTs' understandings of models in several aspects such as, descriptions and roles of scientific models, nature of scientific models, characteristics and benefits of models used in science education, and PSTs' use of models in science teaching.

1.3. Research Questions

The following research questions were explored for the purpose of this study:

1. What understandings do pre-service science teachers possess about scientific models?
2. What are pre-service science teachers' perceptions about the use of models in science education?

1.4. Significance of the Study

Scientific models and teaching models are central to teaching science because some natural phenomena cannot be observable due to various factors like size, time, complicity, etc. but they can be taught by models (Harrison, 2001). If students understand the models, their roles and purposes as well as the limitations, they can compare and contrast the model to the actual phenomenon and gain a better understanding of the concepts (Hitt, White, & Hanson, 2005). With the use of models and modeling activities, students can gain experience with multiple authentic science activities, including making sense of data, generating and revisiting predictions, and engaging in scientific argumentation, which are consistent with science education standards and reform-oriented goals for students' science learning (Nelson & Davis, 2012). In line with these ideas, the vision of the *American Science Education Standards* (National Research Council, 1996) and science education reforms in other countries require science teachers to be knowledgeable about models (as cited in Crawford & Cullin, 2004). Similarly, Turkish science education curriculum (MoNE, 2005), which embraces constructivist views of learning, also give emphasis on the use of models in several means, like encouraging teachers to use representational and modeling tools (like video records and simulations) as educational sources for teaching scientific concepts which are deficient due to several reasons like availability, cost, or security. In the national science education curriculum (Grades 6 through 8), the use or construction of models are frequently offered for teaching scientific concepts like, cell, parts of a flower, atom, compounds and molecules, layers of the Earth, and human body systems (circulatory, digestive, respiratory, etc.). Moreover, realizing the importance of models and how to use them in the development of scientific knowledge, and presenting models for the aim of explaining ideas to others is given as a science-technology-society-environment objective. Further, data processing and model developing is presented as a science process skill to be gained by students. In the curriculum, limitations of models are also mentioned, and teachers are also informed about possible misconceptions that may emerge during the use of models and modeling activities. Teachers are also asked to inform their students about the characteristics and limitations of models.

For these and other reasons, science teachers need to use models effectively in their instructions; however, models are rarely incorporated in classroom settings for anything other than illustrative or communicative purposes (Davis, Kenyon, Hug, Nelson, Beyer, Schwarz & Reiser, 2008). Lack of high-quality curriculum materials is a reason but proper use of models and engaging students in modeling activities also require a high demand on teachers (Davis et al., 2008). Acknowledging the role that teachers play in promoting their students' learning (Davis et al., 2008), it is important to uncover both in-service and pre-service science teachers' understandings of models as well as the use of models in their instructions. In the literature, most research into models were focused on students' (e.g. Chittleborough, Treagust, Mamiala & Mocerino, 2005; Grosslight, Unger, Jay & Smith, 1991; Treagust, Chittleborough & Mamiala, 2002; among others), and teachers' (e.g. Harrison, 2001; Justi & Gilbert, 2002a, 2002b, 2003; Van Driel & Verloop, 1999, 2002) understandings of models. However, there appear to be few studies related to PSTs' understandings of models (e.g. Aktan, 2005; Berber & Güzel, 2009; Crawford & Cullin, 2004; Valanides & Angeli, 2008). More research is obviously needed in order to establish a clearer framework of PSTs' understandings of models. PSTs' perceptions about models are important because the way they perceive and use models may affect their students' understandings of models. The appropriate use of models can improve students' understanding in the development of scientific ideas. When students are able to realize the role, purposes and limitations of models, they may learn scientific concepts more effectively. Moreover, to our knowledge, PSTs' understandings in the context of the use of models models, that is, how they perceive and use models in their teaching practices, did not receive much attention by researchers, as well. The present dissertation, therefore, also aims to fill this gap in the developing literature by providing findings about PSTs' perceptions and use of models through analyzing the data from interviews, lesson plans and classroom observations. Besides, to our current knowledge again, there has been only a single study that attempted to investigate PSTs' understandings of models in Turkey (Berber & Güzel, 2009) which relied on quantitative responses. The current study extended this previous study's findings by providing a methodological alternative and including findings from qualitative data sources. In this study, in addition to an open-ended instrument, through interviews, it was aimed to reveal PSTs' understandings of models in detail since interviewing is an in-depth data gathering method which allows the interviewer to deeply explore the respondent's feelings and perspectives on the issue investigated. The current study, therefore, aimed to provide findings about PSTs' understandings of models and thereby add to the limited literature.

The findings of this study might have several implications. The results are relevant for PSTs, teacher training programs, curriculum developers, and textbook authors. There is obviously a need to address PSTs' understandings about models for *PSTs themselves*. It is important for them to appreciate the role that models play in science teaching. Therefore, the findings might contribute to PSTs in developing sound understandings of scientific models before they start their teaching profession. With the findings of this study, they might reconsider their understandings of models, and look for ways to develop them. PSTs should develop sophisticated understandings of scientific models and should have the required knowledge and abilities to use teaching models in their instructions effectively since through teaching, teachers attempt to change, develop or modify their students' thinking and understanding in order to be more scientifically acceptable. Since the study was conducted with PSTs, the findings may also inform *teacher training programs* by explaining how PSTs perceive models. Findings may act as a starting point for the design of educational activities aiming at the improvement of their students' understandings of models. If we want students to learn science in a way that reflects real-world scientific inquiry, it is important that their teachers should have an understanding of how models are developed and used in scientific community (Schwartz & Skjold, 2012). An opportunity for teachers to develop such sophisticated understandings about models is during their undergraduate science courses. Thus, learning about models can be embedded into science, education and teaching profession courses. Indeed, all science disciplines involve models; therefore, all science courses can be appropriate contexts for teaching about models and modeling (Schwartz & Skjold, 2012). Through these courses, PSTs may find the opportunities to improve their knowledge of models and their use in teaching. They may be let to experience some model-based activities that they can use during their teaching practices in the future years. Incorporating scientific models into PSTs' courses may provide rich opportunities for them to engage in multiple authentic scientific practices themselves, and to develop proficiency in engaging their students in scientific practices (Nelson & Davis, 2012). These activities also support PSTs in becoming well-started beginning science teachers (Nelson & Davis, 2012). By examining PSTs' understandings of models, *curriculum makers* might also improve the curriculum by giving emphasis to use of models. The Ministry of Education may provide support to improve schools' instructional infrastructure in terms of models, modeling materials, or software programs. With the findings of this study, curriculum makers may also have the chance to examine the understandings that PSTs hold about models, and they may design instructional strategies that inform and direct teachers in a scientifically acceptable way. The Ministry of Education may also provide in-service trainings in workshops or seminars to express how to integrate models in classroom instruction. Finally, the findings might also have implications for *textbook authors*. In fact, models presented in many science textbooks are generally limited to the physical representations like DNA or atom models, which would result in the false impression that such models are the only scientific models (Halloun, 2007). Findings of this study, therefore, may help textbook authors in organizing the content of book around several other scientific and teaching models. By considering PSTs' understandings of models, textbook writers may select appropriate models and they may take attention to the use or limitations of the models.

Consequently, it is appropriate to state that the proper use of models would improve science education. If we want to enhance students' understandings of models and modeling, it is important that we, as pre-service or in-service teachers, textbook authors, science education researchers, and curriculum developers, know what scientific models are, what their characteristics and purposes are, how they are used by scientists in their research activities, and how they are effectively used in classroom practices.

1.5. Definitions of Important Terms

The following selected terms will be used throughout this study, and their definitions are provided in this section for the purpose of clarification.

Model: Models are ´idealized´ structures that we use to represent the world, via resemblance relations between the model and real-world target systems (Godfrey-Smith, 2006). The target is the actual object of research, and the model is always a representation of the target (Van Der Valk, Van Driel & De Vos, 2007).

Modeling: Modeling is the process of producing a representation of an object, an idea, a system, an event, or a process (Davies & Gilbert, 2003). It is "a systematic activity for developing and applying scientific knowledge in physics (or any science)" (Halloun, 1996, p.1021).

Mental model: Mental models are defined as "an individual's representations about ideas, objects, events, processes or systems, which can be expressed through action, speech, in writing or drawings" (Falcao et al., 2004, p.974).

Scientific model: A scientific model is defined as "a set of *ideas* that describes a natural *process*" (p.2), which are formed by empirical/theoretical objects and processes, and are also consistently assessed, and are guides for the future research (Cartier, Rudolph & Steward, 2001).

Teaching model: A teaching model is defined as "a specially constructed model used by teachers to aid the understanding of a scientific concept" (Cittleborough et al., 2005, p. 196).

Model-based teaching/learning: Model-based learning is defined as "the construction of mental models of phenomena", and model-based teaching as "any implementation that brings together information resources, learning activities, and instructional strategies intended to facilitate mental model-building both in individuals and among groups of learners" (Gobert & Buckley, 2000, p.892).

CHAPTER II

LITERATURE REVIEW

This chapter provides a detailed review of the literature to support and elaborate the ideas presented in the first chapter. The first section describes scientific models and their role in science, and it continues with the use of models in science education. Then, model understandings, together with the reviewed literature on students', teachers' and pre-service science teachers' understandings of models are reported. The chapter ends with the ways to enhance model understanding.

2.1. Scientific Models and Their Role in Science

A scientific model is a research tool to get information from a directly unobservable or immeasurable target, like an atom, a dinosaur, or a black hole (Van Driel & Verloop, 1999). Stated differently, the target is usually inaccessible, and the scientific model is often constructed when the target is too small, too large, too fast, too old, too distant or too complex

(Crawford & Cullin, 2004). The target in this relationship is the point of research, and the scientific model is a representation or explanation of the target (Van Der Valk, Van Driel & De Vos, 2007).

Several characteristics of scientific models are defined (Aktan, 2005; Van Der Valk et al., 2007; Van Driel & Verloop, 1999, 2002). *First,* a model is always related to a target which has a limiting characteristic (either hard to observe or hard to reach), but it should not directly interact with the target (Van Driel & Verloop, 1999). There is always an element of creativity involved in the model's design, related to the purpose (Van Der Valk et al., 2007). This means that a photograph or a spectrum cannot be a model, since they do not exist independently of the target although being very helpful in obtaining information about the target (Van Der Valk et al., 2007). *Second,* the model differs in certain aspects from the target. Depending on the research interest, some aspects of the target may be excluded from the model. Thus, models help scientists focus on the important features of the target that s/he is interested in (i.e., what s/he is trying to understand) without being disturbed by too much detail (Coll, 2006). This characteristic actually implies that the model is usually simpler than the target it represents (Van Driel & Verloop, 1999). In most of the chemical phenomena, for example, simple stick-and-ball models are used to represent the molecules rather than more advanced models, including quantum mechanics (Van Driel & Verloop, 1999). If a model is exactly like its target, it will not be a model, but a copy. Scale models like a house model, or a bridge model, being the exact copies of the target, are therefore not considered as scientific models (Van Driel & Verloop, 1999). *Third,* the model bears some analogies to the target. These analogies enable the researcher to reach the purpose of the model; in particular to derive hypotheses from the model or to make predictions, which may be tested while studying the target (Van Der Valk et al., 2007). By testing these hypotheses, new information about the target may be produced; and by learning about the model, the scientist can learn about the target (Cullin & Crawford, 2003). *Fourth,* models are products of the process of analogy that is seeking the similarities and differences between the phenomenon under study and the thing perceived to be similar to the phenomenon; like the wave model of light, based on a wave on water (Gilbert, Boulter & Rutherford, 1998). To understand the model of an unobservable phenomenon, one should have the ability to see the analogies (Bullock, 1979). *Fifth,* scientific models usually have some lacking points from their targets because they are approximations of the real phenomena that we cannot ever come to know absolutely (Coll, 2006). When we think of the atomic model for the structure of matter, for example, it is possible to think of atoms as being real but what is meant with the term atom is simply a model of a reality (i.e., the composition of matter) we can never truly come to know (Coll, 2006). Due to this nature, models cannot be completely certain, and are tentative that they are open to further revision and development (Crawford & Cullin, 2004). If a model can fully illustrate the concept or the process, then it is not considered as a model, rather an example (Bent, 1984, as cited in Harrison & Treagust, 1998). The development of the early models of atomic structure illustrates the tentative nature of models. According to Bohr's model of atom, for example, the electron orbits the nucleus only in a discrete series of allowed classical trajectories known as stationary states; however, as we know today, the electron in an atom does not follow a definite classical trajectory in a stationary state and is instead better described as a cloud of probability density around the nucleus (Bokulich, 2011). *Sixth,* scientists can have more than one model for the same phenomenon depending on the context, purpose of the scientific research, and perspective of the scientist (Sins, Savelsbergh, van Joolingen, & van Hout-Wolters, 2009). That is, multiple models of a given phenomenon may co-exist (Shwartz, Rogat, Merritt & Krajcik, 2007; Van Der Valk et al., 2007). Science concepts usually depend on multiple models, and the more the concept is abstract, the more likely it requires multiple models, since each model covers a feature of the target concept (Harrison & Treagust, 1998). For example, biochemists and theoretical chemists use different models for the corpuscular structure of water, or physicists use either the model of light as particle-like or as wave-like depending on their purpose of explanation (Crawford & Cullin, 2004; Justi & Van Driel, 2005b). Similarly, the 'Valence Shell Electron Pair Repulsion' model is available for deciding the arrangement of atoms in a molecule, but quantum mechanics is also needed to explain complex details of molecular structure and reactivity like in the example of the unusual electron configuration of molecular di-oxygen (O_2) that is not explained well by other models (Coll, 2006). *Lastly*, scientists evaluate models empirically and conceptually to see whether they can explain the data and predict the results of forthcoming investigations; or to see how well they are consistent with the other accepted models and knowledge (Cartier, 2000; Cartier, Stewart & Zoellner, 2006; Shwartz et al., 2007). In other words, as Crawford and Cullin (2004, p.1382) stated, "to evaluate a particular model, scientists do not ask whether it is right or not. Rather, they ask: (1) Can the model *explain all the observations*? (2) How can the model be used to *predict* the behavior of the system if it is manipulated in a specific way? (3) How is the model *consistent with other ideas* about how the world works and with other models in science?" A good fit with data means that the model is reliable, that is, it works well (Coll, 2006). However, when the model was found to conflict with data, it means that some fundamental characteristics of the target are not fully understood, and further investigation about the target is needed. As a result of these investigations, models can be modified, altered or overthrown (Aktan, 2005). The evolution of the early models of atomic structure (like Thomson's 'Plum Pudding' model of atom and Bohr model of atom) is an example that illustrates this process – that is, how scientists discard models after evaluation and testing (Coll, 2006).

Apart from the characteristics of scientific models mentioned above, the roles that models take in science are also described by several means. For example, scientific models are used to *represent* the world through resemblance relations between the models and the target systems (Giere, 1988, as cited in Godfrey-Smith, 2006). Giere (2004, p.743) proposes representing practice in science as: "S uses X to represent W for purposes P"; where S is the scientist(s), W is the aspect of the real world, and P is the purpose. X, on the other hand, can be words, equations, diagrams, graphs, pictures, or computer generated images. Models are used to represent the aspects of the real world for several purposes, so models are the X here as the primary representational tools in science. Scientists are using models to represent aspects of the world through developing similarities between the model and the represented real-world target systems (Giere, 2004). Representation is considered as a major role of models because scientists reason and produce knowledge from such representations through modeling experiences (Justi & Van Driel, 2005a). That is, in order to provide information about the target system, a model must be representative; it should have some aspects from the reality (Frigg, 2002). Representation is not the only role of models; they may have other roles like simplifying the real phenomena. Models in science are sometimes representations of phenomena produced for *simplification* of the phenomena that are then to be used in inquiries to develop explanations about them (Christofilis & Kousathana, 2005). They are naturally simplified versions of their targets and they help scientists in focusing on the key features of the targets (Coll, 2006). It is the scientist, who creates the model, decides the features to neglect (Etkina, Warren & Gentile, 2006). In the atomic model for the structure of the matter, for example, the composition of matter is shown in a simplified way.

Scientific laws, together with the models that represent them, are also the basis for explanations in science and scientific theories, and are used as tools to foresee and predict events (Ben-Zvi & Genut, 1998). That is, models also help scientists describe and *explain* the natural phenomena (Bokulich, 2011; Gilbert et al., 1998; Mashhadi, 1999), and *make predictions* and *obtain information* about the target that is inaccessible for direct observation (Gilbert et al., 1998; Halloun, 2007; Van Driel & Verloop, 1999). They can test or predict about the attributes of certain phenomena; and they can also function as objects or ideas that provide and suggest explanations or descriptions about the phenomena (Aktan, 2005). In other words, scientists construct models in order to generate predictions, explanations or interpretations for creating theories, and for testing and analyzing them. Through observations and the related scientific principles, scientists try to model the behaviors of the natural phenomena, and generate scientific predictions or explanations through inferences from models (Hestenes, 1996). When studying scientific phenomena, scientists usually build several models, and by analyzing these models, they draw inferences about the concepts/systems represented by these models (Halloun, 1996). For example, the prediction about the existence of the planet Uranus was first made by Adams and Le Verier based on a model, which includes the concept of gravity. Right after this prediction, the planet is identified by observation (Van Driel & Verloop, 1999).

Models also affect the questions that scientists ask about the world and the evidence they are looking for to support the arguments, and they also help scientists as instruments in designing investigations (Cartier et al., 2006). Scientific models are actually the expressed models that are developed by scientists as ´outputs´ or ´products´ of their scientific activities (Taber, 2008). Therefore, models, together with other scientific activities, aim to *produce new knowledge*. Another important role of models in science is providing *communication* between scientists (Van Driel & Verloop, 1999; Hitt, 2004). Through comparing and testing the models with others, scientists come up with consensus models (Van Driel & Verloop, 1999). Producing and using models, and comparing and communicating them with other scientists, is a central issue in the growth of scientific knowledge (Justi & Van Driel, 2005b).

In short, scientific models have important roles in science. This can either be to describe the behavior of a phenomenon, to establish the entities it has, to attribute the causes and effects of that behavior, or to predict its behavior under certain conditions (Gilbert et al., 1998). They are developed to explain how things work in nature. Thinking and reasoning rely on models, and through thinking and reasoning with models, scientists explain abstract phenomena and make predictions about them. They build, test, compare and revise models and use them to communicate and get ideas about how the real world works. Models having important roles is not limited to just science; they also have important roles in science education. In the following section, the use of models in science education is reported.

2.2. Use of Models in Science Education

Besides considering models as science's tools, they also function as major learning and teaching tools (Crawford & Cullin, 2004; Treagust, Chittleborough & Mamiala, 2004). The role that models play in academic/pure science has both similarities with and differences from their role in science education. For scientists, models can provide a means for generating new knowledge (Davis et al., 2008) or, are a kind of simplified and accessible summary of their studies (Gilbert, Boulter, & Rutherford, 1998). In science education, on the other hand, they are accessible representations of abstract concepts, and are also organizational frameworks to teach and learn inaccessible facts (Gilbert, Boulter, & Rutherford, 1998). They help students to develop new understandings of a phenomenon and move toward being able to apply those ideas to making predictions about a new phenomenon (Davis et al., 2008).

In fact, teachers cannot reproduce several scientific concepts or processes in the classrooms; however, their models are available to use. Various scientific models like Darwin's model of natural selection, Lamarck's model of inheritance, the billiard ball model of the gas, or Watson and Crick's model of DNA are used to clarify and explain the related scientific concepts. The use of such scientific models can *improve students' understanding* in the development of scientific ideas and the development of a better understanding of the particular content area (Gobert & Buckley, 2000; Hitt, 2004; Treagust et al., 2002). Models are also important in the *simplification* of difficult concepts (Falcao et al., 2004). Teachers use models to explain some important and difficult aspects of several concepts, and this is best achieved by simplifying the model to explain key ideas, like the simple tube for an earthworm's gut. So, models used in education are usually simplified versions of scientific models depending on the grade level of the students and the nature of concept studied. In fact, during their instructions, teachers use properly-simplified versions of scientific models instead of the sophisticated models used by scientists (Justi & Van Driel, 2005b). The structure of scientific knowledge can be made clearer for students by organizing course content around a small number of basic models (Hestenes, 1996). Building a cladogram to clarify the similarities and differences among characteristics of living things, or using a line model or hand model to explain basic processes of evolution, for example, may let students comprehend the concepts of biological diversity and evolution better (Apaydın, Çobanoğlu, & Taşkın, 2006). Students may also produce models through their assignments, which do not mostly have a public status like scientific models but are for developing personal understanding (Taber, 2008). Instructional approaches that are based on models engage students in the authentic practice of using models as tools for *visualization, explanation* or *prediction* (Petridou, Psillos, Hatzikraniotis, & Viiri, 2009). With the help of models, abstract concepts become concrete since they become tangible for students (Hitt, White, & Hanson, 2005). So, models are also developed with the aim of visualizing or materializing particular topics in order to promote meaningful learning (Falcao et al., 2004). They are beneficial if the concept in the physical world cannot be seen by naked eye, or the concept happens too slow or too rapid to observe, or simply abstract in nature. Giving the opportunity to explore, describe and explain scientific ideas, models make science *relevant* and *interesting* (Hodgson, 1995; as cited in Harrison & Treagust, 2000a). They increase students' *curiosity* and *imagination*, and therefore enhance creative thinking (Harrison & Treagust, 2000a).

Models have important roles in teaching students about the *history and philosophy of science,* as well. Earlier science education reforms assert that, if students understand how scientific knowledge is developed, and how historical, philosophical and technological contexts influence its development, then they will gain a more comprehensive view of science and become more engaged by the learning of science (Justi & Gilbert, 2000). For the inclusion of history and philosophy of science in science education, models provide a suitable basis since teaching the historical development of models may help students understand how new scientific knowledge is created by combining old and new ideas (Justi & Gilbert, 2000). A teaching approach that involves the historical context of the development of models of atom from the ancient Greek model to quantum mechanics model (Justi & Gilbert, 2000), for example, may help students understand how scientists developed early models of atomic structure and how models are changed after evaluation and testing (Coll, 2006). At this point, it can be easily inferred that, a good understanding of the *nature of science* also inherently involves the role and the nature of models (Mashhadi. 1999). That is, with the use of models, the understanding of the nature of science and scientific enterprise may be facilitated (Coll, France & Taylor, 2005). The key connection between the nature of models and the nature of science is that, from a scientific point of view, models are not completely accurate and are tentative and open to further revision and development (Crawford & Cullin, 2004). Moreover, there can be multiple models for the same scientific phenomena, and this multiplicity of models depends on the perspective of the scientist and the purpose of the research being conducted (Gobert, O' Dwyer, Horwitz, Buckley, Tal Levy & Wilensky, 2010). As in the example of the models of atom, when teachers use multiple models in their instructions, students can predict that actually "no individual model is ´right´" (Harrison & Treagust, 1998, p.424), and they can deduce the aspects of nature of science like uncertainty, tentativeness, and the creativity involved in the construction of scientific knowledge. These connections between the nature of models and nature of science emerges the idea that nature of models is a subset of nature of science (Gobert et al., 2010), and the aspects of nature of science that are directly related to the use of models are the tentativeness of models, the need for continual revision and development of models, the role that creativity plays in building models and the existence of multiple models for the same phenomenon (Crawford & Cullin, 2004). Consequently, it can be said that understanding the nature of models and their use in science can be a fundamental component of the nature of science.

The abovementioned research suggests that models have central roles in science education (Crawford & Cullin, 2004; Justi & Gilbert, 2002b; Treagust, Chittleborough & Mamiala, 2004). The effective use of teaching and scientific models, therefore, may influence students' learning. Through the appropriate use of scientific models and well-developed teaching models, teachers may facilitate learning several scientific concepts for their students. Taber (2008) presents the process of learning from scientific, curricular and teaching models in Figure 2.1 below. The figure represents the transformation of knowledge through a succession of models and takes attention to how these models and their developers play significant roles in students' learning.

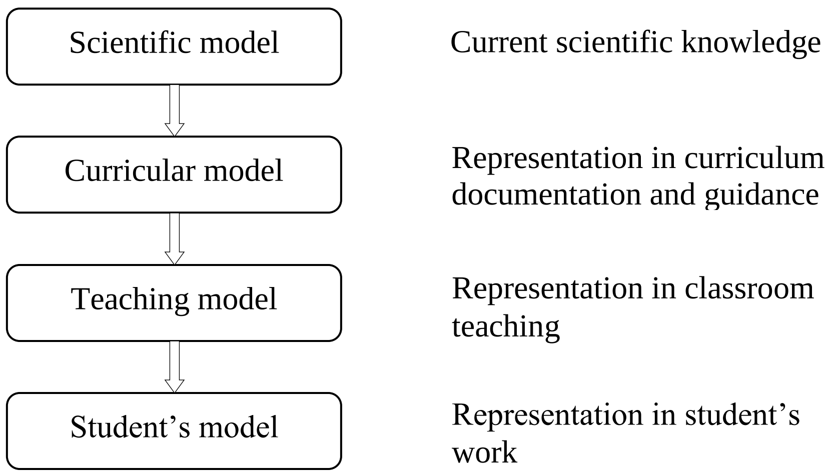


Figure 2.1. Transformation of knowledge through a succession of models (Taber, 2008, p.184)

The figure implies that scientific models, developed in the light of scientific knowledge, are represented in the curriculum as curricular models as a result of the work of curriculum developers. Teachers, then, develop teaching models to represent the related phenomena in the classroom. Finally, students form their own models as a result of their learning. The important point to consider in the figure, however, is that; the intermediate succession levels are all expressed models, and the errors do not imply a direct transmission between models (Taber, 2008). For example, according to Taber, a teacher may work from the textbook, reinterpreting the expressed model of the textbook author's interpretation of a curricular model, may come up with his own mental model in mind and express it as a teaching model that is appropriate for classroom teaching. The influence of curriculum developers and teachers, as well as the effective use of models in students' learning can easily be predicted when this indirect transmission is considered. Through the appropriate use of scientific models and well-developed teaching models, teachers may provide good learning environments for their students. Coll and Treagust (2003) offered some criteria (See Table 2.1) that teaching models should have after the work of Gilbert, Boulter and Rutherford (2000).

Table 2.1. Criteria for teaching models (Coll & Treagust, 2003, p.465)

Criteria for teaching models	
Completeness	The entities of which the model is composed and the relationships between those entities should be clearly understood
Coherent	Level of detail of explanation it provides matches the needs of the students
Concrete	The model should be comprehensible to students
Conceptual	The model should form a clear bridge between underlying theory and the phenomena being explained
Correct	The scope of the model should be made clear
Considerate	The model should be linguistically well presented

Table 2.1 suggests that a teaching model should ensure six criteria, that is, it should be complete by providing clear understanding about the entities it has, be coherent with the needs of the students, be concrete enough to be comprehended by the students, be conceptual by providing the relation between the theory and the phenomena, be correct by clarifying the scope of the model, and finally be considerate by being linguistically well-presented. It is important that these criteria offered by Coll and Treagust (2003) should be possibly met for all models since the models used in textbooks and science lessons might lead to the construction of unscientific model understandings when they are misunderstood by learners. One possible problem may occur when attributes of the model that are not shared with what is being modeled (the target) is demonstrated (AAAS, 1990, as cited in Al-Balushi, 2011). For example, although the use of pedagogical-metaphorical models, like ball and sticks, makes the concepts of atom and bonds accessible to students, students may possess alternative understandings like considering electrons as solid and static (rather than diffuse and dynamic), and molecular bonds as material connections rather than forces (Harrison & Treagust, 2000a). Similarly, as Coll (2006) reported, alternative conceptions may evolve as a consequence of the use of inappropriate diagrams that highlight and exaggerate particular features of the scientific phenomenon. Coll gives the example of the diagrams used to show the intermolecular interactions between solids, liquids and gases, and states that, the use of such diagrams that exaggerate the spacing between particles in liquids (to show the greater movement between the particles in the liquid phase) usually leads students to form the alternative conception that the particles are spaced out (Coll, 2006). To avoid such misconceptions, Coll suggests encouraging students to draw their own diagrams, and help them to be more critical of diagrams in textbooks and other curriculum material. Hitt, White, and Hanson (2005) also emphasize the importance of discussing and addressing the limitations of models before proceeding with a modeling activity, so that students would be able to compare and contrast the model with the concept it represents and avoid misconceptions. They suggest that students should know in advance that models are imperfect representations and are designed by scientists to address specific questions. It has significant importance to make students and teachers aware of the difference that exists between the model and the reality.

In line with these understandings, Ben-Zvi and Genut (1998) also claim that; when a model is used in an uncritical way, it may also lead to misconceptions. As the researchers reported, for example, although the development of the Periodic Table appears to be constructivist, it is used in an empiricist way; that is, the historical development of the Table, its changing nature, development of it on the basis of a relatively subjective view of the reality, and need for modification and questioning are not usually covered, avoiding students from scientific thinking. When the Table was first constructed, the aim was to organize the accumulated knowledge about the elements and their compounds; therefore, the periodicity of the data as evidenced on the macro level constituted the Table (Ben-Zvi & Genut, 1998). In the following years, however, with the development of the theory of atomic structure, the periodicity began to reflect the arrangement of extra-nuclear electrons in the atoms, that is, the structure of matter at the micro level (Ben-Zvi & Genut, 1998). What is clear is that, since the Table has always been a graphical representation of the Periodic Law, changes in the theory that explains the Law had always led to new forms of the Table (Ben-Zvi & Genut, 1998). This short history of the Table suggests that the development of it can be presented to students in a constructivist way; however, this type of information is rarely presented. The existence of competing theories about the Table are not mentioned, rather, success stories as evidence of the idea that science has developed by inductive reasoning are commonly used (Ben-Zvi & Genut, 1998). Moreover, with the use of just one form of the Table, considering scientific theory as continually subject to questioning and modification is ignored (Ben-Zvi & Genut, 1998). However, if the changing forms of the Table are given, students would appreciate the limitations of the Table, and they would recognize that any generalization based on the Table must be treated with caution (Ben-Zvi & Genut, 1998). According to the researchers, it is important to treat the Table with caution since it may lead to misconceptions when any characteristic which is not really present in the Table is suggested.

In sum, it is obvious that teachers as well as curriculum developers and texbook writers play significant roles in the construction of sound understandings of science. Therefore, their understandings of models should be in concern. In the following section, model understandings, followed by students' and teachers' (pre-service teachers' as well) understandings of models, are reported.

2.3. Model Understandings

A good understanding of models is an important aspect of a good understanding of science, since models play an important role in both science and science learning at all levels of education (Gobert et al., 2010). This importance requires some essential model understandings that teachers as well as students should possess in order to support learning and teaching several scientific concepts. It is important that they have a good understanding of scientific models in order to generate sound explanations about scientific phenomena. However, findings of several studies show that both teachers and students hold naïve epistemologies of these concepts. In the following sections, the studies about students', teachers' and pre-service teachers' understandings of models are reported separately.

2.3.1. Research on Students' Understandings of Models

To develop a scientific understanding of models, students should be aware of the nature and significance of models, their roles in developing scientific concepts, and they should also be able to produce, test and evaluate particular models. However, related research, although being limited, shows that students usually hold ′naïve realist′ epistemologies about models by considering models as exact copies of reality (Van Driel & Verloop, 1999).

In one of these studies, Grosslight et al. (1991) examined 33 seventh-grade and 22 eleventh-grade American students' understandings of models and their use in science, through clinical interviews. Specifically, the authors investigated students' understanding on the purpose of models, kinds of models, developing and changing models, and multiple models for the same phenomenon. The results showed that students held naïve conceptions about models. For example, most of them thought that models are physical copies of reality rather than constructed representations. The students rarely referred models as representations of ideas or abstract concepts. Most of the students also described models as being similar to the real thing. Students' responses indicated that, observing, communicating, learning and understanding, providing references and examples, and making things accessible and clear were the purposes of models. Students were also certain about the changing nature of models. Majority of them agreed that scientists can change a model if something is wrong with the model, or new information is found about the target. Students were also agreed that scientists may have more than one model for the same thing since they can have different views of the same phenomenon. The researchers also found that students' experiences with scientific models were limited, and suggested that students should have more experience with models in order to develop a better understanding about the nature of models. In their study, Grosslight et al. (1991) also developed three levels of thinking (i.e., Level 1, Level 2, and Level 3) about nature of scientific models and modeling. The differences through the levels were based on the understanding of the relationship between the model and the reality, and the role that ideas play with respect to models. Students who exhibited Level 1 understanding held a 'naïve realist' epistemology of models, and considered models as toys or simple copies of reality. In Level 2 understanding, students were aware of the purpose of a model. They appreciated the ideas and choices of the modeler, and realized that the model should not exactly correspond with the real-world target. However, students at this level still focused on the model and the target, not the ideas represented; for them, testing a model meant testing the workability of the model itself, not the underlying ideas. Finally, in Level 3 understanding, students realized the explanatory and predictive role of models; that is, they acknowledged that the purpose of a model was to develop and test ideas rather than serving as a copy of the reality. They also realized the role of the scientist in constructing a model; and comprehended that models can be manipulated and tested. The main characteristic that distinguishes Level 2 from Level 3 was that, the main focus of a Level 2 understanding was still on the model and the reality, not on the ideas portrayed. Regarding these levels of model understandings, Grosslight et al. (1991) found that the majority (67%) of seventh graders were at Level 1, 12% were at Level 2, and 18% fell in between Levels 1 and 2. Of the eleventh graders, on the other hand, only 23% were at Level 1 and the rest were between Level 1/2 (36%) and Level 2 (36%). None of the students in Grosslight et al.'s (1991) study reached Level 3.

In another study, Treagust, Chittleborough and Mamiala (2002) showed that students may have both sophisticated and naïve understandings about different aspects of scientific models. The researchers developed a 27-item Likert-type questionnaire named ´Students' Understanding of Models in Science´ (SUMS) to measure secondary (13-15 years old) students' understanding of scientific models in Australia (N= 228). Their findings revealed five themes about students' understanding of scientific models: scientific models as multiple representations, models as exact replicas, models as explanatory tools, how scientific models are used, and the changing nature of scientific models. The results of this study showed that more than half of the students (60%) recognized the value of multiple scientific models in displaying particular aspects and versions of the scientific phenomena.

The researchers reported that these results contrasted with those of Grosslight et al. (1991) where students rarely realized the existence of multiple models. The results also revealed that although most of the students held a sound understanding of the multiplicity of models, still majority (75%) of the students held the idea that a model needs to be close to the real thing. Even, 43% agreed that a model is an exact replica of its target. 20% of the students in their study realized that scientific models are more than being copies of their target. Concerning this finding, the researchers thought that, students' experiences with general models, which are usually scale replicas, are the starting point of their understanding of scientific models. They concluded that, clarifying the differences between different types of models may be effective in teaching and learning science and a better understanding of scientific models. Regarding the understandings about models as explanatory tools, the students displayed good findings by agreeing that scientific models represent things visually or physically (74%), and are also used to show ideas (79%). In respect of the use of models, although half of the students agreed that scientific models are used to make predictions, formulate theories and show how information is used, still the other half were not sure or disagreed with this idea. It was concluded from this finding that many students did not understand how scientific models are used in the development of scientific knowledge. These results were reported to be similar to those of Grosslight et al.'s (1991) which recommend that students should have the opportunity to experience models as tools of scientific inquiry rather than simple packages of facts to be learned. Regarding the changing nature of scientific models, students were certain that models change with new findings (71%) and with new theories and evidence (71%). Regarding this finding, the researchers concluded that the clear understanding about the changing nature of scientific models introduces students the uncertainty of scientific knowledge and nature of science which are important in learning science.

In a separate study, Chittleborough, Treagust, Mamiala and Mocerino (2005) investigated Australian students' (grade 8 to freshman, N=275) perceptions of the role and purpose of scientific models in the process of science and in the process of learning. They used the 6-item Views on Models and Modeling (VOMMS) instrument which requires students to choose between two alternatives for each item and then provide written reasoning for their responses. The VOMMS instrument identifies three characteristics of scientific models: the understandings about ´models as representations´, the ´multiplicity of models´, and the ´dynamic/changing nature of models´. The quantitative results gained through the instrument showed that most of the students had a scientifically acceptable understanding of scientific models; and as the grade increases, the level of understanding of the models also increases. Regarding the understandings about models as representations, the percentages of students who considered models as exact copies of reality, rather than as representations, were higher for the students at lower grades. Similarly, although most students agreed with the coexistence of multiple models, the researchers found significant differences between grade levels. Students at lower grades tended to hold the idea that only one model is preferable to explain scientific ideas. Regarding the dynamic nature of models, the researchers also found that older students demonstrated a better understanding of the role and diversity of models than did the younger students. Especially in the statements that assert that scientists are influenced by their feelings and motives in their decisions to accept a newly proposed model, and scientific models will not change in future years; an increasing improvement toward a scientifically accepted response was found with the increasing age of students. Youngers tended to believe that in accepting a new model, scientists are influenced by their feelings, and scientific models may not change in future years. The researchers concluded from these findings that students gain a better understanding of the role of models as they learn more about science. The researchers also identified students' understandings about the role of models in learning through the qualitative results gained through the written responses of the VOMMS instrument. The findings showed that many students appreciated to roles of scientific models in learning. Many of the students were aware of the explanatory and descriptive roles of models in learning. Similar to the previous findings, older students expressed a better understanding of the role of models in learning than the younger students.

In a recent study, in Oman, Al-Balushi (2011) explored 9-11 graders' (N=845) and prospective science teachers' (N=108) evaluation of the credibility of scientific models that represent natural entities and phenomena through a survey called Epistemologies about the Credibility of Scientific Models (ECSM). The instrument is composed of a list of natural entities and phenomena that range from concrete to abstract in nature, such as the microscopic (e.g. living cells, blood cells, bacteria, viruses) or telescopic (e.g. meteors and meteorites, planets) entities, or microscopic representations or symbols (e.g. atoms, electrons, protons, water molecules, salt crystals), or highly theoretical entities (e.g. photons, magnetic field, microwaves, alpha rays, electron cloud), and natural processes (e.g. photosynthesis, viral life cycle and cell division). The ECSM instrument identified four epistemological levels, which were certainty, imaginary, suspicious, and denial; thus, the researcher called it as the CISD taxonomy. Students at the certainty level believed that the natural entity or phenomenon is real and the textbook illustrations reflect how it really is. Students at the imaginary level, on the other hand, believed that the natural entity or phenomenon is real, but the textbook illustrations reflect the scientists' imagination of how it really is. At this level, students also believe that these illustrations are close to reality and scientists try to prove them. At the suspicious level, student still believed that the natural entity or phenomenon is real, but they thought that scientists cannot imagine it, and if there are textbook illustrations for this entity or phenomenon, then these illustrations are far from reality. Lastly, at the denial level, students believed that the natural entity or phenomenon is not real, and it does not exist. Findings of the study revealed seven different combinations of CISD levels, which were certainty, certainty–imaginary, imaginary, imaginary–suspicious, imaginary–suspicious–denial, suspicious–denial and certainty –suspicious–denial. It was also found that the students assigned the natural entities and phenomena to these levels according to their level of abstractness. That is, the entities that were represented by photographs or micrographs like meteors and meteorites, blood cells and bacteria, for example, fell at the certainty level, while the theoretical entities like electron cloud and photons fell at the suspicious–denial level. Moreover, the overall students' epistemological perceptions across grade levels showed a decrease in the certainty level and an increase in the imaginary level. To illustrate, in the suspicious level, Grade 11 was the highest (21.73%), followed by the college level (20.68%), grade 10 (18.73%) and grade 9 (16.78%). The researcher also reported that detailed microscopic and more abstract knowledge raised the suspicious and denial levels of some entities (e.g. viral life cycle, magnetic lines of force, covalent bonding, salt crystal and protons) in tenth graders compared to other grade levels. Tenth graders were also found to express the highest denial level. In the denial level, Grade 10 was the highest (5.97%), then grade 11 (3.60%), grade 9 (2.76%) and finally the college level (0.83%). The researcher mentioned about the need for further research that is based on qualitative research methodologies to explore these findings. He suggested that interviews with students, their teachers and analysis of their textbook for the indented concepts, and comparisons with other populations that use different science textbooks might disclose tenth graders' epistemological positions regarding some entities and phenomena.

The deficiencies of students on the concept of scientific models were also revealed classroom implementations about scientific models. In a study by Loper (2005), for example, the processes of teaching and learning about scientific models in an eighth-grade American classroom, where students completed two independent inquiry projects using a specific software and curriculum, were investigated. During these two projects, which were Force-and-Motion Project and Science Fair Project, they used the Inquiry Island software, which was specifically developed by the researchers to scaffold scientific inquiry and reflections of the students. The researcher recorded students' and teachers' talks about models for two months, and analyzed video records of small-group work and whole-class interactions, and students' written work to analyze the data. The findings showed that although they sometimes appeared to be able to produce scientific models of the proper form, students had difficulties in understanding what a model is, the nature, function and purpose of scientific models. The difficulties in understandings of scientific models were also revealed in Cartier's (2000) study. In the study, Cartier explored high school students' (N=26) ideas about nature of scientific models in a genetics course with a modeling approach. The approach included assessment, justification, construction and revision of explanatory models in genetics. Students engaged in activities and discussion about the nature of models, and constructed and revised their own models of genetic concepts. The researcher collected data in a variety of ways: students' written work (notebooks, journals, exams, and posters), audio and video recordings (from lab group meetings and class presentations), researcher's field notes and interviews data. The researcher found that students usually considered scientific models as physical/visual representations of ideas, or verbal explanations, but not as conceptual tools for explaining natural phenomena. They thought that models are used to demonstrate or proof ideas rather than explaining or predicting data. However, according to the reassessments in the middle and end of the course (after 9 weeks), changes in the students' ideas were reported. Most of the students demonstrated understanding of the conceptual nature of scientific models, and understood the role of models in explaining data, and the need on models to predict results.

In another study, Saari and Viiri (2003) investigated seventh-grade students' (N=31) understanding of the concept of models, and the impact of a research-based sequence for teaching the concept of modeling to students. The researchers gathered data through pre- and post-interviews and open-questionnaires. The analyses of the pre-interviews showed that students' notions of models before the learning sequence were very limited. Twenty-nine of the 31 students considered models as objects that must be copied exactly. The researchers planned their learning sequence by considering these beliefs. The concept of modeling was taught while the students were learning the change of states of matter. Analyses of the post-interviews revealed improvement in students' understanding of models. After the learning sequence, only two students held the naïve idea that models are objects that must be copied exactly. Remaining of the students, on the other hand, developed an improved understanding and thought that a model represents a target that is either known or unknown. Half of them (N=16) realized the purpose of a model as to provide an idea about the target and to help in its conceptualization. As a result of these findings, the researchers claimed that teaching related to models and modeling has improved students' notions of models.

Improvement in understandings of scientific models as result of model building activities was also reported in a study conducted in Turkey. In their study, Sarıkaya, Selvi and Doğan Bora, (2004) conducted an experimental study examining high school students' achievement in mitosis and meiosis concepts, in which the experimental group (N=32) received traditional instruction and model building activities, and the control group (N=24) received only traditional instruction. Although there were no statistically significant difference between the groups in terms of achievement before the instruction in pre-test scores, post-test results showed significant differences between the two groups in favor of the experimental group. The results showed that the use of model building activities increased the students' achievement in mitosis and meiosis concepts. Moreover, it was found that such types of hands on model building activities increased students' attitudes and motivation towards science courses. The researchers recommended that with the construction of models through making use of available materials, teaching and learning several scientific concepts may become more interesting.

To be brief, the research findings demonstrated that students mostly hold naïve understandings about scientific models since they usually considered models as exact replicas of the target systems, and since they usually do not realize the multiplicity and dynamic nature of scientific models. However, it was also evidenced that, through several applications in the classroom, students' understandings of models can be improved. At this point, teachers' knowledge of models is of great importance since they are responsible for designing and conducting teaching situations for students to learn science (Justi & Van Driel, 2005a). In the following section, the studies related to teachers' understandings about models and modeling concepts are reported.

2.3.2. Research on Teachers' Understandings of Models

Teachers should hold sophisticated understandings of models, and they should have the required knowledge and abilities to use these models in their instructions effectively since they help their students build scientifically acceptable understandings. However, related research suggests that teachers themselves also possess limited and varied understandings about models (Harrison, 2001; Justi & Gilbert, 2002a, 2002b, 2003; Van Driel & Verloop, 1999).

In one of these studies, Van Driel and Verloop (1999) examined experienced science teachers' content knowledge about models and modeling in science in the context of a new Dutch curriculum innovation project, which specifically gives more attention to the role and nature of models and modeling in science. Data were collected through an open-item questionnaire with seven items, and a Likert-type scale with 32 items. The open-item questionnaire, which was administered to a group of 15 science teachers, addressed four themes about scientific models, namely, the types of representations of models, goals and functions of models in science, characteristics of scientific models, and design and revision of models. The 32-item Likert-type questionnaire, on the other hand, was administered to another group of 71 science teachers, and addressed participants' understandings about types of representation, goals and functions, characteristics, and design and development of models. Results obtained through the two instruments showed that, teachers' understandings of models and modeling in science were limited including several inconsistencies. Teachers generally shared the idea that a model is a simplified or schematic representation of reality. Although possessing such a general description of models, their content knowledge of models and modeling was found to be varied. Although the explanatory or descriptive function of models were frequently stated by the teachers, some important functions like, using models to make predictions or recognizing a model as a tool for obtaining information about a target that is not available for direct observation, were rarely mentioned.

In a separate study, Van Driel and Verloop (2002) investigated teachers' use of teaching activities concerning models and modeling in the context of the reform in science education in Netherlands. The study differs from the previous study that the focus of interest shifted from teachers' content knowledge to their use of teaching activities concerning models and modeling. Particularly, in the latter study, the teaching activities concerning models and modeling that are applied by science teachers as they get prepared for teaching the new science curriculum were investigated. Moreover, the teachers' knowledge about the ways that their students perceive models and how they assess their students' modeling abilities were also explored. For these purposes, first, seven science teachers were interviewed to reveal teachers' knowledge about teaching models and modeling in science. The two dimensions emerged during the interviews constituted also the structure of the questionnaire, which were the use of specific teaching activities with respect to models and modeling (TAM), and the teachers' knowledge of students' views of models and modeling abilities (KSM). The final form of the questionnaire included 30 Likert-type items, and it was completed by a group of 74 science teachers. Results indicated two groups of teachers. One group of teachers preferred to use teaching activities that are usually teacher-directed. These teachers focused on the content of models rather than on the design and development of models. They thought that their students had limited abilities in dealing with abstractions or they had difficulties in building models themselves. The other group of teachers discussed the nature of models and modeling with their students, and encouraged their students to design and develop models. These teachers used more student-directed teaching activities. They exhibited a higher confidence in their students' views of models and modeling abilities. The results gained through the questionnaire also revealed the same two groups of teachers. The distinction between the groups, however, was not found to be related to teachers' subject (physics, biology or chemistry) or teaching experience. Likewise, the use of teaching activities was found to be loosely related to the teachers' knowledge of their students.

Similarly, Harrison (2001) investigated ten Australian science teachers' understandings of models and their use in science teaching via semi-focused interviews. The researcher also investigated how models are used in science textbooks. During the interviews, the teachers were shown a series of analogical models including a scale model heart or eye, a toy model boat, a text-book diagram of diffusion across a semi-permeable membrane, representations of ammonia, and a simple tube for an earthworm's gut, and were invited to comment on these models. Then, Harrison asked the teachers to reflect their thinking on Gilbert's (1993) four assertions about models (i.e., models are the main products of science, modeling is part of the scientific method, models are major learning tools in science education, and models are major teaching tools in science education), and when interesting ideas about these assertions were found, he asked further questions to solicit reasons and/or examples behind. Harrison found that all teachers accepted models as major tools of science; however, three teachers disagreed about models being the main products of science. Two teachers, on the other hand, were unsure whether models are important learning tools and three did not certify models as major teaching tools. The researcher categorized teachers' modeling levels according to the levels provided in Grosslight et al.'s (1991) study, and it was found that three of the ten teachers were at Level 3, two were between Level 3 and Level 2, three were at Level 2, and two were below Level 2. Teachers who were at Level 2 or below were unlikely to show clear understandings about models and their use in science, and they could not use models in their instructions effectively. Moreover, Harrison also found that teachers depended mostly on textbooks for planning their lessons; however, textbooks did not clearly discussed models. Chemistry textbooks were found to use the most models and physics textbooks the least with biology in between. Harrison offers that more emphasis should be placed on models and modeling in science teaching and on science textbooks since students, possessing naïve understandings of models, cannot differentiate between models and realities themselves. It is also recommended that science textbook authors should pay more attention to the models and modeling processes on which science depends.

In a series of investigations, Justi and Gilbert (2002a, 2002b, 2003) explored teachers' understanding and use of models and modeling through semi-structured interviews with thirty-nine Brazilian science teachers, working in primary (N=10) and secondary (N=10) schools, as well as prospective teachers (N=10) and university instructors (N=9). In one of these studies, Justi and Gilbert (2002a) focused on teachers' perceptions of the role of models in science teaching. The results showed that teachers' understandings of models and modeling were organized in three groups, namely, the status and value of models in science education, the influences that inform the translation of these general ideas into classroom practice, and how they respond to the outcomes of students' modeling activities. Regarding the relationship between the models used in science and the models used in science education, although some teachers shared the idea that scientific models are so important that no changes should be made to them for teaching, most of the teachers recognized that scientific models should be simplified according to the teaching purpose, or special teaching models can be used. As contributions that models can make to science education, ninety percent of the teachers thought that models can help students by visualizing abstract concepts, and help in promoting conceptual change and learning about the nature of science. They thought that models may help students by favoring the establishment of new relationships, and by making students think in different ways. Some considered models as mediators between student's knowledge, teachers' knowledge and scientific knowledge. The understandings about the characteristics of models used in science education were also varied. The mostly shared idea was that models should make ideas more accessible to students. Models' being as accurate as possible and making contribution to the development of understanding were among the other characteristics defined. These findings showed that teachers recognized the importance of models. However, although recognizing the importance of models theoretically, the findings also showed that the teachers did not prefer to use modeling activities in their classrooms, and they also ignored their students' ideas about models and modeling. The researchers reported that about half of the teachers either did not know their students' thoughts about the nature of models or, showed low level of interest to what their students say about models. Moreover, although majority of the teachers (72%) said that they would engage students in a scientific process including the use of models, only 29 percent performed this just by asking their students to explain their models.

In another study, Justi and Gilbert (2002b) focused on same teachers' views on the skills needed to produce scientific models successfully. The findings, in general, showed that the teachers recognized the importance of a clear understanding of the purpose for producing the model, and the identification of the students who will make use of the model, in order to produce scientific models successfully. The teachers thought that personal experiences and knowledge of the modeler affects the success in modeling. Moreover, they realized that success in modeling is also linked to personal attributes, and they thought that a successful modeler should have an active interest in building the model, s/he should be a creative person, and s/he should also be persistent – should not give up if the model is not good. About designing and performing empirical tests, on the other hand, teachers thought that a successful modeler should have good manual skills, should be a good observer, should have the capacity for abstract thinking, and the capacity for logical thinking. The ability to communicate and the capacity to express ideas in different ways were also seen to be important in modeling. Lastly, the teachers recognized the need for being flexible in the presentation of the models to diverse students; however, similar to the findings reported in Van Driel and Verloop's (1999) study, the teachers did not emphasize the need to consider the scope and limitations of models during the process of modeling.

Lastly, Justi and Gilbert (2003) reported the same science teachers' understandings about the nature of models. The researchers identified seven aspects of the participants' notions of a model. They were the nature of a model, the use of it, the entities of which it consists, its relative uniqueness, the time span over which it is used, its status in respect of the making of prediction, and the basis of accreditation for its existence and use. The researchers reported that, teachers' notions of model were complex, and the notions differed among teachers with degrees in chemistry or physics and biology or teachers with teacher training certificates. The researchers found that all participants considered models as representations. Regarding the use of models, most of them mentioned about their explanatory role (92%), and their use for creativity and visualization (87%), and for prediction (82%). In respect of entities aspect, although events (38%), processes (31%), and ideas (36%) are seen as models, more than half of the teachers (59%) considered models as objects. About the uniqueness of models, a great majority (82%) of the teachers shared the idea that a given model is one of the several available. Regarding the stability of a model over time, the teachers showed scientifically reasonable understandings and thought that a model should be changed due to the problems with its nature, or use, or explanatory adequacy. The use of models in making predictions was also noted by 82 percent of the teachers. The issue of accreditation, on the other hand, was recognized by 38 percent of the teachers, and interestingly, most of these teachers believed that a model is accredited by the individual producing it. Lastly, when teachers' educational backgrounds together with the aspects evolved are considered, it was observed that teachers with primary teaching certificates held the most simple and everyday meaning views of models like asserting the idea that models cannot be changed. The situation was similar with the teachers with biology degrees. However, teachers with chemistry or physics degrees showed a more comprehensive notion of models, which was often consistently close to an accepted scientific viewpoint.

In Turkey, Güneş, Gülçiçek and Bağcı (2004) investigated instructors' ideas about models, and their use, purposes and roles in science. The participants were physics (N=9), chemistry (N=6), biology (N=3), science (N=4), and mathematics (N=3) instructors working in education faculties of different universities. The researchers adapted a 31-item (30 item Likert-type and an open-ended item) instrument based on a previous study of Treagust et al. (2002). The instrument assessed participants' understandings of models in six aspects, namely, models as multiple representations, models as exact replicas, models as explanations, use of scientific models, changing nature of models and model examples. Results, in general, showed that the instructors had limited knowledge about the nature of models and modeling. The limitation in the understanding was especially on the extent to which the model represents its target and on deciding on whether a given example is a model or not. The participants, on the other hand, recognized the existence of multiple models, the explanatory role of models, their use in science, and their changing nature. Regarding models as exact replicas aspect, interestingly, 36 percent of the participants supported the idea that a model should resemble to its target. As it can be easily predicted from the example of the model of magnetic field lines, models do not always resemble to their targets. Similarly, 36 percent of the participants also shared the idea that a model shows what the real thing looks like. The researchers classified the examples of models provided in the open item of the questionnaire according to Harrison and Treagust's (2000b) classification of analogical models. In respect of this aspect, the researchers found that participants' examples of models were limited to scale models, maps-diagrams-tables, mathematical models, theoretical models, and pedagogical-analogical models. Considering the frequencies of these models used, it was found that theoretical models (i.e., atom model) and scale models (i.e., mock ups) were found to be mentioned more than others. The researchers suggested that, as being an indispensable part of their academic lives, the nature of models should be well understood by the instructors.

To conclude, the findings showed that, similar to the students, most of the teachers also held limited understandings about the notion of models. Similarly, in respect of the use of models in classrooms, it was found that science teachers usually depended on textbooks; however, the textbooks did not provide sufficient information about models. In the following section, the studies done in the purpose of investigating teacher candidates' understandings of models and modeling concepts are reported.

2.3.3. Research on Pre-service Science Teachers' Understandings of Models

There are a few studies in the literature that investigate pre-service science teachers' understandings of models (Aktan, 2005; Berber & Güzel, 2009; Crawford & Cullin, 2004; Valanides & Angeli, 2008). In one of these studies, Aktan (2005) explored American PSTs' understandings of models and modeling, and their attitudes towards the use of models in science teaching. The participants were seven PSTs, six of whom were enrolled in biology teacher education and one in chemistry teacher education program. The researcher collected the data through semi-structured interviews, and open-item and Likert-type questionnaires. The results showed that PSTs' understandings were limited and there were variations among their understandings of the concept of model and the nature of models. The researcher reported that none of the participants were able to display Grosslight et al.'s Level 3 understanding. The participants viewed models as materialistic examples and representations. When defining models, they referred to an example, a representation, or a simplified version of the real thing. They also believed that a model can be built as an exact representation of its target. Regarding the purpose of a model, the participants believed that the purpose is to make phenomena more accessible, and more interesting and understandable. According to a scientific view, however, models are built for testing and developing ideas. In respect of the use of models in science teaching, on the other hand, the prospective science teachers showed positive attitudes towards the use of models. They favored three-dimensional models and thought of them as the best structures to employ in science teaching. According to them, in science teaching, models provide access to the phenomena that could not normally be accessed or explained, and they make instruction more interesting and effective. The participants also shared the idea that in order to use models effectively in science teaching, the teachers should consider their students' level, past experiences and prior knowledge. They thought that a successful modeler should build accurate and realistic models, which are not complex. According to them, the simplicity of the model should depend on the experience of students. In respect of the characteristics that a good modeler should have, creativity was reported to be most essential. The participants believed that a good modeler must be creative and s/he must also be knowledgeable and be able to communicate well. Lastly, although the participants thought that scientific models are important aspects of science teaching and learning, some factors like level of learner, time, lack of modeling experience, and limited knowledge of models appeared to affect their perceptions about the use of models in science classes negatively. They thought that these factors restrain the possibility of using models and allowing students to build their own models.

In another study, Berber and Güzel (2009) investigated Turkish pre-service science, physics, chemistry, biology, and mathematics teachers' (N=435) understandings of models in science through My Views of Models and Modeling (VOMMS) instrument. The instrument identifies three characteristics of scientific models: models as representations, multiplicity of models, and dynamic/changing nature of models. Findings revealed that 83 percent of the participants defined scientific models as representations, but still 15 percent defined them as exact copies of the reality. Regarding the multiplicity of models, the majority (93%) of the participants recognized that there can be multiple models that explain a certain scientific phenomenon. They also stated that, in accepting a model, scientists' decisions are based on the facts that support the reality and the theory (75%) rather than their personal feelings and motives (5%). However, interestingly, a considerable group of the participants (20%) agreed on both responses and thought that scientists' decisions in accepting a new model are both based on the facts and are also affected by their personal feelings. Very similarly, almost half of the participants (46%) shared *both* ideas that the acceptance of a new scientific model 'requires support by a large majority of scientists' and 'occurs when it can be used successfully to explain results', while 42 percent agreed on the first and 11 percent on the second idea. The researchers interpreted this finding from the written responses of the participants and stated that if a model successfully explains the results, then it is naturally supported by the scientists. In respect of the dynamic nature of scientific models, although 56 percent of the participants thought that scientific models would change in future years, interestingly again, 34 percent of them shared the idea that they would not change and 11 percent were unsure. The emerging ideas in the written responses were also interesting: 'models are based on facts, and facts do not change', 'an accepted model should adapt every future condition', 'if it will change, then why is it developed?', scientific models should not change, it is not a game', 'models are designed so as not to change', 'truth is certain, it does not change'. It is really easy to predict from these responses that the participants hold a naïve understanding of the nature of science and scientific models. Lastly, the researchers asked the participants to qualify the given examples (the principles of Newton, the evolutionary theory, the Pythagorean Theorem, $E = mc^2$, Bohr model of atom, DNA model, maps, graphics, mock ups, and simulations) as models or not. Findings showed that although 69 percent of the participants identified Bohr model of atom and DNA model as models, more than 70 percent of them did not define the evolutionary theory, the Pythagorean Theorem, $E = mc^2$ and simulations as models. The researchers suggested that, in order to eliminate these naïve understandings, courses and assignments about the history of science should be designed, and students should be given the opportunity to build and test their own models.

In addition to the descriptive studies mentioned above, intervention studies have also been conducted in an attempt to promote understandings about models. Crawford and Cullin (2004), for example, used the software program ´Model-It´ to investigate and enhance understandings of scientific models. The researchers examined pre-service science teachers' (N=14) understandings of models and modeling in science, the possible change that may occur after building and testing dynamic computer models, and finally their intentions to teach about scientific modeling. The model-based instruction in the study involved investigating real-world phenomena; and then designing, building, and testing computer models about these real-world phenomena. Before and after the modeling module, the participants completed an open-ended questionnaire to investigate their notions about scientific models and their views regarding teaching about scientific models and modeling. The researchers also used semi-structured interviews to further explore PSTs' understandings, and the participants were asked to report their reflections about their modeling experience. The findings revealed that although initially possessing a limited view of models and modeling, participants developed more clear ways to talk about scientific models after engaging in the modeling experience. Their notions before the modeling experience were classified as Level 2 modelers (according to Grosslight et al.'s scheme), who considers models as related to ideas and realizes that there is not a one-to-one correspondence between the model and the real thing. The participants viewed scientific models as representations of objects or phenomena that are used to explain the targets. They shared the idea that scientists change models based on new information and can have more than one model for the same target. The participants, however, did not possess the ideas that models also play roles in the development of new ideas, or scientists may interpret the same data in new ways and therefore can change their models. After the modeling experience, although the participants did not jump to a Level 3 understanding, their ideas about the use of scientific models and their language of modeling improved. Their understandings about the use of scientific models shifted from the view that models are used to explain scientific phenomena to the view that models are also used to test ideas and the modeler can himself/herself use models to understand scientific phenomena. Moreover, after the modeling experience, they became more competent in the modeling terminology. The modeling experience also created changes in participants' views of how teachers can use models. Before the modeling experience, they shared the idea that models are used just to explain concepts to students. After the modeling experience, however, they viewed models as cognitive tools that help students in constructing explanations about the natural phenomena. As a result of the improvements found in pre-service science teachers understandings of scientific models and modeling, the researchers suggested the use of such modeling experiences to strengthen the understandings about models and modeling in science.

Likewise, Valanides and Angeli (2008) investigated pre-service primary teachers' knowledge about the use of models and modeling in science teaching and learning, and they used the same tool (i.e., Model-It) to support participants' learning and teaching about scientific models. The participants in the study were 47 fourth-year pre-service teachers who were enrolled in a science education methods course. Findings showed that although the models built by the pre-service teachers were found to be structurally correct but simplistic, the tool used (Model-It) effectively helped pre-service teachers to build, test and reflect on scientific models. The researchers suggested that participating students in such modeling activities not only improve their knowledge of scientific models, but also promote accurate and productive epistemologies of science. When students construct a sophisticated understanding of scientific models and modeling, they also understand the nature of scientific knowledge as a human construct, and reason about scientific evidence and realize the tentative nature of scientific knowledge.

In a recent study, Danusso, Testa and Vicentini (2010) investigated prospective physics, mathematics and engineering teachers' knowledge of scientific models and modeling, and the effectiveness of a research-based teacher education intervention aimed at improving knowledge about scientific models and modeling. The participants were 400 prospective teachers from two Italian universities, and the teacher education scenario in which this research intervention carried out was the Post Graduate Specialization School in Secondary Teaching (PGSSST). PGSSST was a two-year mandatory education that leads to a certification to teach in secondary schools in Italy. The research design of the study was a survey–trial–redesign–trial approach, where in the *survey phase,* an investigation of the prospective teachers' knowledge of scientific models has been carried out, while in the *first design phase,* the first version of the teaching intervention on models and modeling was designed on the basis of the literature and survey phase results, in the *first trial phase,* the core components of the intervention have been implemented, and in the *redesign phase,* a refined version of the intervention is formed. The results of the study showed that prospective teachers' knowledge about models and modeling was poor and confused. Only about one-third (37%) of the overall sample held an informed knowledge about scientific models, and described a scientific model as an abstract representation of a phenomenon with the aim of characterizing and studying it. These PSTs recognized the main function of a scientific model as to make future predictions. About half of the sample (48%), however, held an incomplete or declarative knowledge about scientific models by describing a scientific model as a set of rules which characterize a phenomenon, and by defining its function as simplifying the analysis of the phenomenon and making the phenomenon understandable. About one-tenth (9%), on the other hand, confused models with scientific method, theory, or teaching method, and thought that a scientific model is a schema which contains all the information useful to a teacher for his usual classroom practice, in order to have a series of steps to follow, while the function of scientific models is to allow the experimenter to create theories. Finally, a non-negligible percentage of prospective teachers (6%) gave incoherent responses resulting in a very poor understanding of the scientific models, and they described a scientific model as a conceptual structure that is applicable to the different scientific subjects whose main functions are to clarify, emphasize and describe a particular theory. Despite these confused understandings about models and modeling, the researchers reported that the implementation results supported the effectiveness of the designed intervention and of the refinement process. The post-test results showed that, after the intervention, about 66% of the prospective teachers were able to propose models of complex systems/phenomena identifying correctly their components and functions. Even, the intervention showed a satisfactory long-term effectiveness that five months after the last session of the intervention, more than 60% of the prospective teachers still possessed informed understanding about models.

A more recent study by Schwartz and Skjold (2012) explored pre-service teachers' conceptions of scientific models before and after a science course that uses multiple models and explicit instruction about models and modeling. Participants were 71 pre-service teachers enrolled in an undergraduate biology course, which addressed topics of nature of science, scientific inquiry, cells, genetics, molecular processes, and biotechnology, at a large university in the United States. During the course, the concept of models was explored through activities and discussions. Models were emphasized throughout the course as specific examples of products and processes in scientific inquiry, as well as teaching and learning tools. Class discussions were done on relevant aspects of nature of science such as empirical nature, tentativeness, creativity, and subjectivity. For example, pre-service teachers experienced model construction and testing with the nature of science "tube" activity, which is an example of a black box activity where pre-service teachers make observations of the tube and its function, and then infer what is on the inside of the tube that explains their observations by constructing models to test their hypotheses. During this activity, pre-service teachers were encouraged to consider what makes a model valid, how models might change, and the value of a model even though they may not know if their model is an exact replica of the real thing. In addition to the tube model, pre-service teachers were exposed to the Watson and Crick DNA model, where they studied the historical cases that lead to the development of the DNA model. They also constructed paper models of DNA and discussed uses, assumptions, and limitations of each model as they represent different features of molecules and DNA structure. Pre-service teachers were also exposed to simulation models of DNA replication, transcription, and translation, and, they designed and constructed their own dynamic models of the process of translation. As pre-service teachers designed, constructed and presented their models, they were also asked some questions for discussion about the strengths, limitations and functions of models, and how they are useful for addressing aspects of nature of science. As a consequence, results of the study showed that this intervention increased pre-service teachers' recognition of models as representations of scientists' ideas and explanations of processes. Before the intervention, pre-service teachers considered models as physical representations of objects to be visualized, as an experimental procedure that scientists follow, and as a chart that scientists use to record data. After the intervention, their ideas shifted from seeing models as merely representations of objects, either exact replicas or simplifications, to understanding that models have functions related to processes and explanations of ideas. At the end of the intervention, the researchers reported that, more than half the pre-service teachers (52%) were able to recognize the explanatory role of models; and this category showed the largest gain (from 7% to 52%). However, not all of these participants were able to consider explanations as inferences or representations of scientists' ideas as well as data. The researchers also reported that although some of the participants recognized that models are more than products that help others understand a phenomenon, seeing the role of models as tools for learning was still a predominant view among the participants, with limited understandings about how models are used by scientists to develop and test ideas. Participants tended to describe models as visible, and the purpose as to make something that cannot normally be seen, visible (32%). They also tended to describe the role of models as tools for teaching and learning, as opposed to tools that scientists use in their research, by implying that models are products of inquiry that explain or describe phenomena for learners (45%). The notion of using models for further research and testing, or as part of the process of inquiry, is missing from these responses.

Given the review of the literature, it is seen that pre-service science teachers do not generally possess adequate understandings of models and modeling in science (Aktan, 2005; Berber & Güzel, 2009). However, research also indicate that they science teachers hold positive attitudes towards the use of models (Aktan, 2005), and the intervention studies that aim to promote model understandings show some success at moving students from naïve to more sophisticated understandings of models (Crawford & Cullin, 2004; Danusso, Testa & Vicentini, 2010; Schwartz & Skjold, 2012; Valanides & Angeli, 2008). Therefore, despite the difficulties, efforts should be undertaken to help both pre-service and in-service teachers understand the nature of models modeling, so that they help their own students learn about models and modeling by providing them with the opportunities to engage in scientific inquiry and modeling (Valanides & Angeli, 2008). Similar to the tool Model-It which enhances pre-service teachers' understandings about models, there are also some other applications and suggestions present in the literature to support and enhance model understanding. In the following section, such attempts and suggestions to enhance model understanding are examined in detail.

2.3.4. Enhancing Model Understanding

There are several ways offered by researchers to enhance model understandings, majority of which are proposed to teachers for improving their students' model understandings. To illustrate, rather than using pre-existing models, developing and manipulating models is offered as a critical way to enhance conceptual understanding and model understandings. Halloun (1998), for example, offers science teachers to consider students' initial knowledge and construct the scientific concepts systematically within the context of schematic models rather than behaving like information providers. Similarly, Prins, Bulte, Van Driel and Pilot (2008) offered that rather than providing students with the models designed by others and letting them memorize the facts, teachers should encourage their students to involve in modeling processes and let them develop, evaluate and test their own models through authentic modeling practices. Coll et al., (2005) claim that students' conceptual development would be most effective when they are able to construct and critique both their own models and scientists' models of scientific phenomena.

In order to encourage students participate in learning by constructing and using models to understand the scientific phenomenon, Wells, Hestenes and Swackhamer (1995) proposed a model developing method for high school physics. The researchers described four main phases of model development: description, formulation, ramification and validation. In the description phase, the teacher functions as a moderator, non-judgmentally recording all suggestions, asking occasionally for further clarification but never acting as an authority or a source of knowledge. Students are directed to identify quantitatively measurable parameters that may exhibit some cause-effect relationships. Here, it is critical that students should differentiate the independent and dependent variables. Thus, the issue of ´identifying and controlling variables´ is very critical to modeling, which is rarely addressed in traditional instruction. Having completed the descriptive phase, the teacher directs the class into the formulation phase by raising the central problem: to develop a functional relationship between the specified problems. A brief discussion is followed to find those parameters, and then the class is divided into teams to perform the task on their own. The teacher then selects a group, which can raise significant issues for class discussion – this group often has taken an inappropriate approach. Here, the group members are expected to present a detailed explanation with graphical and mathematical representations, and propose a model. Then, each individual prepares a report, writing the work done in class in their groups. Grading is done by selecting one report at random from each group and asking them to defend their model. This random selection ensures that every member of the group understands all aspects of the model that they have developed. The end product is a mathematical or physical model together with evidence for a claim that accurately represents the system.

Gilbert (2004) offers another instructional strategy that includes the use of models in the science curriculum, as well. He thinks that till now several models are developed in science, and when the most significant of those models are selected and introduced into the curriculum with ´key explanatory stories´, they would make a good contribution to students' understanding of science. The researcher also says that a ´model-based-science-curriculum´ should also give the students the chance to produce and test their own models. For such an implementation, the researcher offers four steps, which are followed by one another. The first step is ´learning to use of models´, where students use models in a phenomenon where the model successfully represents the certain behavior of the target, or solves the problem. The next step is ´learning to revise models´, where students are supposed to change the model, like revising the model in a simulation of a scientific activity to see that it can represent the target in other contexts. The third step is ´learning the reconstruction of a model´, where students are asked to create a model they know exists but with lacking details, like the re-creation of a model. The last step is ′learning to construct models de novo′, where students recognize the formation of the features of the complete model from the components of it. Gilbert (2004) also takes attention to the need for a long time and a good understanding of particular models for students to achieve these stages.

Besides letting students develop models, Harrison and Treagust (1998, 2000a) offer other recommendations for teachers about teaching with models. According to the researchers, since the models are mostly scientists' or teachers' products, students may not be able to understand the analogs that are used to explain the concepts. The researchers, therefore, highlight the need for teachers to plan model and analogy use in their lessons. An approach involving focus, action, and reflection (FAR) provides a solution to this problem, where "focus involves pre-lesson planning, in which the teacher focuses on the concept's difficulty, the students' prior knowledge and ability, and the analog model's familiarity. Action deals with the in-lesson presentation of the familiar analogy or model, and stresses the need to cooperatively map the shared and unshared attributes. Reflection is the post-lesson evaluation of the analogy's or model's effectiveness and identifies modifications necessary for subsequent lessons or next time the analogy or model is used" (Harrison and Treagust, 1998, p. 423). The researchers suggest that, teachers should check their students' understandings about the models they are planning to use. They should not expect their students reliably interpret models, rather they should provide analog-target mappings of the models. However, they should also be aware of the emerging conceptions of their students about the models, analogies and metaphors used in the classroom. Harrison and Treagust (1998; 2000a) also recommend teachers to challenge students to use more abstract and difficult models to develop student-modeling skills. They also suggest that students should experience the need for multiple models and they should be encouraged to use multiple models whenever possible.

In line with the recommendations of Harrison and Treagust (1998, 2000a), Nelson and Davis (2012) recommend teachers to help students develop understandings about the nature of scientific models. They suggest that teachers should help students understand not only factual and conceptual aspects of the scientific knowledge, but also help them see how scientific models and modeling can be useful in developing and enhancing their own science content understandings (Nelson & Davis, 2012). As the researchers reported, when working with a model of the solar system, for example, besides presenting this model as a representation of the order of the planets relative to the sun, teachers should also form sound understandings about the nature of this representation as a scientific model. That is, teachers should also emphasize that the model is not an accurate scalar representation, and it can be revised on the basis of new understandings and scientific evidence, as was recently demonstrated by the changed status of Pluto (Nelson & Davis, 2012).

In order to use models in science courses more effectively and thereby develop students' understandings and abilities about models, specific skills that teachers should have are also reported in the literature. According to Gilbert (2004), for example, teacher education should provide teachers some specific knowledge and skills. First, teachers' ´subject content knowledge´ should include a good understanding of ´curriculum models´ including the purposes, nature and limitations of models. Second, teachers should have a ´curricular knowledge´ including when, how and why models should be used in the curriculum. Third, teachers' ´pedagogical content knowledge´ should also cover their abilities to develop good ´teaching models´, understand their students' mental models and to deal with the resulting models as they are expressed. And lastly, teachers should have a good understanding of the model concept itself (Gilbert, 2004, p.126). Similar to Gilbert (2004), Coll et al., (2005) also claim that students' conceptual development would be most effective when teachers have a good pedagogical content knowledge about the nature of science -in particular, the role of models, metaphor and analogy in scientific communities of practice- and when they are aware of the range of possible mental models of scientific phenomena that their students may hold.

In sum, suggestions such as these mentioned above propose that fostering understandings about models is possible. These suggestions share some common points. First of all, students should learn to use models, but they also need to learn to develop, construct and revise models. ın other words, they should be encouraged to engage in properly-designed model-based activities. Second, teachers should discuss the roles, importance and nature of models, as well as their limitations and weaknesses, when they are used. And, finally, for the effective use of models in science classes and to develop students' understandings and abilities about models, teachers should have a good pedagogical content knowledge about the role, nature and limitations of models, and they should have the abilities to develop effective teaching models.

2.4. General Conclusion

The role of models in science and in science education is well documented in literature. This is because models play important roles in science, and many topics in science education need models for their conceptualization. This importance requires students and teachers to hold sound understandings about models and modeling. However, research suggests that both students and teachers usually hold limited conceptions about models by considering them scaled versions of the real thing and not realizing their explanatory and predictive nature (Crawford & Cullin, 2004; Grosslight et al., 1991; Harrison, 2001; Justi & Gilbert, 2003). From this point, the present study aims to explore Turkish pre-service science teachers' understandings of models. The findings would reveal their notions about scientific models and teaching models, and are expected to contribute to the developing literature.

CHAPTER III

METHODS

This chapter specifies the methods that are employed to gather and analyze data in this study. Specifically, the chapter addresses details regarding the design of the study, the participants, data sources, the procedures followed, the analyses that were carried out, trustworthiness of the study, and the limitations of the study.

3.1. Research Design

To explore pre-service science teachers' (PSTs') understandings of models, the employment of qualitative research methods was considered as appropriate. In qualitative research, the purpose is to reveal the meanings and understandings that people have constructed; and for this purpose data are collected through interviews, observations and documents, and are presented in a richly descriptive way (Merriam, 1998). The nature and purpose of this study requires understanding a certain group of PSTs' understandings of models in a holistic and descriptive way. Therefore, the employment of qualitative research, more specifically a case study, was needed.

In case studies, a bounded system (case) or multiple bounded systems (cases) are investigated and described through detailed and in-depth data collection methods from multiple data sources (Creswell, 2007). The bounded system investigated can be "a single person who is a case example of some phenomenon, a program, a group, an institution, a community, or a specific policy" (Merriam, 2009, p.40). Case studies are typical in that the unit of analysis rather than the topic of investigation characterize a case study (Merriam, 2009). Case studies are also common in qualitative studies in the field of education (Merriam & Associates, 2002). The case in these studies could be a student, a teacher, a principal, a program, a class, a school, a community, or a specific policy (Merriam & Associates, 2002). The only point to question is that the unit of analysis should be bounded, that is, there should be a limit to the number of people to be participated in the study (Merriam & Associates, 2002). The unit of analysis in this study was fourteen PSTs who were attending ′Practice Teaching in Elementary Education′ course in their last year of university education in a public university.

Case studies do not have certain data collection or data analysis methods (Merriam, 2009). However, data sources in a case study, as in other types of qualitative research designs, should be extensive, and the researcher should provide in-depth descriptions of the case (Creswell, 2007). In case studies, data are described through detailed and in-depth data collection methods from multiple data sources like observations, interviews, audiovisual materials, documents and reports (Creswell, 2007). For the purpose of this study, data were collected in several ways (questionnaire, interviews, documents and class observations) to provide a rich description of the context. The data collection strategies of this study are given in detail in the following section.

3.2. Data Collection

For the purpose of the study, data were collected in four ways: (a) My Views of Models and Modeling (VOMMS) instrument, (b) interviews, (c) lesson plans and (d) class observations. An overview of the research phases including the research questions with their corresponding aims, data collection instruments, and data analysis methods is outlined in Table 3.1.

Table 3.1. Summary of the research design

Research Question	Aim	Instrument	Data Analysis
What understandings do pre-service science teachers possess about scientific models?	To revel PSTs' understandings about scientific models in various aspects like, descriptions, characteristics/nature and role of scientific models	VOMMS Instrument and Interviews	Qualitative data analyses through coding the interview transcripts and written responses
What are pre-service science teachers' perceptions about the use of models in science education?	To reveal PSTs' understandings about the characteristics and use of models, and to explore the models they prefer to use in their classroom practices	Interviews, Lesson Plans, Class Observations	Qualitative data analyses – coding interview transcripts, document analysis, class observation analysis

3.2.1. Participants

Participants in the study included fourteen senior pre-service science teachers (four males, ten females) enrolled in Elementary Science Education (ESE) program in the Elementary Education department of the Faculty of Education at a large public university located in Ankara.

Study Context

The ESE program provides a program of study that leads to a Bachelor of Science in Elementary Science Education. All ESE majors are required to complete several science courses (i.e., biology, chemistry, and physics) and mathematics, as well as courses of education and teaching profession; and graduates of the program are prepared as science teachers, who are responsible for teaching all science subject areas in Grades 6-8. In this study, the point of interest was pre-service science teachers' understandings of models, and their use of these models in their teaching practices; therefore, one of the courses offered by the ESE program, -that is, Practice Teaching in Elementary Education-, was the course context of this study.

The Practice Teaching in Elementary Education is one of the two must courses identified by the Higher Education Council that are related to field experience. The course is a five credit course with two hour theoretical and six hours field experience per week, and PSTs typically take this course at the very last (eighth) semester of their education.

Teaching practices implemented in the context of this course was twofold. The PSTs were first required to prepare lesson plans to teach a topic and make oral presentations (micro teaching) which takes about 20/30 minutes, at the university. The presentations were followed by whole-class debriefing sessions where peers as well as instructors comment on the work presented. Following the presentations, the PSTs were supposed to submit one-page self-critique of their teaching in the following week of each of their presentations. In the second phase of the course, on the other hand, under the guidance of their mentor teachers, the PSTs were supposed to gain experience in both observing and participating actively in a range of educational activities under typical conditions in the selected cooperative schools. For the purpose of the course, they were required to plan, implement and reflect on lessons in their cooperating schools. For these lessons, the PSTs were also expected to prepare lesson plans and write a self-critique about their teaching. The class sessions that PSTs implemented in the cooperating schools were observed and assessed both by the instructor of the course and the mentor teacher in the cooperating school.

3.2.2. Data Sources

The data sources of this study included My Views of Models and Modeling (VOMMS) instrument, interviews, lesson plans, and class observations. In the following sections, each of these data sources is described in detail.

3.2.2.1. 'My Views of Models and Modeling in Science' Instrument

The instrument ′My Views of Models and Modeling in Science′ (VOMMS) was originally developed by Treagust, Chittleborough and Mamilia, (2004), and adapted into Turkish by the researcher (Appendix A). The VOMMS instrument includes a total of 6 items that identify three characteristics of scientific models, namely, the understandings about ′models as representations′, the ′multiplicity of models′, and the ′dynamic/ changing nature of models′, and the items were reported to be evolved from Aikenhead and Ryan's (1992) Views of Science-Technology-Society (VOSTS) questionnaire. Each item of the instrument requires the participants to choose between two alternative statements about scientific models, and then asks participants to justify their choice with a written response. These written explanations were used to ensure that the PSTs had interpreted the questions correctly, and they also provided detailed data about their understandings.

3.2.2.2. Semi-Structured Interviews

Semi-structured interviews served as the primary data source of this study (Appendix B). The interviews probed possible themes and patterns about participants' understanding of models. Participants were let to express their thoughts aloud and reflect upon their experiences, and the researcher directed the questions occasionally depending on the responses of the participants through probing and follow-up questions (Patton, 2002).

The interview questions and probing questions were developed based on several previous studies (Grosslight et al., 1991; Gobert & Discenna, 1997; Crawford & Cullin, 2004; Aktan, 2005), and were specifically aimed to reveal the participants' understanding about descriptions, roles, characteristics and use of models. All PSTs were asked the basic questions in the same order. However, in response to their answers, the probing questions they were asked changed. That is, some questions were added to explore their ideas in detail, or some were skipped when they seemed redundant. To establish consistency, all interviews were done individually in a quiet room, and all were conducted by the researcher. The interviews took approximately 30-35 minutes, and they were audio-recorded and were transcribed verbatim by the researcher.

3.2.2.3. Lesson Plans

As stated previously, each pre-service science teacher prepared and submitted lesson plans for the lessons they were teaching both at the university and in the cooperating school, as the requirements of the Practice Teaching in Elementary Education course. The lesson plans they prepared for the teaching practice in the cooperating schools were the data source for this study since teaching practices in these cooperating schools let them experience the real classroom settings. Data gained through these lesson plans provided information about PSTs' perceptions and use of models in their instructions.

The lesson plans typically included date, school, grade level of students, name of the topic, timing, prerequisite knowledge, objectives, instructional materials, instructional technology and media to be used, teaching methods to be applied, pre-assignments, preparations of the students and the teacher, presentation of the topic integrated with objectives, teaching aids, and teaching methods, post-assignments, and evaluation; and the PSTs were required to give special attention to attainment of *Science Process Skills* (SPS), *Science Technology Society and Environment (*STSE), and *Nature of Science* (NOS) objectives stated in the new national science curriculum. The lesson plans were copied and then analyzed for the purpose of this study.

3.2.2.4. Class Observations

The data gained through the class observations during the teaching practice of the participants in the cooperating schools also provided information about the PSTs' use of models during their teaching practices. The practices were video recorded in order to verify and observe how the PSTs used the models they mentioned in their lesson plans. All teaching practices were video-recorded by the researcher. The researcher was allowed to sit at the back of the classroom and record the PSTs' teaching practices. She tried to capture PSTs' modeling activities since the interest was in the models they used. The teaching practices took one class hour, which typically takes 35-40 minutes.

3.2.3. Procedure

In 2009-2010 Fall Semester, all the senior PSTs enrolled in the ESE program at the university were first asked to take VOMMS instrument. Among them, 35 of the PSTs showed their willingness, and were administered the instrument in this semester. Then, these PSTs were sent an e-mail that briefly explains the purpose and procedure of the rest of the study. In the responding e-mails, 14 of the PSTs stated their willingness to participate in the rest of the study. With these 14 PSTs, face-to-face meetings on specific dates and times for interviews were arranged, and the interviews were done before 2009-2010 Spring Semester. In 2009-2010 Spring Semester, as a part of the Practice Teaching in Elementary

Education course, the pre-service teachers were sent to the cooperating schools. The teaching practices of the participants in these schools were then video recorded by the researcher. The lesson plans they prepared were also copied. In Figure 3.1, an overview of the timeline for the data collection is given.

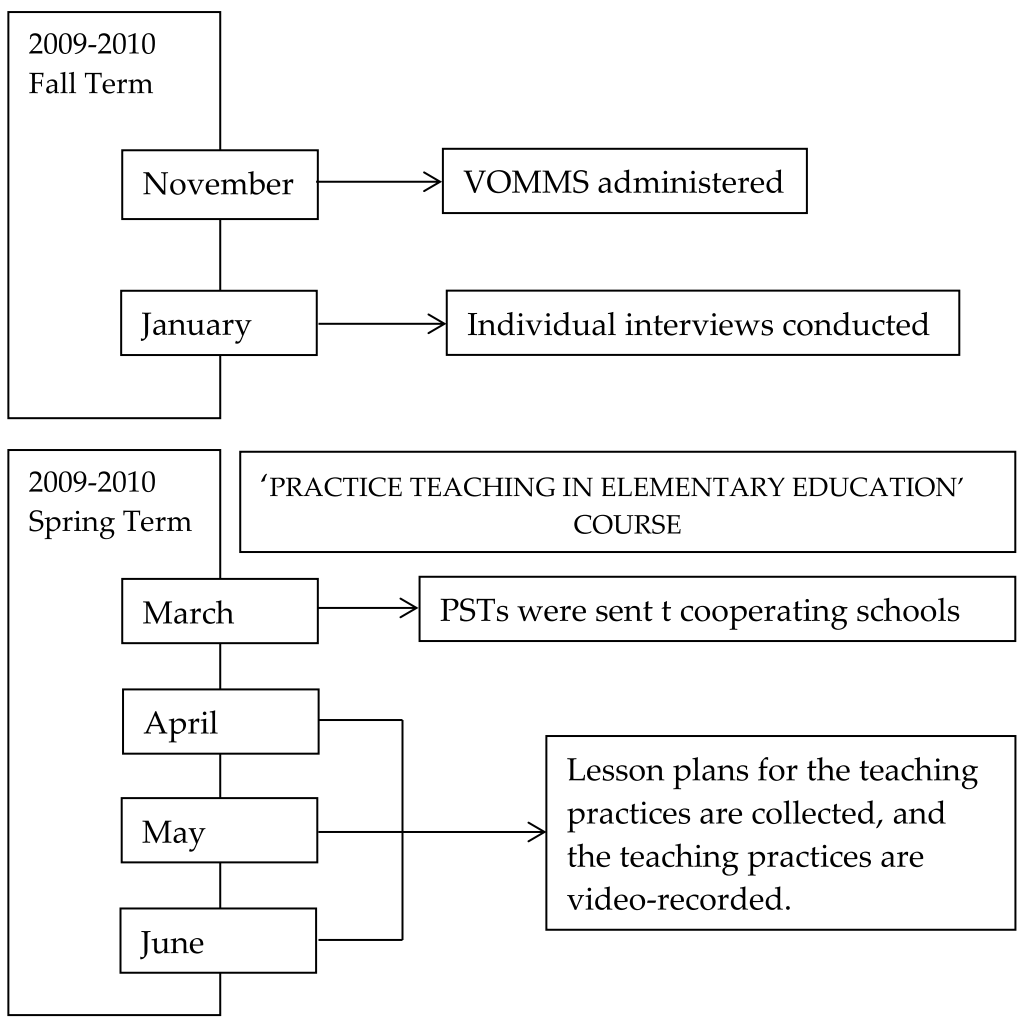


Figure 3.1. An overview of the timeline for the study

3.3. Role of the Researcher

In qualitative studies, the role of the researcher should be clarified since the interaction between the researcher and the participants is of great importance in terms of clarifying the biases that may affect the study. As stated previously, the participants of this study were PSTs enrolled in the ESE program. The researcher has also been working as a research assistant at the same program, and has assisted several courses including Practice Teaching in Elementary Education course. This assistantship provided the researcher a chance to have close contact with the participants of the study, and gave the participants the chance to feel more comfortable during the intervention of the study. In order to make the PSTs feel comfortable, for example, the researcher let them to specify the date, time and the class they would teach in the cooperating schools according to their and the mentor teachers' availability.

3.4. Data Analyses

The participants' responses to VOMMS instrument, interviews, lesson plans and class observations comprised the data set of this study. Data collected from the VOMMS instrument were analyzed by using qualitative data analysis methods. For each VOMMS item, the PSTs chose between two alternatives and then explained their choice as a written response. Almost all of the participants provided written responses to justify their options. These written responses were transcribed by the researcher, and the transcripts were read several times in order to look for emerging codes. As the similarities in data surfaced, categories were determined. A colleague crosschecked the codes and categories to verify the accuracy of the coding practice. These codes and categories provided insight into participants' understanding of models. Interview data were also analyzed based on qualitative coding techniques to reveal themes and patterns from the data. First, the recordings were transcribed verbatim. Then, the researcher continuously read and re-read the transcriptions, and looked for significant words or phrases that are related to participants' understandings of models. The researcher took reflective notes in the margins as the phrases were emerged. Following the repetition of this process for several times, the researcher reached the frequently appeared phrases and deduced the data into meaningful codes. Categories were formed in the light of the research questions, and were continually assessed throughout the coding process. In the meantime, a colleague was also asked to follow the coding process, and the researcher and her colleague periodically came together to discuss on the codes till they reached full consensus about the final codes and categories. After the coding of all the data was complete, the codes and categories were revisited in order to assess the accuracy of the coding. A cohort including one professor, one associate professor and one assistant professor checked the coded categories in order to verify the accuracy of the process, as well.

Lesson plans, on the other hand, were analyzed through document analysis. Each lesson plan was read by the researcher to reveal PSTs' perceptions about the use of models in their teaching, as well as to see what kinds of models they preferred to use. PSTs' understandings about the use of models were investigated in their lesson plans, because they may mention about the use and necessity of using models (that they were planning to use in their instructions) in their lesson plans. Moreover, attention was also paid on the analysis of the content of the lesson plans in terms of the models – whether the PSTs planned to use models in their classrooms during the instruction or not.

Lastly, the video-recorded teaching practices in real classroom settings in the cooperating schools were watched by the researcher after analyzing the corresponding lesson plans. The researcher examined whether and how the PST used the models that s/he mentioned in her/his lesson plan. Moreover, the video records were also examined in terms of possible use of models that were not mentioned in the lesson plans. Displays (scans from lesson plans and screenshots from video records) were created to show the model practices that PSTs used, and these displays provided as representations from their lesson plans and classroom practices.

3.5. Trustworthiness of the Study

Reliability and validity are two important issues to consider in every research. The concept of reliability requires that another researcher studying the same research questions by using the same procedures and instruments would find similar results with the teacher. This is in short, related to the replicability of findings. The concept of validity, on the other hand, requires that the researcher is measuring the thing that is actually intended to be measured. It is an issue of accuracy of findings.

The issues of validity and reliability are considered to be typical to positivist paradigm. They are the two elements that a researcher should be concerned when designing a study. Qualitative studies, however, should be evaluated within the context of particular settings or people. In qualitative studies, these two issues are covered as ´trustworthiness´ of the study. Four criteria are suggested by Lincoln and Guba (1985), which are widely accepted for a trustworthy study. The first consideration is the ´credibility´ of the study. Credibility can be thought as the internal validity of the study, that is, it questions whether the study measures what is actually intended. According to Lincoln and Guba (1985) credibility is one of the most important factors in establishing trustworthiness. Random sampling, willingness of participants to participate in the study, peer debriefing, member checks for the verification of the researcher's analysis of data, clarification of researchers' background, experience and role in the investigation, detailed description of the context, and triangulation are offered strategies to establish credibility. Pre-service science teachers in this study were all voluntarily participated in the study. Detailed information about the researcher and her role in this research were also declared. The issue of researcher bias was also clarified. The sources of bias, assumptions and beliefs were disclosed. It is important for the researcher to describe her belief and biases to allow readers understand their possible effect on the study.

Triangulation strategies were also used to establish credibility. They involve the use of different methods for data collection, like observations, focus groups, documents and individual interviews in order to compare data for consistency of response. In this study, the data was triangulated with the analysis of interviews, observations, document analysis, and an instrument. Other validity strategies that was used to established accuracy of this study were peer debriefing and cross-checking of the findings. The study was reviewed by the supervisor and two experienced researchers, who follow the ongoing study. Depending on their feedback and suggestions, the data analyses strategies were shaped and the codes and categories were reviewed. A colleague also analyzed the data as a co-coder. She is also a research assistant in the same department with the researcher of the study and is experienced in the field of qualitative data coding. She was familiar with the concept of scientific models but even so an interview was analyzed together to make a practice for the coding strategies. At the end of the coding process, we discussed about developing and assigning names for the categories and reached almost full agreement.

Second issue is ′transferability′ of the study, which is the generalizability or external validity of a study. In positivist studies, the aim is to show that the results of the study are applicable to other situations. However, in qualitative studies, which typically deal with particular environments and individuals, it is not possible to generalize the findings to other situations. Therefore, it is the researcher's responsibility to provide sufficient information about the work in order to let the reader to make such a transfer (Lincoln & Guba, 1985). To ensure this, detailed contextual description of the study was provided to the readers in order to allow a proper understanding about it.

Third issue is ′dependability′ of the study. This consideration is the reliability in positivist approach, that is, if the study is repeated in the same context, similar results with the previous study will be found. To establish dependability, the methodology of the study needs to be reported in a detailed way so that another researcher can repeat the work. In order to ensure reliability so that another researcher can clearly follow the procedure used in this study and to arrive at same conclusions, rich descriptions of the research were provided. Such descriptions included the properties of the sample, and the data collection and analysis procedures.

Last issue is the ′conformability′ of the study, or objectivity of the study. It is not actually easy to ensure a real objectivity even in a quantitative research since instruments are all developed by humans. However, the researcher in a qualitative study should try to ensure that the findings are ideas or experiences of the participants, not those of the researcher. Triangulating the findings from several data sources may help in ensuring conformability. An in-depth description of the methodology of the study and recognition and clarification of the researcher about his/her role, beliefs and assumptions are also important in ensuring conformability.

3.6. Limitations of the study

There are a number of limitations that should be recognized in this study. One of them is that since the number of participants in the study was small, generalizability of the findings is not possible. Therefore, findings should be interpreted with caution. Second, due to the nature of the course (Practice Teaching in Elementary Education) lesson plans and the corresponding video records in real classroom settings were limited to just one class hour for each PST. That is, a single lesson plan was prepared and a single teaching practice was video-recorded for a PST, which may not be sufficient for examining their use of models. Lastly, since the study was conducted in a Turkish science teacher preparation program, all data were gathered in PSTs' mother tongue (i.e., Turkish), and later transcribed and translated into English for analysis. The translation of texts from Turkish to English, therefore, may lead to a loss in meanings.

CHAPTER IV

FINDINGS

The present study aims to investigate two main research questions. The first one is to explore pre-service science teachers' understandings of scientific models; and, second one is to investigate their perceptions about the use of models in science education. For these purposes, data were collected by qualitative means from 14 volunteer pre-service science teachers (PSTs) who were enrolling the Practice Teaching in Elementary Education course. In order to respond to the first research question, the participants were administered the 'My Views of Models and Modeling in Science' (VOMMS) instrument and then were interviewed. For the second research question, on the other hand, data obtained from the interviews together with the lesson plans and classroom observations were examined.

In this chapter, findings gathered from the above-mentioned multiple data sources are reported. First, pre-service science teachers' understandings of scientific models, then their perceptions about the use of models in science education are presented.

4.1. Pre-service Science Teachers' Understandings of Scientific Models

Data collected through the VOMMS instrument and the interviews aimed at answering the first research question of the study:

"What understandings do pre-service science teachers possess about scientific models?"

The findings revealed that PSTs' understandings fell into two main categories, which are (1) descriptions and roles of scientific models, and (2) nature of scientific models. The following section begins with PSTs' understandings about descriptions of scientific models and is followed by roles of scientific models. Brackets (at the end of excerpts taken from participants' responses) were used to indicate the source of information, either from the interviews [I] or from the VOMMS instrument [V]. In the brackets, abbreviations like P1, P2 … P14, were used together with the sources of information for indicating the participant from whom the excerpt is taken.

4.1.1. Descriptions and Roles of Scientific Models

In the following parts, findings related to the descriptions and roles of scientific models are presented separately under the headings of 'Descriptions of Scientific Models' and 'Roles of Scientific Models'.

4.1.1.1. Descriptions of Scientific Models

This category formed out of the responses that PSTs gave in response to describing scientific models. Data from the interviews and the VOMMS instrument led us to conclude that PSTs described models as *explanations*, *representations*, and *exact replicas* of scientific phenomena. The coding scheme and the frequencies for descriptions of scientific models are presented in Table 4.1.

Models as Explanations

'Models as explanations' in this study refer to an understanding that specifies scientific models as tools that are generated to explain scientific phenomena. PSTs thought that models are used to explain scientific phenomena which may have several limiting attributes like being *unobservable*, *unknown* or *unavailable*. Some also believed that models are explanations that are reached at the end of scientific research. When describing models as explanations of unobservable, unknown, or unavailable phenomena, the most common example that PST referred to was the models of atom. Examples from the excerpts are provided below.

Table 4.1. Coding scheme and frequencies for descriptions of scientific models

Description	Explanation	Frequency (N=14)
Models as Explanations	PSTs describe models as tools that are generated to explain scientific phenomena which may have several limiting attributes like being unobservable, unknown or unavailable.	11
Models as Representations	PSTs describe scientific models as representing the real thing that is usually inaccessible to direct observation.	10
Models as Exact Replicas	PSTs refer to the closeness of the model to the real thing, and usually mention that a closeness or resemblance is necessary.	1

> Models help us understand abstract concepts, as well as the materials or objects that are too large or too small to our perception. Atom models, for instance, are the product of an effort to explain atomic structures without actually seeing the sub-atomic particles. [V: P9]

> Models used in science… atomic models… structures that are used or designed for explaining specific data.. like atom models or cell membrane models. (…) I can say that they [models] are auxiliary schemata used for explaining things that cannot be seen or known obviously. [I: P13]

> They [models] can also be used for explaining the things that are invisible to naked eye. For instance, although we cannot see atoms, models help us infer how an atom looks like. [I: P12]

> Through constructing models, we try to understand the phenomena that we cannot observe with naked eye, or abstract concepts. [I: P8]

> Scientific models are the models that explain the working mechanism of things that we cannot understand or access under normal conditions. [I: P9]

As stated previously, some of the PSTs considered models as explanations that are reached at the end of scientific research. P14, for example, perceived models as explanations that are arrived at the end of scientific studies. She said that:

> For example, atom models… They [scientists] apparently built a model consisting of protons, neutrons, etc., as a result of their prolonged studies. What else… We have Bohr atom model, and raisin pie model. They [scientists] found out that the atom consists of protons, neutrons, etc., and concluded that it looks like a raisin pie, and they called this model as 'raison pie model'. Thus, we can name models as what they concluded at the end of their research. [I: P14]

Examples given to PSTs by the researcher (e.g. evolutionary theory, model of the solar system) provided further evidence for their understandings of models as explanations. For instance, when they were asked whether evolutionary theory is a model or not, some PSTs responded that it is a model since it tries to explain something. Below are the two sample excerpts.

> I think, it [evolutionary theory] is a model since it tries to explain certain phenomena… it tries to explain the universe. (…) For instance, I want to talk about dinosaurs. What happened to them? Did I know how they look like? I did not. What do I do with the evolutionary theory? I explain them with that model [evolutionary theory]. [I: P3]

> Evolutionary theory… In fact, it is a model, as well. It tries to explain lots of things. (…) The Hardy Weinberg principle, for instance, tries to explain such things as distribution of genes in nature. [I: P13]

PSTs' understandings of models as explanations were also observed in their responses to the question asking whether the physical model of the solar system is a model or not. P14, for example, emphasized the role of scientific models in explaining the structure of the solar system. P8, on the other hand, focused on the size of the solar system, and mentioned about the impossibility of observing such a huge system as a whole under normal conditions. Below are the excerpts from these two PSTs' responses.

> It [physical model of the solar system] is a model, because it shows us a system. This system includes planets, moons, etc. It explains something, just like a model does. [I: P14]

> It [physical model of solar system] is a model, because we cannot conceive or observe the solar system as a whole due to its size. (…) It is a mock-up for the planets, implying that it could be a model. [I: P8]

As the above excerpts clearly indicate, the PSTs' in this study thought that there exist some limiting factors about the real thing to be modeled (i.e., being unavailable, unobservable, or abstract). Even, some PSTs claimed that if the real thing does not have such characteristics, then its model could not be developed. That is, the PSTs believed that, if the real thing is observable, or if it exists, then it cannot be modeled. For example, in relation to the example of the solar system model, two of the PSTs said that since the solar system is something exists/present, it cannot be modeled. Below are their excerpts.

> It [solar system] is already a reality per se. We are able to observe it by telescopes. This system already exists. For this reason, it [the physical model of solar system] is not a model. [I: P1]

> I do not think it [physical model of solar system] is a model. The solar system is already a reality. We all know that the Sun is out there. Its location is fixed. Same is true for the Earth. In my opinion, a model is developed for explaining something unknown to us. [I: P4]

In general, the PSTs, who portrayed explanatory nature of models, usually pointed out the limiting attributes of the real thing. They thought that there is a need for models to explain the thing which is unobservable, unknown or unavailable. Two of the PSTs even thought that existing phenomena (such as the solar system) cannot be modeled. Interestingly, these PSTs considered the solar system as an observable phenomenon. These responses showed that although some PSTs had limited understandings about the nature of the real thing (i.e., solar system), they were usually aware of the role of models in explaining several scientific phenomena which cannot be observed or reached directly.

Apart from describing models as explanations, PSTs also perceived models as representations. Following part presents PSTs' descriptions of models as representations.

Models as Representations

In this study, 'models as representations' refers to an understanding that specifies models as representing the real thing. It was evident from the data that PSTs considered models as *representing the real thing, representing the structure of the real thing, representing unobservable or unknown concepts*, or *representing ideas*. Moreover, they described models as *visual* or *three-dimensional representations*. Below are some sample responses of the PSTs, who took attention to the nature of the real thing as being unobservable, unknown or abstract.

> [The purpose of models] might be to represent the unknown. I am not sure, though. [I: P4]
>
> We build models for better comprehend abstract concepts. Visual representations retain longer in the memory. [V: P8]
>
> For example, we are not able to see atoms but by reaching certain conclusions, we can infer what it looks like. Models, therefore, represent our inferences. [I: P12]
>
> It [a model] is used for representing what we cannot see directly. When we think of a teacher, for instance, s/he cannot show a student what DNA is. However, s/he can bring a DNA model to the classroom, thereby reify the concept. [I: P13]

P5 was the only PST who mentioned models as representing the ideas. She said that models represent the ideas in a holistic way. Below is her idea about the term ‘model’.

> What models remind me is the visual representation of an idea to people. (…) [A model is] a visual tool for covering scientific knowledge in a holistic way; let’s say. [I: P5]

The data provided evidence that the PSTs were aware of the representative nature of models. However, some of them still harbored some doubt to call certain examples as models. For example, some PSTs did not call ‘chemical formulae’ as models and put up the claim that models should represent the structure of the real thing. Accordingly, they failed to consider ‘CO_2’ as a model but all agreed that a ball-and-stick structure representing carbon dioxide is a model. Below are P4 and P2’s ideas about ‘CO_2’ as being a model or not.

> In my opinion, representation of carbon dioxide by CO_2 is just for nominal purposes. It does not provide much information about its [carbon dioxide] contents. It shows us what atoms it [carbon dioxide] includes, but does not give much information about its structure. I think the models I have just mentioned [ball-and-stick models] are better models. [I: P2]

> I do not perceive it [CO_2] is a model, because it is just a formula. Its model should represent its chemical structure.

> (…) Model represents… how can I say? .. the structure of something. [I: P4]

Similarly, P5 also thought that a model should represent the structure of the real thing. According to her, a model should provide a holistic representation of the real thing. She thought that the chemical formula (i.e., CO_2) can provide limited information about carbon dioxide's structure, while a ball-and-stick model helps us examine carbon dioxide in several different dimensions. Below is the dialog between her and the researcher.

> *Researcher:* Are chemical formulae, such as CO_2, models?
>
> *P5:* No, they are not. It is only the closed formula of carbon dioxide. I define models as products representing an idea wholly. However, we can see only a certain part of carbon dioxide in the formula [i.e., CO_2].
>
> *Researcher:* So, what if, I represent the structure of carbon dioxide by balls and sticks?
>
> *P5:* I can say that it is now closer to a model, because it helps us to see carbon dioxide's structure better. Conformations, bond angles, for instance, provide an opportunity to better examine the structure in comparison to the closed formulae. [I: P5]

On the contrary, P13 considered 'CO_2' as a model. According to her, CO_2 clearly identified the contents of carbon dioxide as carbon and oxygen. At first glance, her understanding seemed to be different from others, however, as the interview continued with follow up questions, it was understood that she also believed that a model should represent the structure of the real thing. Below is the dialog.

P13: CO_2 is a model. It represents the structure of the molecule consisting of one carbon atom and two oxygen atoms. In short, while closed form show us the contents of molecules, open formulae illustrate us their structure.

Researcher: So, how about presenting carbon dioxide by balls and sticks?

P13: It would be a model, too.

Researcher: Are the symbols of chemical elements – H for hydrogen, for instance – models?

P13: No, It is not a model. I mean, it [H] is not a model by itself. It lacks numerical values, such as proton numbers that must be written next to the symbol. It is only a symbol. This kind of representation would not enable us to understand what kind of structure a hydrogen atom has. [I: P13]

As mentioned before, PSTs described models as being *visual* and *three-dimensional (3D) representations*. Most of the PSTs indicated their agreement on the idea that a model should be visual, which is associated with 2D or 3D representations. Further, some PSTs specified 2D representations (like drawings and pictures) as models but still most of them favored 3D representations as being *real* models. Sample responses of PSTs, who assert models as visual representations, are given below.

> *P6:* When models are mentioned, I tend to think of something that visualizes in my mind.
> *Researcher:* Does it have to be concrete?
> *P6:* Yes, that is what it means to me. [I: P6]

> What models remind me is a visual representation of an idea to people. (…) A visual tool for covering scientific knowledge in a holistic way; let's say. [I: P5]

> Models are visual images constructed for the purpose of a better understanding of scientific concepts. (…) It [a chemical formula] is not a model. I think, a model must be something visual. We can call it a model, if and only if it provides us with the molecular structure of CO_2, including the atomic bonds. CO_2 formula is more like a 'written expression of chemistry'. We cannot call it truly a model. [I: P12]

Some PSTs associated models with concrete/physical objects. P9, for example, declared that "I perceive models something tangible, some concrete thing" [I: P9]. Likewise, when asked to reflect on 'CO_2' as being a model or not, P7 said that:

> It [CO_2] is not a model. It would be a model only if it introduced a concrete image of carbon atom. [I: P7]

Some other participants considered chemical formulae as representations of models. According to them, ball-and-stick models of the molecules are *real* models, while the formulae are representations of these *real* models. P10, for example, hesitated to call chemical formulae as models but she was quite sure that the ball-and-stick model was a model:

Researcher: Are chemical formulae, like CO_2, models?

P10: Yes, it is a model. We have seen its magnified version represented by balls connected to one another with sticks. That type of model is also in use.

Researcher: The written form? Is CO_2 not a model?

P10: That is a model but it seems more like expression of the model itself. I am not sure if it is a misconception but what model visualizes in my mind includes shapes and things like that. When I see the shape of carbon dioxide, I call it the model of carbon dioxide, which makes CO_2 merely a name. [P10]

Unlike P10, some of the PSTs rejected the idea that chemical formulae (i.e., CO_2) were models. P6, for example, was quite sure that the *ball-and-stick* model of carbon dioxide, as well as carbon dioxide constructed from *play dough* was models, while 'CO_2' itself was not. Below is the dialog between her and the researcher.

Researcher: Are chemical formulae such as CO_2 models?

P6: No, I do not think it is a model. It is rather a symbolic representation of carbon dioxide.

Researcher: Is 'a representation' not a model?

P6: In fact, a representation may also be a model.. but.. how can I say? .. it is more like the representation of carbon dioxide in chemical terminology. I cannot define it thoroughly right now.. but that formula [CO_2] represents carbon dioxide. We cannot say it is truly a model. We cannot call it a model, anyway. It is not a model.

Researcher: What about a ball-and-stick representation of carbon dioxide?

P6: Now I can say that it is a model.

Researcher: What if I built carbon dioxide with play dough?

P6: Then I call it as a model without no doubt.

Researcher: What would make it a model then?

P6: Because in that case [play dough], we visualize what is written by a formula. A young child would tell us that s/he read a letter C, a letter O, and a number 2 below. However, introducing a model as a compound of carbon and oxygen [with play dough], would visualize something in child's mind. We would show its structure. I think, this is the reason why it is a model. [I: P6]

The idea that a model should be three-dimensional was also evidenced when PSTs reflected their understandings about the drawings as models. When P12 thought aloud about the drawings of dinosaurs, for instance, he stated that mock-ups of dinosaurs rather than drawings of dinosaurs are models:

> While thinking, something came to my mind: I wonder whether the drawings of dinosaurs are models, as well? .. I think, dinosaur mock-ups, rather than drawings, can be called models. (…) Drawings are drawings; they are not models, they are not 3D. [I: P12]

Similarly, P9 did not accept drawing of a 3D structure of DNA as a model, although he accepted the 3D model of DNA as a model. Below is the dialog.

Researcher: Is the 3D structure of DNA is a model?

P6: Of course, yes. It is the double helix model of DNA. It provides us with the opportunity to see something [DNA] that is invisible to naked eye.

Researcher: What if we drew that 3D structure [DNA]? Would that drawing be a model?

P6: No, it would not. I mean… according to me… a model is something tangible. That drawing does not give… I mean, I may not understand the 3D shape of the DNA from a drawing. [I: P9]

While some PSTs did not consider drawings (i.e., DNA) as models, others considered them as models. P11 and P13, for instance, leaned their justification on the representative nature of drawings. P2, on the other hand, gave emphasis on the explanatory power of models. Below are their excerpts.

> If we draw DNA.. it would be a model. I think it is a depiction or representation of DNA. It [drawing of DNA] is a model. [I: P11]

> Yes, it [drawing of DNA] is a model. Although not in three-dimensional form, it would be a model since it would represent DNA in any case. [I: P13]

> Yes. It [drawing of DNA] is also a model. Doesn't it explain DNA adequately? (…) If I manage to understand it [DNA], I would call it [drawing of DNA] a model. [I: P2]

Similarly, when asked why drawings of atom are models, for example, P6 said that they represent the inner structure of the matter. Below is her excerpt.

> Indeed, a drawing might be regarded as a model in science. Consider the atom. Its content is unknown to us. However, what is inside the atom is represented as neutrons, electrons, the nucleus, etc. We can see those representations in the drawing, after all. [I: P6]

In sum, the PSTs who described models as representations, believed that the real thing is unknown or unobservable. Most of them held the idea that models represent the structure of the real thing by providing more detailed and visual information about it. In connection with this finding, PSTs usually considered models as being visual and three dimensional. Although some accepted drawings as models, most of the PSTs favored three dimensional models and labeled them as *real* models.

Besides considering models as representations, some PSTs described models by referring to their closeness to the real thing. In the following section, their understandings about models as exact replicas of real thing are presented.

Models as Exact Replicas

In this study, 'models as exact replicas' refer to an understanding that specifies models as copies of their targets. This code stemmed from PSTs' understandings in response to how close a model to the real thing is. Data demonstrated that the PSTs, in general, shared the idea that a model needs to be *close to the real thing*, but cannot be an *exact copy* of it. While some PSTs asserted that a model needs to reflect all of the characteristics of the real thing, some others thought that, a model does not necessarily include every detail of the real thing; it depends on the purpose and complexity of the model. What is more, the question asking whether a photograph is a model or not further uncover PSTs' ideas about the relation between the model and the real thing; and it was evident that, with some exceptions, most of the PSTs did not believe in the presence of a direct relation between the model and the real thing. Thus, they did not perceive a photograph of the real thing as a model.

Some PSTs mentioned about the closeness of a model to the real thing as they defined what a model is. Below is P10's response to the question: '*what comes to your mind when you hear the word model?*' The participant pointed to the notion that models themselves are not real; rather, they are products of observations and inferences. A very similar description was given by P2, who emphasized the notion that models are not the real things but are close to them. Below are the two excerpts.

> They [models] remind me of things like atom models. Models are things that are not real, yet designed by scientists as close to the real thing as possible. (…) They are models – the things that scientists construct as a result of their observations and inferences in a close manner to the real thing. [I: P10]

> The model concept in my mind is not directly the real thing itself, but it is very close to the real thing. [I: P2]

Some PSTs believed that a model's closeness to the real thing is necessary. P6, for example, stated that, closeness is necessary because the model should give similar ideas about the real thing to everybody. P13, on the other hand, thought that closeness is necessary to prevent misunderstandings about the real thing. The excerpts are given below.

> I think, it [model] must be close to the real thing, because it is the model or example of it, and it should not look like anything else. [I: P11]

> We know that an atom consists of protons, neutrons, and nucleus… For this reason, I must have such an image that it [atom model] should show the nucleus at the center and electrons orbiting around. They [models] should not contradict with my knowledge about them [real thing]. They may not be identical with the target but at least, they must look similar, so that everyone could think or visualize the same thing when they look at the model. (…) They must bear kind of a resemblance. [I: P6]

> An exact resemblance? Of course. It [model] should be close to the real thing to the greatest extent possible. [I: P8]

> There should be a certain level of closeness. Of course, there will be differences as well, but these differences should not cause a misconception. They [models] should be close to the real things as much as possible. [I: P13]

Although the PSTs believed in the closeness between the model and the real thing, all with one exception, shared the idea that a model cannot be an exact copy of the real thing. These PSTs emphasized that there should be a strong resemblance or a good explanatory power of models. Below are some sample excerpts.

> It [model] does not need to be an exact copy of it [real thing]. It is impossible. However, since it is expected that the model should explain the real thing as clearly as possible, its resemblance is unavoidable. For instance, in a DNA model, you need to address structural details such as bases, double or triple helix structures. These important structural details must surely resemble. [I: P13]

> It [model] cannot be an exact copy. What do we say, after all? A model. It cannot be the same [as the real thing]. However, it [model] should explain the real thing in the best way possible, and represent it in the best way in terms of visuality. [I: P2]

> Models cannot be exact copies of the real thing. It is not possible. However, they can explain the real thing (…) I mean, models can resemble real things but cannot copy them. They might explain the real thing or help people understand the real thing. [I: P14]

The only PST who supported the idea that a model might be an exact copy of the real thing offered that exact resemblance improves children's mental development. Below is his excerpt.

> They [model and real thing] might be totally identical, which in turn can contribute to a child's mental development. Consider a toy car, for instance, it has two front wheels and an axle shaft connecting these wheels. However, if that toy car had an engine inside, it would provide the child with a more realistic view of cars, which may facilitate child's

> mental development, making the child a higher achiever. [I: P1]

Some PSTs shared the idea that a model needs to include all of the details of the real thing, or it is better if it includes. Below are these PSTs' responses to the question asking whether the model should include every element/detail of the real thing or not.

> Yes, it [model] must include certain details. If new information is discovered, it must be included in the model. [I: P10]

> A good model must include every detail of the real thing. The more details a model includes, the better it is. [I: P9]

> I do not think that it would be able to include all details. It would be better, though, if it did. It would become the real thing itself if it included all details. However, it must resemble the real thing as much as possible. [I: P7]

Conversely, some other PSTs did not find it necessary for a model to include every detail of the real thing. P12, for example, said that the purpose of constructing models is to eliminate the complexity of the real thing. For this reason, models do not necessarily involve every detail of the real thing. P5, on the other hand, thought that it is enough for models to give a general idea about the real thing; models do not necessarily cover every detail of the real thing. P13 supported the idea that it is not possible for a model to include every detail but it is necessary for a model to include the details that it aims to explain. Lastly, P4 stated that since a model can explain a different aspect of the real thing, it does not need to cover every aspect of it. Below are the related excerpts to the question: *should the model include every detail of the real thing?*

> No. One of the purposes of constructing models is ruling out the complexity of real thing. For that reason, it [model] does not have to include all details. It may simplify the real thing. [I: P12]
>
> It is not necessary for a model to include every detail. (…) Models provide us with a neat and general idea of the real thing. [I: P5]
>
> No, it [including every detail] is not possible but a model must include the aspects you would like to tell or explain about the real thing. [I: P13]
>
> No. It does not need to include everything related to the real thing. Each model can explain a different aspect of the real thing. While one model shows the helix structure of DNA, the other can show acids and bases in the DNA. The details may vary. Some of the DNA models might be simpler, and the others more complicated, but they all might show the same thing [DNA] in general. (…) While you introduce only the helix structure to elementary level students, you may like to add acids and bases to that model in higher levels. In university level, on the other hand, the model becomes more complex, including such things like the six types of histones that are built by the DNA. [I: P4]

The interview question asking whether a photograph of the real thing is a model (or not), further clarified PSTs' understandings about the relation between model and real thing. While some PSTs identified photographs (of real things) as models, others did not consider them as models since models are not in direct relation with real things, and still others were undecided about accepting a photograph of the real thing as a model. In this aspect, two of the PSTs (P5 and P3) addressed the role of creativity in constructing models:

> A photograph of the real thing would not be a model. This [a photograph] would mean that we see the real thing itself. Models however, give an idea about things. This is more like this: when we take a photograph of a classroom, we cannot expect somebody to express an idea about that classroom merely by looking at the photograph. However, when we mention the details such as a blackboard, and a few desks, it would be easier for that person to have a general idea on the classroom. This is the important point: these details do not evoke the same idea in every person. There is the creativity aspect; models are the products of creativity. [I: P5]

> A model is something you construct in attempt to understand the real thing. That [photograph of the real thing] is the real thing itself, rather than a model of it. I think a model is something we construct. What is the purpose of a model? One reaches a conclusion through constructing a model. That is what model is for. It is not the real thing itself.

> When I look at a photograph of cell, it is the cell itself. Thus, the photograph is not a model. [I: P3]

P7 believed that model and real thing are not directly related. In her response, she referred to the nature of the real thing as being unobservable or unavailable, and said that, models are constructed in attempt to make the real things observable and available which are actually not:

> It [photograph of the real thing] is already the real thing itself. We construct models for the things that cannot be explained totally. (…) If it showed exactly the real thing, it would be the real thing itself, which would rule out the need for a model. [I: P7]

Similarly, other PSTs (P13, P4 and P9) did not perceive photographs of real things as models. P13 responded by simply calling photograph of real thing as real thing itself but P4 failed to provide a clear reasoning for their claims. P9, on the other hand, stated that a photograph of real thing is not a model because it does not have a three dimensional nature. Below are their responses.

> In fact, it [photograph of the real thing] is the real thing. I mean, not a model but the real thing itself. [I: P13]

> No, it [photograph of the real thing] is not a model, because it is already the real thing. A model is something else. I think a model is not a normal state. I feel it but I cannot describe. [I: P4]

> Is a photograph of the real thing a model? This is a good question. It is not a model, because it is just a screenshot. A model reminds me of a more concrete object. The screenshot of a phenomenon cannot provide me with details about the real thing. For example, I may not be able to visualize a three-dimensional image of the double helix structure [from the photograph]. [I: P9]

As stated previously, some PSTs were undecided about whether photograph of real thing is a model. P8, for example, tended to call a photograph as a model due to its resemblance to the real thing but he was not sure. P10, on the other hand, thought that a photograph is somehow the real thing itself, so it is not a model; but due to its limited nature in representing the real thing, it could be called as a model. Another PST, P2, first characterized a photograph as a model due to its closeness to the real thing but later on she changed her mind and said that a model does not have to be an exact replica of the real thing. Below are some sample excerpts.

> I am not sure but we may consider it [photograph of real thing] as a model because it resembles the real thing. I am undecided. [I: P8]

> A photograph of real thing is the real thing itself; it does not include all details [of the real thing] at all. Therefore, we may not be able to grasp the real thing's structure completely. In fact, this could make the photograph a model, as well. It [photograph of the real thing] would not help me

> understand the content of the real thing completely. There would certainly be some details I cannot see in that photograph. Thus, it may also be a model… I am not sure. [I: P10]

> It [photograph of real thing] may be a model. I think it is very close to the real thing. But… No, it is not a model. A model does not have to be a copy of the real thing. I think it cannot be a model. [I: P2]

Contrary to others, some of the PSTs were quite sure that photographs of real things were models. Below is a sample excerpt.

> The photograph is almost same with the real thing. I think it [photograph of real thing] is a model. (…) In case of DNA, for example, the photograph of DNA could be represented as a DNA model, after all. [I: P11]

In general, it was evident from the data that PSTs did not regard models as exact copies of real things. However, they shared the idea that a model should be close to the real thing as much as possible. The discussion about photographs (of real things) yielded PSTs' understandings about the relation between models and the real things. With some exceptions, most of the PSTs did not identify photographs of real things as models. They thought that models are not the real things themselves, rather are products of human being constructed to understand real things.

4.1.1.2. Roles of Scientific Models

When PSTs' descriptions of models as explanations, representations and exact replicas were revisited, their understandings about the roles of models were also uncovered. Although these roles were denoted occasionally above, it might be helpful to iterate them in here to provide a more clear picture. According to the participants, models *facilitate understanding, simplify complex concepts*, *reify abstract concepts, visualize concepts in mind,* and *contribute scientific development*. These roles were actually nested within one another in PSTs' responses. That is, for example, some PST thought that models may facilitate understanding of some concepts by simplifying them; or they help visualizing concepts in mind through reifying.

Coding scheme and frequencies for PSTs' understandings of roles of models are given in Table 4.2.

Facilitating Understanding

As the name implies, *facilitating understanding* refers to an understanding that identifies models as tools that assist or promote understanding (unobservable or complex) scientific concepts. PSTs, in this study, believed that scientific models facilitate understanding scientific concepts through *simplifying*, *reifying,* or *visualizing them in our minds.*

Table 4.2. Coding scheme and frequencies for roles of scientific models

Roles of SM	Explanation	Frequency (N=14)
facilitating understanding	PSTs mention that scientific models facilitate understanding scientific concepts mainly by simplifying and/or visualizing them.	9
by simplifying	PSTs think that scientific models simplify scientific phenomena and reduce their complexity.	4
by reifying	PSTs refer to the unobservable or abstract nature of the real thing, and state that scientific models reify these phenomena.	8
by visualizing concepts in mind	PSTs mention that the use of models helps us form visuals of the scientific phenomena in our minds.	7
contributing scientific development	PSTs think that scientific models are tools used in the process, development and production of scientific knowledge.	6

Simplifying refers to an understanding that devotes scientific models as tools that simplify complex scientific phenomena. PSTs in this study thought that scientific models simplify complex scientific phenomena, and therefore, facilitate understanding them. Some sample excerpts are below.

> A model reminds me of a simplified version of the real thing. It is not a copy of the real thing but it must bear some associations about it, it should make it easier to understand the real thing. [I: P2]
>
> Reducing complexity is one of its [model's] purposes. For this reason, it [model] does not have to include all details. It can simplify the real thing. [I: P12]
>
> They [models] are developed for facilitating understanding by reducing the real thing to the simplest level, like developing formulae. [I: P3]
>
> Models reduce difficult-to-understand concepts to simpler concepts; thus they [models] facilitate understanding. [I: P9]
>
> They [models] are materials that should not reflect the real thing completely, but should have some implications about it. They should facilitate understanding of the real thing. I think this is what they are used for. (…) They are developed for making things clear for people to understand. They are also developed by scientists for facilitating their own work. [I: P2]

Reifying refers to concretization or objectification of abstract or unobservable scientific phenomena. PSTs in this study thought that scientific models reify abstract phenomena, and therefore, facilitate understanding them. Below are some examples from their excerpts.

> Models are generally used to reify real thing that is abstract in nature. [V: P13]
>
> Models are used for reification of phenomena. [V: P1]
>
> Models remind me of reification of abstract concepts. [I: P8]
>
> Models are developed for reification of abstract concepts. The model itself should not be too abstract in this respect. It has to appeal to the understanding of people. Making an abstract model of an abstract concept would not make any sense. [I: P9]
>
> In order for something to be regarded a model, it must be standing in front of my eyes. I think this is the purpose of a model – visualizing something, reifying. For example, describing the atom to students could be a difficult task but reifying it by using models would help. It is the purpose of a model to facilitate understanding. [I: P12]
>
> [A DNA model] is indeed a model; because it shows us the DNA which is something that we cannot see (…) its model reifies it [DNA]. [I: P7]

Visualizing concepts in mind refers to an understanding which asserts that models help us visualize (unobservable or abstract) concepts in our minds. The PSTs in this study believed that the real thing is unobservable, and scientific models are visual; so that these models help us visualize the scientific concepts in minds and therefore, facilitate our understanding. Below are some sample excerpts.

> We would have more difficulty in understanding, DNA for example, if it was not for the models. I think models facilitate learning. They provide a basis in our mind, on which we build further knowledge. When I have the structure of DNA in my mind, I can locate its parts on the image in my mind when I come across some data about it. [I: P10]

> DNA is nothing but a word. But what if I make a model of it? DNA is invisible to naked eye but when I see that model, I can visualize it in my mind. [I: P3]

> Models show how ideas or things function. Therefore, they yield a better understanding of the concept, and an image is formed in minds when the concept is mentioned, increasing the retention of it [the concept]. [V: P6]

> The purpose of models is to facilitate understanding things that are unobservable. They help visualize something that is invisible to be seen by naked eye. [I: P7]

> Models show how ideas or things work. Therefore, they yield a better understanding of the concept, and an image is formed in minds when the concept is mentioned, increasing the retention of it [the concept]. [V: P6]

> It [DNA model] can be used as a model, because it visualizes the DNA in our minds even though we cannot actually see it. [I: P6]

> When we talk about carbon dioxide, no child would be able to visualize it in mind at all, but after seeing its model, it might be possible for the child to visualize it in mind. [I: P9]

> A model is not the real thing itself; it just tries to make us visualize the real thing in mind. [I: P2]

> A model is a device for explaining science. It is a tool we use for visualization of a phenomenon in our minds. [I: P1]

The other role that PSTs devote to scientific models was contributing scientific development. In the following part, their understandings on this issue are presented.

Contributing Scientific Development

'Contributing scientific development' refers to an understanding that specifies scientific models as a part of developing scientific knowledge. When PSTs reflected their understandings of the role of models in science, they stated that models have important roles in science, and even they are a part of doing science. P13, for example, addressed the role of communication in science:

> Models are widely used in science. Bohr and Rutherford, for instance, developed their atom models by using the models developed earlier. By utilizing existing models, they developed new models. [I: P13]

In a similar manner, P1 emphasized the important role that models play in science. Below is his response.

> Models are the basis for science. If it were not for models, there would be no science. I think science began with models or one can argue that it was models that motivated science. It is not important whether a given model is right or wrong. When someone introduces a model, then scientific development begins. If no one introduces any model, then science is almost hardly possible. [I: P1]

PSTs also referred to 'contributing scientific development' as a role of scientific models as they reflected their ideas about the purpose of using models in science. Below are examples from their excerpts.

> While conducting a scientific study, it is easier to make changes on a previously developed model. This means, we can see the variables there, and thus it would be possible for us to make changes on them [models] or replace them [models] with new ones. Changes can first be made on the model, and then, they can be proven in the light of new evidence obtained from experiments. [I: P6]

> It is possible to embark a research on a model. A model is actually required as a basis for adding new findings or making changes, or is a starting point for new research. Scientists need some data to advance from, because they will have to bring something forward through that model. They just need a concrete basis to rest their efforts on. The concepts of atom or DNA, for example, can be reified

> through models for a better conceptualization. When they remain abstract, it might be both more difficult for us to understand the concepts and more difficult for scientists to proceed with further investigations. [I: P10]

> Models support subsequent developments in science. Thus, they stimulate scientific improvement. After all, a modeled concept can be said to be understood to some extent, and that concept might keep developing as more studies are conducted on it. Further progression can be ensured. [I: P7]

> From a scientific perspective, models are constructed for producing something new in science, or they function as a tool for future studies, in my opinion. [I: P14]

In conclusion, as observed from the data, the PSTs in this study believed that the real thing to be modeled is abstract, unobservable, unavailable or complex. Therefore, according to them, models facilitate understanding such concepts through simplifying, reifying or visualizing them. Moreover, the PSTs thought that through the use of scientific models, subsequent development of scientific knowledge is satisfied.

4.1.2. Nature of Scientific Models

Nature of science refers to the values and assumptions inherent to science, scientific knowledge, and the development of scientific knowledge (Lederman, 1992). In parallel with this definition, nature of scientific models can be characterized as values and assumptions which are present in the development of scientific models. The PSTs' understandings of nature of scientific models fall into five main categories, which are *subjective nature of scientific models, social and cultural embeddedness of scientific models, dynamic (tentative) nature of scientific models, empirical nature of scientific models*, and *the role of creativity and imagination in the construction of scientific models.* These categories are reported in the following sections; and the coding scheme and frequencies for PSTs' understandings of nature of scientific models are presented in Table 4.3.

Subjective Nature of Scientific Models

Subjective nature of science stresses that scientists' prior knowledge, experiences, beliefs, expectations, and education influence their work (Abd-El-Khalick, Lederman, Bell & Schwartz, 2001). In this study, most of the PSTs acknowledged the role of *subjectivity* in the development of scientific models. Their understandings stemmed from their responses to the questions asking about 'the existence of multiple models for the same phenomenon', and about 'the acceptance of a newly developed model'.

When PSTs were asked if it is possible to have multiple models for the same phenomenon, they said that many models could be developed due to the subjective nature of science. Below are sample excerpts.

Table 4.3. Coding scheme and frequencies for nature of scientific models

Nature of SM	Explanation	Frequency (N=14)
subjective nature	PSTs refer to subjective nature of scientific models as they justify the presence of multiple models, and state that, scientists' interpretations, perspectives, beliefs and background knowledge affects the models they develop, which in turn results in existence of multiple models.	11
social and cultural embeddedness	PSTs refer to social and cultural issues embedded in scientific models (i.e., religion, culture, social environment) as they justify the presence of multiple models, and as they mention about the acceptance of newly proposed models (i.e., when a new model is proposed, scientists' decisions in accepting this model are influenced by their social-cultural beliefs).	6
empirical nature	PSTs think that models are evidence-based and are products of inferences. They refer to this nature as they mention about the acceptance of newly proposed models by stating that accepting a new model, scientists examine whether it rests on valid data, tests, or evidences.	7
dynamic (tentative) nature	PSTs mention that scientific models are not certain but are subject to change if better-explaining models are developed (e.g. atom models).	14
creative and imaginative nature	PSTs refer to creativity as they justify the presence of multiple models. They also devote creativity and imagination as required skills to develop models (i.e., creativity and imagination are essential to develop models).	9

Each scientist can contribute the real thing differently, and accordingly construct different models. [V: P13]

Light, for instance. There are particle and wave models. (…) I mean, it [having multiple models] depends on the perspective of the scientists and varies according to their prior knowledge or interest. [I: P9]

Each scientist may develop different models. It is about NOS [nature of science]. It bases on the interpretation of scientists in evaluating data; it depends on subjectivity… Maybe, theory-ladenness, - from which theory s/he starts with. All are influential factors. [I: P7]

Of course, there might be different views in science. While a scientist represents the skin of a dinosaur in some color, another scientist can use a different color. Resulting in different interpretations or different data, they can develop different models. (…) This is either because of the differences between data or of the differences between interpretations of scientists. (…) Interpretation of data differs due to previous knowledge, social interaction, or cultural background of a scientist. Certain data can be interpreted differently by different scientists. [I: P12]

It [having multiple models] may be affected by the previous knowledge [of the scientist] on the issue studied. S/he might, as well, have some expectations or pre-judgments about the issue, and what s/he develops might be affected by those expectations, which lead to construction of a different model. [I: P2]

> Since each scientist has different ideas, background knowledge, and creativity, each can develop different models. [V: P10]

Some PSTs referred to the evolutionary theory as they explained the existence of multiple models for the same phenomena. Subjective nature of science was their reasoning for the existence of multiple models. Below are these PSTs' responses to the question: *Do you think that scientists can ever have more than one model for the same phenomenon?*

> Yes [scientists can have more than one model for the same phenomenon]. Some scientists, for example, argue that the changes in nature happened through adaptation, while some others put emphasis on genetic mutations. Even though they are both evolutionists, they have different perspectives. Perspectives vary according to the field of study or background of the scientists. [I: P13]

> Yes, [scientists can have more than one model for the same phenomenon] because there is the subjectivity factor. Studying the same data, different scientists can make different interpretations. It has already been the case throughout the history. I do not remember their names but different interpretations on a given physical or biological phenomena have always been the case. Presence of different arguments and interpretations further support the idea that science is subjective. (…) Interpretations may differ in accordance with beliefs, as well. Some reject evolution because of their religious beliefs. It [evolution] is a controversial subject in Turkey. Some people believe in both

> evolution and hold their religious beliefs, while others make a distinction between them, and still others consider science and religion totally distinct. [I: P4]

> Yes, they can do so [scientists can have more than one model for the same phenomenon]. Religion, culture, the environment in which they grow up, anything can affect their investigation. The evolutionary theory, for example… When you ask people to explain evolution in an Islamic country, they accept that evolution took place but they refer to Qur'an for explanation. They just believe in the evolution of animals, not that of human. Some time ago, there was an atheist evolutionist and a theologian on a television show. The theologian claimed that only animals evolved but humans did not. The other rejected this idea, arguing that humans evolved, as well. In this situation, you see that they both discuss the same thing but one internalized an Islamic view, whereas the other not. [I: P3]

The discussions about the acceptance of a newly proposed model also disclosed PSTs' understandings about the subjective nature of scientific models. When they were asked whether scientists' decision in accepting a newly proposed model is 'based on the facts that support the model and the theory', or is 'influenced by their personal feelings and motives' (VOMMS instrument, item 4); it was observed that some PSTs referred to the subjective nature of science. Below are examples from their written responses.

> Their [scientists'] personal feelings, motives, observations, and experiments affect their decision. [V: P14]

> As well as making use of the relevant data, a scientist can be guided by his or her own background, feelings, and motives. [V: P13]

> Science is subjective, and it is impossible for science not to be affected by creativity and personal thoughts of the scientist. [V: P4]

> A decision rests mostly on the data in the hand but it is also possible that scientists might be affected by their personal feelings and motives. What should be done is reaching an objective conclusion by making decisions based on authentic data. [V: P10]

> Of course, they [scientists] are affected by their personal feelings and motives, but they try to keep them at minimum level. They can test a model by comparing the data obtained in previous experiments. [V: P8]

Similar understandings were revealed in the interviews, as well. Below are sample excerpts.

> Their [scientists'] backgrounds, previous knowledge, social and cultural beliefs, belief systems.. I think the most important criterion is whether it [newly proposed model] conforms to their beliefs or not. It is related to their world views, their conception of world, or perspective. For instance, Newton considered a 'universe' in which there was only one particle; which required a 'fixed' perception of time.

> For this reason, he always measured time as a fixed [absolute] notion. Even if he knew Einstein's relativity theory, he always ignored it, and redirected himself to a fixed notion of time, because his belief directed him to do so. [I: P4]

> I think scientists' acceptance of a newly proposed model is greatly influenced by their expectations and previous knowledge. This can be the most important factor. Scientists might have worked in the same way, or might have thought differently about the model they observed, or expected different things from that model. When expectations are satisfied, it might be easier to accept the model. [I: P2]

In sum, it was observed that most of the PSTs recognized the subjective nature of scientific models. They thought that scientists can have multiple models for the same phenomenon because of the subjectivity embedded in the development of scientific models. Some of them also thought that, scientists' decisions in accepting a newly proposed model is influenced by their personal feelings. The PSTs asserted that differing background knowledge, expectations, and beliefs are influential in scientists' works.

Besides the subjective nature, PSTs' understandings about the social and cultural embeddedness of scientific models were also emerged from the findings. They are presented in the following part.

Social and Cultural Embeddedness of Scientific Models

Social and cultural embeddedness of science implies that science affects and is affected by several elements of the culture (such as politics, socioeconomic factors, and religion) in which it is embedded (Abd-El-Khalick et al., 2001). *Social and cultural embeddedness of scientific models* is emerged from the interviews and the VOMMS instrument as a nature of scientific models. P11, for example, mentioned the social-cultural context as a characteristic of scientific models. Below is her reflection on the properties of scientific models.

> It is possible that they [models] have cultural and social implications, because the findings might concern the society and its culture. [I: P11]

Similar to the findings presented in the previous part (subjective nature of scientific models), discussions about 'the existence of multiple models for the same phenomenon' and 'the acceptance of newly proposed models' also revealed understandings about the social and cultural embeddedness of scientific models. Below are sample excerpts.

> Interpretation of data depends on previous knowledge, social interaction, or cultural background of a scientist. [I: P12]

> The interpretation you make depends on your culture, place where you live, socio-economic status, education you take,

> and even perhaps the places you visit. In short, it depends on your perspective. [I: P1]

> To what extent it [new model] is recognized by the people? What does the society think? Who accepts the model? This is important because the extent of his/her [scientists'] own interpretation may be limited. [I: P8]

> If it [newly proposed model] features obvious details incoherent with general human reasoning, such as errors or disapproval of scientific communities, that model will not gain acceptance. [I: P12]

> Even though you claim that you have found something significant, what is its significance? I think it would be about the society… society's acceptance, adoption… What I mean by adoption is its [society's] ability to embrace or reject a given thing. (…) It seems to me that everything would get more difficult if the society does not adopt the given thing. [I: P3]

> In order for a model to be a scientific model, it must gain acceptance and support by the majority [of the scientists]. If only one scientist believes in the validity of a model but the rest do not, that model loses its significance. [V: P11]

As a consequence, it was observed that some PSTs in this study recognized the effects of social and cultural elements in the development of scientific models. They thought that culture and social environment are influential on scientists' work, which in turn results in the development of multiple models. Further, PSTs thought that scientists' decisions in accepting newly proposed models are also affected by the social and cultural elements, and accepting new models requires the support of other scientists or other people in the society.

Apart from social and cultural embeddedness, empirical nature of scientific models was also emerged from the data, which is presented in the following part.

Empirical Nature of Scientific Models

Empirical nature of science denotes that scientific knowledge is, at least partially, derived from observations of the natural world (Abd-El-Khalick et al., 2001). The PSTs in this study recognized that models are *evidence-based*, and are *products of inferences*. Similar to the findings presented in the previous parts (subjective and social-cultural nature of scientific models), discussions about 'the acceptance of newly proposed models' also revealed understandings about the empirical nature of scientific models. When they reflected their understandings about the criteria in accepting a newly proposed scientific model, some of them referred to the empirical nature, and said that models should base on evidence. Below are some examples from their excerpts.

> Evidences are crucial to models… It should be examined whether a given model rests on valid evidences or it is just made up. It [the model] is accepted or rejected by scientific communities according to that. [I: P12]

> They [scientists] conduct tests, and decide on the data they obtain… [in accepting a newly proposed model] [I: P13]

> It [accepting a newly proposed model] depends on the scientific knowledge they [scientists] have obtained up till then. (…) There are always lots of scientific articles published related to them [models]. If those models rest on scientific and valid information, they will be accepted. [I: P9]

> I think former studies must be checked, and whether these studies are scientific must be considered. (…) [I: P1]

> Scientific data, and the data s/he [scientists] collected… I think it [acceptance] must depend on those data and their validity. There must be no single error. The data must rest on good observations, and environmental conditions, such as, the control group or experimental group should be kept fixed. These must be taken into consideration. [I: P11]

P4 and P10 also referred to the empirical nature of models as a characteristic of scientific models. In their explanations, they mentioned that models are products of inferences:

> Scientific models should be developed in the light of scientific data... I think they must be developed through a process of observation, inference, prediction, etc… [I: P4]

> Models are things that scientist develop through their observations and inferences, in order to define the real thing. (…) Models remind me of things that are not in full

> resemblance with real thing but designed through inferences, observations, and creativity. [I: P10]

In sum, it was observed that some of the PSTs in this study regarded scientific models as products of observations, inferences, experiments, data and scientific knowledge. That is, they were aware of the empirical nature of scientific models.

In addition to the empirical nature, dynamic nature of scientific models was another theme evolved from the findings. Understandings about the empirical nature of scientific models are reported below.

Dynamic Nature of Scientific Models

Dynamic (or tentative) nature of science implies that scientific knowledge is never absolute or certain but is subject to change (Abd-El-Khalick et al., 2001). Most of the PSTs in this study had plausible understandings about tentativeness, and shared the idea that models are *not certain*. Sample excerpts are provided below.

> I think, nothing is certain in the world. Models are not certain, as well. They [models] are nothing but possible explanations of the phenomena. [I: P4]

> Science does not yield certain information, but is the most plausible explanation of happenings. Cell model and atom model, for instance, have reached their present states after

> undergoing several changes, and they are still open to changes. [V: P4]

> What makes it [a model] scientific is its purpose, or its potential contributions to science. However, we cannot build a certain model at all. There is no certainty in science; science is tentative. [I: P14]

> Science is never objective, permanent, or certain. Everything about science [including models] is subject to changes in the future. [V: P12]

> There is no one-hundred-per-cent certainty in science. That is, it would be wrong to use the term 'unchangeable' in science. Scientific models might be subject to future changes. [V: P3]

PSTs' understandings of the 'uncertainty of scientific models' were also revealed from their responses to the discussions on the multiplicity of models. Below are sample excerpts.

> Scientific phenomena can be explained through multiple models, because there is never one absolute truth. Thus, a given scientific phenomenon can be explained by different models that handle different aspects. [V: P9]

> Yes, they can [scientists can have more than one model for the same phenomenon]. There is no such thing as certainty in science. [I: P3]

> There is never only one absolute truth. What we consider scientific facts today might be fairy tales of future. [V: P4]

All of the PSTs in this study were agree about the changing nature of models, and the models of atom were the example they sometimes referred. Below are some sample excerpts from the interviews and the VOMMS instrument.

> Models cannot be the copies of the real thing. They can change or develop. [V: P14]
>
> Scientific models can change. Models we accept today are those which explain the related phenomenon in the best way possible. Once a better-explaining model is developed, they will lose their status. [V: P9]
>
> Scientific thoughts and models are subject to changes and developments in time [V: P14]
>
> Scientific information can always change with new developments and new data. When we look at the history of science, we can see that lots of models have lost their validity today. [V: P4]
>
> Of course they [models] can change. They are subject to changes in time, as in the case of atom models. [I: P8]
>
> I think models are open to changes. Consider atom models… Someone resembled the atom to a raisin pie. Then it is found that it has a nucleus in the center; positive-charged protons, uncharged neutrons inside the nucleus, and electrons around it. They [electrons] have definite orbits. Then someone comes and questions the validity of those orbits, claiming that it is not possible to know their velocity and location, and that

> they are inside electron clouds. This disproved the existence of orbits… [I: P1]

The PSTs in this study were aware of the reasons why scientific models change. A considerable number of PSTs shared the idea that models change in the light of *new findings/evidence,* and in response to the developments in *technology and research*. They also recognized that models change if they have *limitations*. Below are sample excerpts from the PSTs who mentioned that models change with new findings, technology and research.

> Models may not be exact copies of the real thing. New findings can change existing models. [V: P11]

> Even though a model might have been built after long studies, it is subject to changes in subsequent years due to the tentative nature of science. Newly-discovered data, technological advances, and the perspectives of different scientists lead to this change. [V: P5]

> They [models] certainly change. Through new technologies and researches, through new findings… they may change completely or partially, as in the case of the atom models. [I: P10]

> It [change of models] depends on scientific and technological developments, scientific innovations or new inventions… For example, when microscope was invented, we were able to see the cells, and scientists were able to study its organelles. Before that, the content of a cell was unknown. In the case of

> atom models for example, while scientists could study atoms only at a simpler level in the past, now they can examine it in a more detailed way. [I: P14]

> They [models] are subject to changes, because they can develop with new evidence or new findings. (…) Why do they change? When we examine the model in the light of new evidence and advanced technology, we may decide to add new properties to the model, or the model might turn out to be totally ineffective and might need changes. (…) They [models] may also change if they cannot explain the phenomena well. The former cell model, for instance, was replaced with a new one when microscope was invented. Existing models are updated or changed completely once new inventions are made. [I: P6]

> Science is always open to changes. For this reason, they [models] may change as new findings and developments take place. [V: P13]

> Of course they [models] change. They may change due to changes in scientific knowledge. [I: P9]

Some PSTs also recognized that models might have certain limitations in explaining the real thing effectively and might have low explanatory power; thus, they may go under changes. Below are some examples from PSTs' excerpts.

> With developing scientific knowledge; when it is evident that former information is inefficient, scientists find the existing

> model insufficient and they change it. Models change in accordance with scientific knowledge. [I: P7]
>
> The model must be changed once new information is available. (…) If some given information is no longer valid, causing misconceptions in the students, the model must surely be changed. [I: P12]
>
> It [model] can be changed or developed if it does not work anymore. Its weak points can be figured out and a new model can be developed. [I: P1]

In sum, it was observed that all of the PSTs in this study were aware of the dynamic nature of scientific models. They were agree with the idea that models are not certain, and may change with new findings and new technological developments. Regarding the changing nature of models, the PSTs usually referred to the models of atom, and said that several atom models were proposed in time as scientists gained new information about the atom. Some PSTs also recognized that models might have limitations in explaining the real thing effectively and therefore, they may go into changes.

As a last aspect, the creative and imaginative nature of scientific models was emerged from the findings of this study. PSTs' understandings about the creative and imaginative nature of scientific models are presented in the following part.

Creative and Imaginative Nature of Scientific Models

According to the creative and imaginative nature of science, developing scientific knowledge involves human imagination and creativity, although it is empirical and involves observations of natural phenomena (Abd-El-Khalick et al., 2001). Some concepts in science like atoms, for instance, are theoretical models or explanations that involve creativity in their development (Abd-El-Khalick et al., 2001). The PSTs in this study were aware of the creativity involved in the construction of models. P8, for example, mentioned about the creativity involved in the development of models, and said that scientists use their creativity in the points that they cannot see and explain. Below is his excerpt.

> Scientists use their creativity while developing models such as the DNA model. They know that it [DNA] has a helix-shaped structure. Scientists already observe this structure and design the model in accordance. They use their creativity for the points they cannot define. [P8]

In defining a model, P12 referred to the role of imagination in developing models. Below is the excerpt.

> Models are things that are developed through imagination of the scientists. I mean, they are not designed merely by imagination, but also through the data collected. (…) [While these models are designed] creativity is certainly at work but it must also rest on scientific knowledge, as well. [I: P12]

Some PSTs thought that multiple models for the same phenomenon may exist due to the creativity of scientists who develop them. Below are these PSTs' responses to the question: *Can scientists have more than one model for the same phenomenon?*

> This [having multiple models for the same phenomenon] is related to the nature of science. It is all about creativity. Different scientists may come up with different ideas as they develop models. [I: P1]
>
> Yes, they can [have multiple models for the same phenomenon]. It is related to the creativity of the scientist to some extent. [I: P2]
>
> They [scientists] can have multiple models. The models they develop depend on the creativity of the scientists. [V: P3]

PSTs' understandings of the creative and imaginative nature of scientific models were also revealed from their ideas about the 'skills required for the development models'. When PSTs were asked the question: *Who develop models;* they mentioned that creativity and imagination are the required skills to develop models. Below are examples from the excerpts.

> I think anyone having enough capability can develop models. (…) Knowledge is crucial. Imagination and creativity are also at work. I think models are products of these skills. [I: P6]

Creativity is essential if a good model is to be developed. [I: P12]

I am not sure but they [models] must be developed by creative people. [I: P8]

In sum, it was observed that some of the PSTs acknowledged the role of creativity and imagination in constructing models. Recognizing the role of creativity involved in designing models, PSTs believed in the presence of multiple models for the same phenomenon. Further, creativity and imagination were considered as one of the important skills needed to construct models. The PSTs thought that people with these skills can better develop models.

4.2. Pre-service Science Teachers' Perceptions about the Use of Models in Science Education

Data collected through the interviews, lesson plans and classroom observations aimed at responding the second research question of the study:

"What are pre-service science teachers' perceptions about the use of models in science education?"

The findings revealed that PSTs' understandings fall into three main categories, which are (1) characteristics of models used in science education, (2) necessity and benefits of using models in science education, and (3) PSTs' use of models in their instructions. Brackets were used (at the end of excerpts taken from participants' responses) to indicate the source of information, either from the interviews [I], from the lesson plans [LP], or from the classroom observations [V]. The following section begins with PSTs' perceptions about the characteristics of models.

4.2.1. Characteristics of Models Used in Science Education

This category formed out of the PSTs' responses to the questions discussed during the interviews about their perceptions of models used in science education. Analyses of the data revealed that PSTs attributed several characteristics to models, among them are being *simple, appropriate to grade level, three dimensional, explanatory*, and *accurate*. The coding scheme and frequencies for the characteristics of models used in science education are presented in Table 4.4.

Simplicity

In this study, as the name implies, *simplicity* refers to being easy-to-understand and not being complicated. A number of PSTs mentioned about simplicity as a characteristic of models. When asked whether there is a difference between scientific models and teaching models, almost all of the PSTs responded that there should be differences. The most common response was that, models used in science education should be simpler than scientific ones.

Table 4.4. Coding scheme and frequencies for characteristics of models used in science education

Characteristic	Explanation	Frequency (N=14)
simple	PSTs characterize models used in science education as simple; or in comparison to scientific models, they mention that these models are simpler versions of scientific models.	9
appropriate to grade level	PSTs think that models used in science education should be appropriate to grade level that students can understand.	5
explanatory	PSTs refer to being explanatory as a characteristic of models by declaring that they should explain the real thing clearly.	5
accurate	PSTs think that models should accurately explain/represent the real thing, avoiding misunderstandings.	4
three dimensional	PSTs believe that models used in science education should be three dimensional.	3

According to P4, for example, if a model is complicated, then nobody can understand it, except scientists. Below is her excerpt.

> I think simplicity is the key factor here. No one, except scientists themselves, can understand anything if the model is too complicated. They [models used in science education] should be simpler. [I: P4]

Similarly, other PSTs thought that scientists have the ability to understand complex phenomena but students do not; therefore, models used in science education should be developed as simple as possible. Below are some sample excerpts.

> Models used in science education are simpler than scientific models, because I do not think students can comprehend too complicated information. (…) When a scientist builds a model, s/he takes each aspect of the real thing into consideration. There are lots of details in scientists' models. However, it is not necessary to present every detail in the model used in the instruction. [I: P5]

> They [models used in science education] can be simpler in order to facilitate students' learning. (…) A complex structure for is difficult for a student to comprehend. If I placed all muscles and organs on the model of the human body system, it is difficult for the student to remember all the information. However, when I remove the muscles [from the model] and place the organs only, they can remember more easily. In other words, models must be simplified. [I: P12]

> They [scientific and models used in science education] must differ. A model that appeals to a scientist may not be appealing to a student. The respiratory system model we utilize during instruction, for instance, might seem too meaningless for a scientist. At this point, level of the audience is important. [I: P7]

> No, they [models used in science education and scientific models] should not be different, even though they [models used in science education] may not necessarily be as detailed as scientific models… They may be simpler than scientific models, or at least resemble them. In fact, what kind of a difference we are talking about? That scientific model is constructed, who can change it? I do not know what kind of difference is required. I think that there could not be another difference except simplification. [I: P8]

Besides being simple, appropriateness to students' grade level was another characteristic of models that PSTs mentioned. The following section presents findings related to this issue.

Appropriateness to students' grade level

In this study, models' *appropriateness to students' grade level* refers to being simple enough so that students at certain grade levels would easily comprehend them. PSTs thought that models used in science education should not be too complicated but be appropriate to students' grade levels. Below are the related excerpts.

Models used in science education must be appropriate to the level of students. However, they should not be oversimplified. They must both transmit the related [scientific] concepts but also be simple enough that even young children can understand them. They must be helpful. [I: P7]

Models used in science education can be simplified versions of scientific models. Their level of complexity may change with respect to students' grade level; they should be simpler in comparison to scientific models, in order to be understood well by students. [I: P9]

They [scientific models and models used in science education] might differ as far as the levels of students are concerned, but after all, both of them are scientific models. They can only differ in terms of level of students. [I: P12]

They [scientific models and models used in science education] must be similar but models used in elementary education might be more simplified, with complicated structures not presented. (…) It is appropriate to start with simple models, because a complex structure may not be well understood [by the elementary-level students] when presented the first. It would be okay at academic level but a complicated model used in an elementary science course might make everything worse. [I: P10]

We cannot use too detailed models in the elementary level. However, the atom model that a physicist uses might be different [than the one used in elementary classes]. (…) Even

> though a simple atomic model is presented to a lower grade student; as the student's grade changes, it is possible to add new elements to that model since the student can understand more about the concept. (…) By this way, it would remain simple, yet a little bit more detailed. [I: P6]

In addition to appropriateness to grade level, explanatory power of models was also emerged from PSTs' responses. PSTs' understandings on this issue are reported in detail in the following section.

Being explanatory (expressiveness)

In this study, *being explanatory* (as a characteristic of models used in science education) refers to having a good explanatory power and being clear, and thus, explaining the real thing well. PSTs thought that models should explain the real thing appropriately. Below are the related excerpts.

> They [models used in science education] should give the general idea [about the scientific concept] – but not superficially, of course. They should explain the [scientific] information clearly. [I: P5]

> They [models used in science education] must explain the real thing well. Why do we use them? Since they explain the concept. They must be useful for explanatory purposes. [I: P7]

> They [models used in science education] must be clear enough, and do not create confusion in students' minds. They must be able to explain, for example, the reason why the nucleus or electrons are there, or why an exchange of electrons takes place while making a compound. The figures we draw for explaining such concepts must be explained in order to retain better in mind. They must be explained through the use of models. The reason why the elements are there must be explained clearly in the model. [I: P10]

> A good model must be clear and understandable to students. [I: P13]

> They [models used in science education] must be explanatory. (…) They must be understood easily by students. I think a model should not be too complicated. Models must appeal to everyone. As I say, models must be coherent, explanatory, and open to developments. [I: P1]

Apart from being explanatory, the PSTs also thought that models used in science education should be accurate. Their understandings related to this issue are presented below in detail.

Accuracy

In this study, *accuracy* of models refers to representing or explaining the real thing in a scientifically acceptable way. Some PSTs identified models used in science education as being *accurate*. Below are sample excerpts.

> A good model… Again, for instance, if it [model] is a symbol of something or an artificial object, it must be represented accurately. In the internal structure of a flower, for instance, male and female organs must be accurately presented in order to be comprehended easily by students. [I: P11]

> Consider a human body model. We should not place the lungs in the place of stomach. Organs must be put in their original places. I admit that model and the real thing cannot resemble each other exactly but the model must be as accurate as possible in order to avoid any misunderstanding. Models should not be in conflict with the real thing or should not create misconception in students. [I: P14]

> A basic property of a good model is its consistency with scientific knowledge. [I: P8]

Being three dimensional was another characteristic of models defined by the PSTs in this study. Understandings about this characteristic are presented in detail in the following section.

Three-dimensionality

In this study, *three-dimensionality* (as a characteristic of models) refers to being able to be seen and touched by the students. Some PSTs thought that models used in science education should be three dimensional. While P12 mentioned that three dimensional models increase students' interest, P4 thought that they increase the effectiveness of teaching. Below are the related excerpts.

> They [models used in science education] must be constructed in three dimensions. Students, for instance, must be able to change the relative position of the Earth to the Sun in a solar system model. I mean, students must be able to interact with the model. They must touch or manipulate the model. Models must be attractive. Vivid colors can be used to catch students' interest. [I: P12]

> They [models used in science education] must be visual… three dimensional… or… how can I say? As in the case of the DNA model, for example, they must be visual. I think it is effective for a model to be visual. (…) Every student must be able to understand its basic elements just by observing it. [I: P4]

In conclusion, it was seen that the PSTs in this study characterized models used in science education as being simple, appropriate to grade level, explanatory, accurate and three dimensional. Although not mentioned frequently, there were also some other characteristics defined by some of the PSTs. Among them are being manipulative [P12, P13], up-to-date [P1], economical [P13], appropriate to the curriculum [P9], and practical [P9].

4.2.2. Necessity and Benefits of Using Models in Science Education

Data collected through the interviews and lesson plans revealed that the PSTs' believed in the *necessity and benefits of using models* during science instruction in attempt to stimulate students' learning, retention and interest. They regarded models as indispensable parts of teaching and learning science, and agreed on the idea that models should be used in teaching scientific concepts where possible. Below are some excerpts from their responses that evidence this finding.

> Using models is the heart of science education. I cannot imagine teaching students anything without the help of models. (…) for example, it is impossible for me to teach human body without using human body model. As a science teacher, I find it crucial to use models in science teaching. [I: P1]

> They [models] are not real, and we may not have the possibility to show the real thing in the classroom. This is true for both students and us [teachers]. It would be more effective to use models to teach difficult-to-explain concepts. For this reason, I believe that they must be used in science education. [I: P2]

> We make use of models in our university education, and I think this provide the basis for our later use of models in elementary education. They [models] must be particularly used in elementary education, because it is easier for adults to visualize things in mind but this is more difficult for elementary students. Comprehending concepts through the use of visual aids is easier for them. [I: P5]

> Models must certainly be used. Of course, we [as science teachers] use them in elementary schools… at the university… As I said before, it helps us visualize something,

> an abstract thing… Reading the textbook alone does not provide retention of the concepts. [I: P2]

> Models are used widely… in laboratories, for example. There are models for the structure of the eye or the cells. There are figures and models used for studying the internal structures of plant cells, as well. Science education is based on models. It [science] is a course composing of models, experiments and observations, which make it different from other disciplines. Direct teaching alone would not retain for a long time in students' mind. Models, however, increase the retention of knowledge. [I: P11]

> I think models are really necessary. You can visualize the respiratory system or circulatory system through models easily. [I: P13]

> It is necessary to use models. I believe that, it is effective in learning the concepts such as cells, DNA, etc. It is an aim of science education to facilitate students' learning. [I: P8]

It was observed from the excerpts above that the PSTs in this study were of the opinion that models are beneficial tools for teaching and learning science. They agreed on the necessity of using models in attempt to facilitate students' science learning. Besides *facilitating learning and teaching*, PSTs also believed that models *increase retention of knowledge and students' interest (and motivation)*, and *facilitate concrete thinking and enhance visual intelligence*. Table 4.5 below summarizes the coding scheme and frequencies for the benefits of using models in science education.

Table 4.5. Coding scheme and frequencies for benefits of using models in science education

Benefit	Explanation	Frequency (N=14)
facilitating learning and teaching	Referring to the abstract nature of the concept to be learned and taught, PSTs state that models facilitate learning and teaching of these concepts, usually by reifying them.	12
enhancing multiple intelligences	PSTs refer to the visual nature of models, and think that due to this nature they appeal to visual intelligence.	4
increasing retention of knowledge	PSTs refer to the visual nature of models and state that visual nature of models increases their retention in minds.	10
facilitating concrete thinking	PSTs think that since models reify and visualize abstract concepts, they appeal to concrete thinking that younger students hold.	4
increasing students' interest	PSTs refer to visual nature of models and mention that this nature increases students' interest towards the concept.	4

Facilitating learning and teaching

In this study, *facilitating learning and teaching* refers that a model is helpful in understanding and teaching scientific concepts. Some of the PSTs considered models as effective teaching tools since they *facilitate learning* of scientific concepts. Below are sample excerpts from their responses.

> Models can facilitate the understanding of concepts, thus making it easier for students to understand the courses [I: P2]
> [Models are helpful in] understanding the given concept better, quicker, and without losing time… they are also helpful in obtaining information easier and more accurately. [I: P11]
>
> We make it easier for students to reach the relevant information by using models. [I: P14]
>
> Models facilitate learning by the use of the five senses… Learning is more effective if we involve more senses. This is what models provide students with. Particularly, tangible models increase the effectiveness of learning. [I: P13]
>
> [By the help of models], learning is facilitated, and knowledge is internalized better in human mind. [I: P5]

Some of the PSTs referred to the abstract nature of the concept to be learned, and thought that models facilitate learning of these abstract concepts by reifying them:

> Models facilitate learning since they reify the concepts. They make concepts easier to understand by all people. It should not be restricted to students. [I: P1]

> The purpose of models is to facilitate science learning. If I had only read about the concept of cells [from the textbooks], for example, it would not retain in my mind for a long time but since I have seen the images in the textbooks, such as sandwich model, I still remember them. Images of models of atom or DNA helix come to my mind when the concepts of atom and DNA are mentioned, because those images facilitate learning. [I: P4]

> As I said before, these [modeled concepts] are more of abstract concepts. It is so difficult to teach a student about 'a matter at speed of light' but it can be easier if a model or simulation representing it is constructed. [I: P9]

> It is difficult for a student to understand the concepts of cell or DNA without the use of models, because they are abstract. Elementary school students would probably hear these terms for the first time in their life, and they would not have any idea about what they are. [I: P8]

Some PSTs also mentioned about models' role in *facilitating teaching*. P13, for example, thought that models facilitate the transfer of knowledge from teachers to students. P2 and P9, on the other hand, stated that models make it easier for teachers to explain difficult-to-teach concepts, which are abstract in nature. Below are the related excerpts.

> In terms of teaching, you [as a teacher] transfer the knowledge more easily. I mean, it [the knowledge] is understood more easily. [I: P13]

> It would be a more effective method to teach a difficult subject through the use of models. [I: P2]

> First of all, they [models] are really effective at teaching abstract concepts. (…) It is really difficult to explain some concepts without the help of models, such as solar system. Without models, actually, it is impossible to conduct a measurement on it [solar system]. But thanks to models, we can provide explanations about it [solar system]. [I: P9]

> The cell concept reminds me of the images like sandwich model in textbooks. Atom reminds me of those images, and DNA, that of helix, because those images facilitate learning, particularly the learning of students with a higher level of visual intelligence. I, for instance, learn more easily through visualizations. [I: P4]

As observed in the excerpt taken from P4, enhancing multiple intelligences was emerged as another benefit of using models. Findings are reported in detail in the following part.

Enhancing (and appealing to) multiple intelligences

In this study, *enhancing multiple intelligences* refers to models' role in improving students' multiple intelligences. According to the multiple intelligences theory, intelligence is not a single entity, rather, it differentiates into a number of modalities (i.e., visual-spatial, linguistic, logical-mathematical, musical, interpersonal, intrapersonal, bodily-kinesthetic, and naturalistic intelligences). In PSTs' responses, visual-spatial intelligence was the predominantly referred intelligence type. The PSTs shared the idea that models enhance and appeal to the visual-spatial intelligences. Below are their excerpts.

> During instruction, first, we [as teachers] give the information [through direct teaching] but then, to provide better retention, we use visualizations such as models. Models appeal to people with visual intelligence. That is why we support the courses with models. [I: P8]

> We use models, such as atom models, body system models, organ models, etc., in teaching science; thus we form something visual in students' mind. Of course these models are not the same as the real organs but they visualize these concepts in students' mind. Students can, at least, make predictions about these concepts. Visuality is something important. There is the visual intelligence in the multiple intelligence theory. We enhance visual intelligences of students. [I: P14]

> Atoms come closer and form bonds. How do we represent this process [bonding]? We draw two atoms and connect them with a line. They form either a covalent or an ionic bond. In order to teach this process to a student, we need to visualize it. The visualization here is a model. (…) There is a common saying, you know: *words fly away, writings remain*. I

> believe in this. As you know, there are different types of intelligences. For this reason, considering that there are approximately 25 to 30 students in a classroom, it is necessary to appeal to every type of intelligence. We can do direct teaching but we should also consider visual intelligences. [I: P1]

Apart from enhancing visual intelligences, the PSTs also thought that use of models increase retention. In the following part, this issue is reported.

Increasing retention of knowledge

In this study, *increasing retention of knowledge* (as a benefit of models) refers to increasing the remembering time of the learned knowledge with the help of models. Almost all of the PSTs were agree with the role that models play in increasing retention. Most of them based their justifications on the visual nature of models. In other words, according to them, visual nature of models increases the retention of scientific concepts. Below are sample excerpts.

> When students have something concrete in their hands… these types of visual things retain longer in their minds. Students might not pay attention to, or might easily forget what is taught on the blackboard; however, they can quickly remember the related models, if we ask the place of stomach, for instance. When you show a model to a student in secondary school, s/he will more likely remember it when

s/he is at university. In short, models help retention of knowledge. [I: P12]

I, for example, remember the enzyme-substrate complex from high school, which means it retains in mind when models are used. [I: P8]

Models are needed for helping students visualize certain phenomena, or making something retain longer in their mind. (...) I think models facilitate remembering. It is easier to remember a model than to remember a text. [I: P6]

Models bring a concrete image to the mind. Just by texts, nothing retains in mind. For example, I remember the place of atomic particles, such as the nucleus in the center and electrons around, through the atomic model; rather than the texts I read about the structure of atom. [I: P10]

Since they [models] are visual and reified forms, as in the case of atomic model, they retain longer in mind. They also prevent memorization. In primary school, students can memorize what atom is but this might be forgotten the next year. However, when the students see the atom models, they will remember those models as the model concept mentioned. Memorized texts would not come to mind but models would. When I think of DNA, for instance, what comes to my mind is the double helix structure of DNA rather than its textbook description. The helix structure also helps me with answering the questions about DNA. I can describe hydrogen bonds, double bonds, etc. over the model I remember. As the written description would not come to

> my mind, I would not be able to reply the questions concerning the DNA if it were not for its model. [I: P10]

> The science courses are enriched by experiments and observations, which involve the use of models. This is what distinguishes science from other courses. Knowledge does not retain with verbal annotations alone. It is the models that provide retention of knowledge. [I: P11]

> Models can make important contribution to lower grade students' learning of the shapes and locations of organs in the body. They [students] may also understand without models, as well, but it is much better for them to learn by seeing. I believe that learning is more permanent when supported with visual aids. [I: P2]

As it is seen from P2's excerpt above, besides providing better retention, another benefit of using models is considered as 'facilitating concrete thinking' by the PSTs. In the following section, their understandings about this theme are presented.

Facilitating (and appealing to) concrete thinking

In this study, *facilitating concrete thinking* refers to making it easier for concrete thinkers to comprehend abstract concepts. Some PSTs in this study thought that models make concepts more understandable for the students at lower grades since they still did not develop abstract thinking ability. Below are sample excerpts.

> Models explain something that we cannot see. They reify the concepts that are invisible to naked eye. Children of those ages [elementary level] have a relatively low abstract thinking ability, and this makes models important. [I: P7]

> Students in elementary grades need reified concepts matching their developmental level. The concepts do not make much sense when you teach them in an abstract way, because they are concrete thinkers, and they want to see things directly. That is why models are of great importance. [I: P13]

Increasing interest and motivation was another theme evolved from PSTs' responses as a benefit of using models. In the following section, PSTs' understandings on this theme are reported in detail.

Increasing interest (and motivation)

In this study, *increasing interest and motivation* refers to arousing the willingness of students towards science courses. Some PSTs thought that models motivate students and increase their interest towards the scientific concepts. Some of the excerpts are given below.

> Models arouse students' interest. We have observed during our practice at elementary schools where the students were more excited during the laboratory hours. They were curious about what they would learn and see. In direct instruction, the teacher talks but everyone in class is occupied with

something else. This is even true for us at the university. Models arouse interest and motivation. [I: P5]

I think exposing students to some visual materials [models here] arouses their interest. They attend courses more keenly. They may not pay attention to what we teach through direct instruction, but if we bring the model of the human body to the classroom, for example, they may show more enthusiasm. [I: P12]

As I also work as a private tutor, I have had similar experiences. Students like them [models]. When I explain the concept of 'fractions' through the use of apples, for example, they pay close attention to the concept. [I: P1]

If a DNA helix structure was given to my hands [as a student in the class], class hours would be more enjoyable. Students can find out new things by playing with and manipulating them [models]. Thus, class hours would become more amusing. [I: P9]

Some PSTs who mentioned in their *lesson plans* about their willingness to use simulations or images also referred to arousing interest and motivation, increasing retention and appealing to visual intelligences. They stated that such visual entities attract students' attention and motivate them, and when students are motivated, they enjoy the course which in turn increases the retention of the concepts they learned. Below are the related excerpts from their lesson plans.

> I will show students an animation [about the possible dangers of electricity] to arouse their interest. (…) I will begin the lesson with such an activity in order to arouse students' interest. [LP: P3]

> At the beginning of the lesson ['sound' concept, grade 6], I will show pictures [that represent 'noise'] in order to arouse students' attention and interest, and motivate them. [LP: P14]

> The poster activity [for introducing different types of ecosystems] will focus children's attention on the subject matter ['ecosystems' concept, grade 7], and it will last longer in their mind, because they will design their posters by seeing, thinking, taking decisions, speculating upon, and particularly enjoying the subject. Organizing such activities with the students at these grades arouses their interest, courage, and motivation. [LP: P11]

> As the images [representing animals] in the slideshow I prepared appeal to visual intelligences of students, they [students] will both have a high level of interest and the topic [food web, grade: 7] will retain longer in their minds. [LP: P7]

In sum, it was observed that the PSTs in this study usually considered models as visual/physical structures. By referring to this nature, they thought that models are beneficial tools in facilitating teaching and learning, increasing retention and interest, and appealing to concrete thinking and visual intelligences since they visualize/reify scientific concepts.

4.2.3. PSTs' Use of Models in their Instructions

Data collected through the interviews revealed PSTs' *intention towards the use of models,* while data collected through lesson plans and class observations revealed the *models they used in their instructions.* As seen from the previous sections, the PSTs in this study valued models as essential tools in science education, and were enthusiastic about using models in their classes. In the following sections, first, the models that the PSTs were planning to use in their instructions, then the models they used in their instructions are presented. The following section begins with models that PSTs' intended to use in their instructions.

4.2.3.1. PSTs' Intention to Use Models

Among the models that the PSTs were planning to use in their instructions were mainly *concrete (material/physical) models* (e.g. human body model, eye model), *drawings, images*, and *simulations*. Moreover, some of the PSTs also indicated their willingness to develop models by themselves in case of unavailability of models at schools. Below are examples from the PSTs' excerpts who mentioned their willingness to use all available models.

> I can use all models that are needed and are also appropriate to the topic. There is no specific example in my mind now, but I can use any model related to the concepts I am going to teach. [I: P2]

> I am planning to use all models I can find. If I am to teach about DNA, for example, a DNA model should be standing on my desk. I would certainly like to use models [in my lessons]. Since I place great importance to visuality, it would be fine to have the model of the topic I am to teach in my hands. [I: P12]

> I think I would use all available models in physics, chemistry, and biology, as soon as they are not complicated. Any model is welcome if it simplifies its subject matter and retain longer in students' mind. [I: P10]

Some PSTs mentioned that they would especially use physical/ concrete models during their instructions. They said that if physical models are not available, they would make use of these models' drawings:

> I will use especially material models such as the body model. (…) I can also try to develop models in my own, or I can present existing models through drawings or images of them. Maybe, I cannot show students a body model in the class but I can prepare a poster myself or present a body model on the computer or on smart board. [I: P14]

> Models are effective teaching tools. I will use material [physical/concrete] models if they are available, but if not, I can teach through drawings of them. [I: P11]

> If existing models meet my demands, I first use them but if they fail to do so, I would develop models myself. [I: P9]

Animations were also among the models that PSTs intended to use. Below is a sample excerpt.

> Animations would be nice. I like that kind of things. I am quite interested in technology. Students like such things [e.g. animations] too. (…) Images can also be used… or the physical models… such as ear model or eye model… we can even bring in a real eye in sacrifice holiday if we are unable to find their models. We may not have every opportunity but I think models are essential, they must be used. [I: P1]

In sum, the PSTs in this study showed willingness towards the use of models in their teaching practices. They mentioned that they would use all available models related to the topic in concern; and if no models are available, they would develop models themselves.

4.2.3.2. Models used by PSTs

Data from the lesson plans and class observations indicated that the PSTs in this study attempted to include several types of models in their teaching practices, such as *drawings, tables, graphs, simulations,* and *concept maps*. The coding scheme and frequency for the models that PSTs used in their instructions are given in Table 4.6. Details about PSTs' uses of these models are presented separately in the following parts.

Table 4.6. Coding scheme and frequencies for models used by PSTs

Model Used	Explanation	Frequency (N=14)
drawings, graphs, tables	PSTs used drawings, tables or graphs to represent, explain, or summarize several scientific phenomena.	10
simulations/animations	PSTs showed simulations or animations of several scientific concepts for the purpose of visualizing them.	5
concept maps	PSTs summarized the key concepts of the topics they instructed through concept maps.	4

Drawings, graphs and tables

The data from the class observations clearly showed that almost all of the PSTs tended to use the blackboard to explain, represent, or summarize the topics of interest during their instructions in real classroom settings at elementary schools. This tendency resulted in the frequent use of *drawings, graphs* and *tables*, which can be considered as models when they provide explanations or representations for the scientific phenomena, and present some attributes about them.

P1, for example, taught the concepts of 'mixtures and solutions' to seventh graders, where he drew a *table* on the blackboard to emphasize and summarize the key concepts about pure and non-pure substances. He presented the *table* in his lesson plan, as well (see Figure 4.1). In the lesson plan, he stated that:

> Through my questions [as a teacher], the students will be able to notice that an element or compound consists of one type of particle, while a mixture consists of multiple matters that retain their features. I will summarize this information by drawing a *table* on the blackboard. [LP: P1]

Below is the table he presented in his lesson plan:

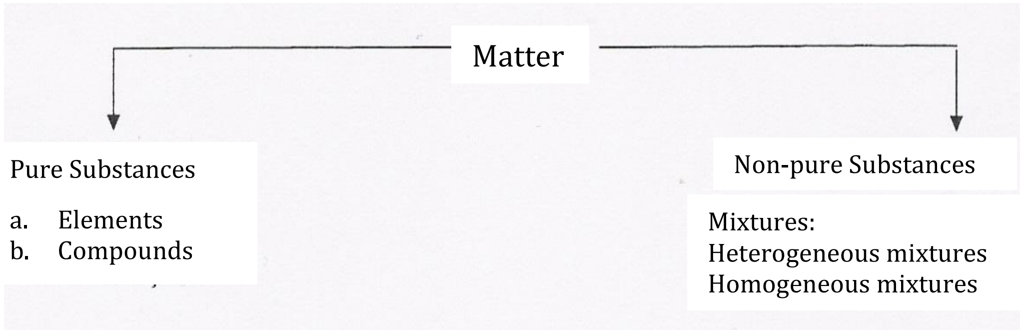


Figure 4.1. Table representing pure and non-pure substances [LP: P1]

Another PST, P7, instructed the 'ecosystems' topic to seventh graders. During her instruction, she also drew a *table* to classify organisms according to the way they obtain their food. She presented the same *table* in her lesson plan as well (see Figure 4.2), and stated that:

> I will [as a teacher] ask students to divide organisms in the food chain [she has shown] according to their nutritional patterns, and I draw a *table* on the blackboard according to their [students'] answers. First, I will divide organisms into three, and then show that consumers are classified as herbivores, carnivores, and omnivores [LP: P7].

The table she gave in her lesson plan is below.

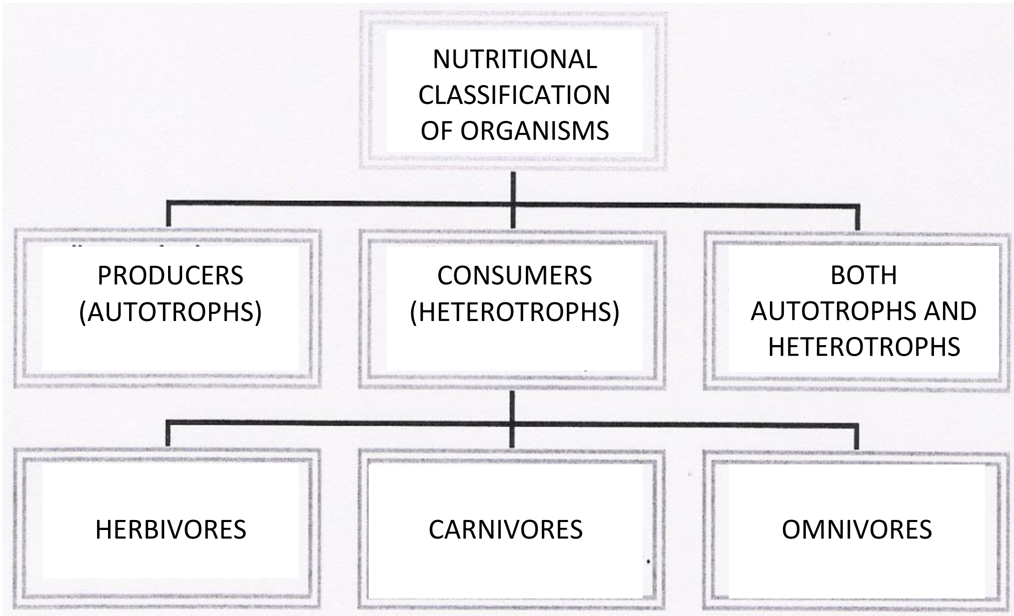


Figure 4.2. Table presenting nutritional classification of organisms [LP: P7]

P13 taught the concept of 'energy flow in an ecosystem' to seventh graders. She used *drawings* of food chains and food webs to explain the energy flow. During her instruction, after drawing a food web on the blackboard and clarifying the concept of food webs, P13 moved to the 'energy pyramid' concept. Giving information about 'producers, consumers, and decomposers', she drew an energy pyramid on the blackboard, and stated that (both during instruction and in the lesson plan) the energy flow among these organisms could also be represented through an energy pyramid. In her lesson plan, she stated that:

> The students identify the common species in the food chains [written on the blackboard], and try to draw a food web by matching these common species. [LP: P13]

P13 attached the drawings of the food web and the energy pyramid to her lesson plan, as well (See Figure 4.3).

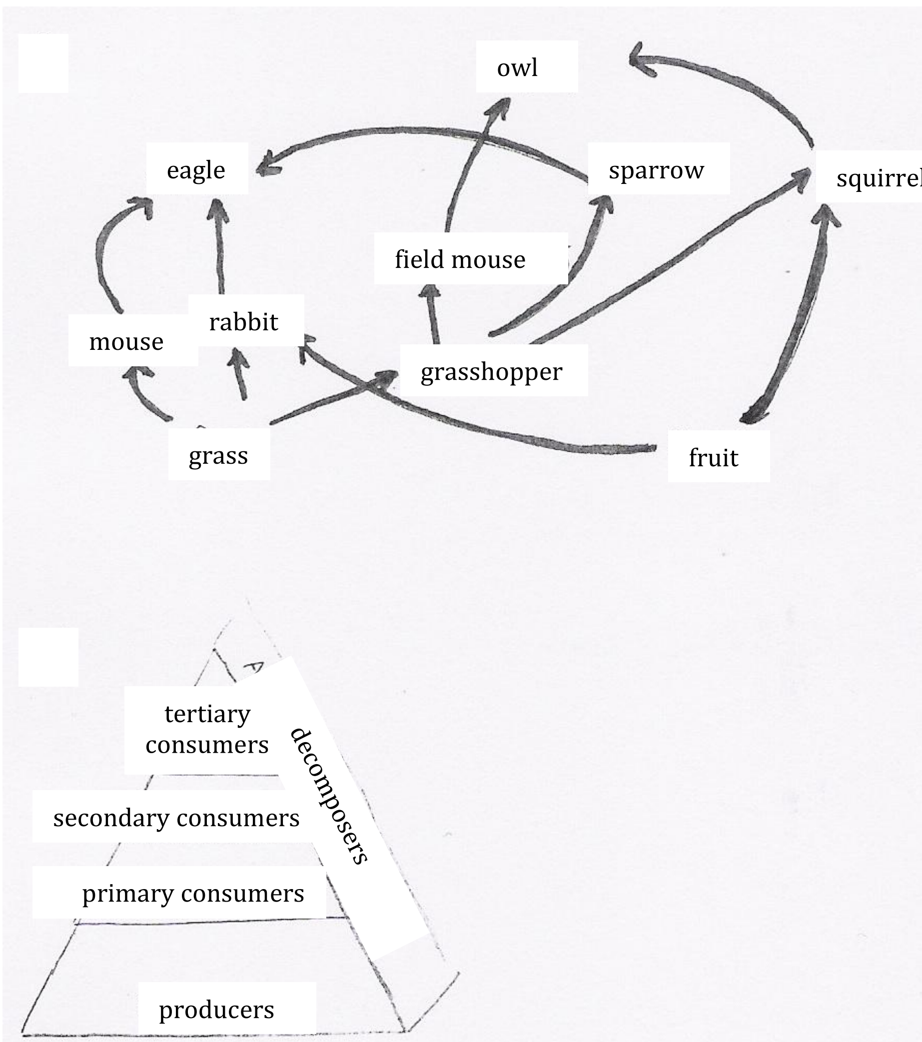


Figure 4.3. Drawings of food web and energy pyramid [LP: P13]

Another participant, P8, instructed 'states of matter and heat transfer' to eighth graders. In his lesson plan, he stated that:

> I [as a teacher] will say that heat is necessary for phase transitions, and I will define each state of transition [i.e., melting, freezing, evaporation, and condensation]. Then, I will *draw* the heat-temperature graph to show the transition from ice to vapor on the blackboard, and label certain points on the graph and ask students to determine the state of matter is in the points I have marked. [LP: P8]

Although P8 did not include in his lesson plan, he drew heat-temperature graphs on the blackboard during his instruction. A screenshot from his instruction where he drew heat-temperature graphs to explain phase transitions of matter is given below (Figure 4.4).

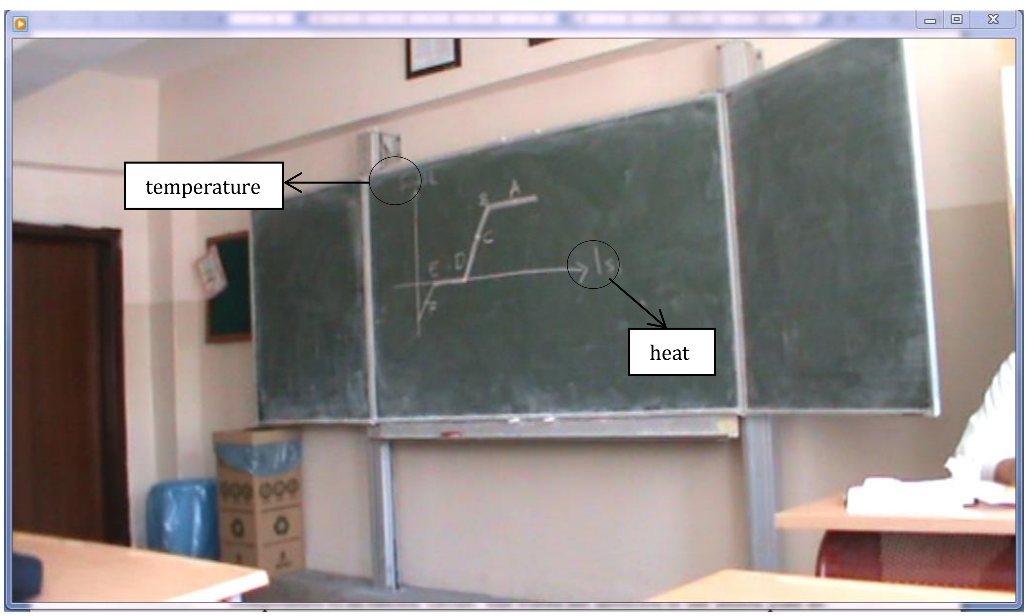


Figure 4.4. A heat-temperature graph (CO: P8)

In her lesson plan on the concept of 'electrical energy' (to sixth graders), P3 stated that,

> I [as a teacher] will write the elements of an electric circuit on the blackboard, and then, *draw* a model of the simple circuit with those elements. [LP: P3]

She (P3) did not provide a drawing of simple electric circuit in her lesson plan, but she *drew* a simple electric circuit on the blackboard to introduce the elements of an electric circuit. Below is the screenshot from her instruction (Figure 4.5).

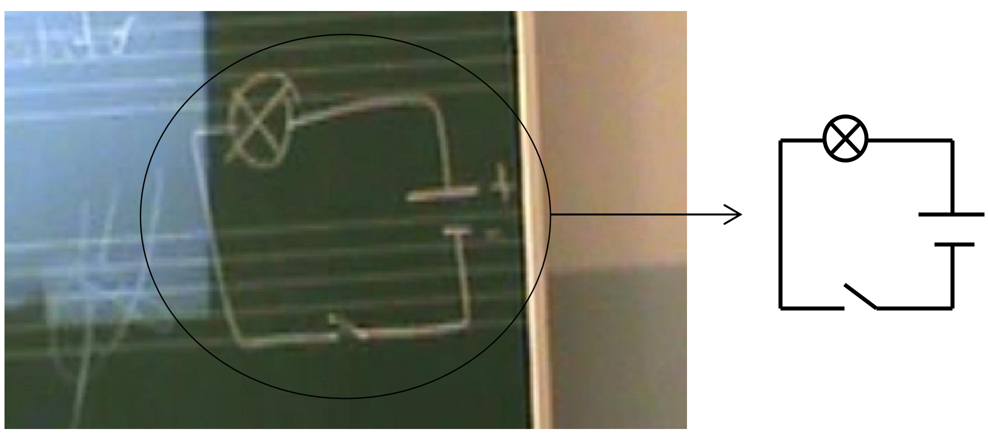


Figure 4.5. A drawing of a simple electric circuit [CO: P3]

In her lesson plan on the concept of 'sound' (to sixth graders), P5 mentioned about the analogy between sound waves and water waves, and stated that:

> Spreading of sound waves is like the water waves in a pond. Although sound waves and water waves are similar in that they both travel from one point to another, sound waves travel in all directions from the source of the sound, whereas water waves travel on the surface of water. [LP: P5]

P5 did not provide the drawing of the spreading of sound waves in her lesson plan but she drew lines on the blackboard to represent the spreading of sound waves. A screenshot is provided below (Figure 4.6).

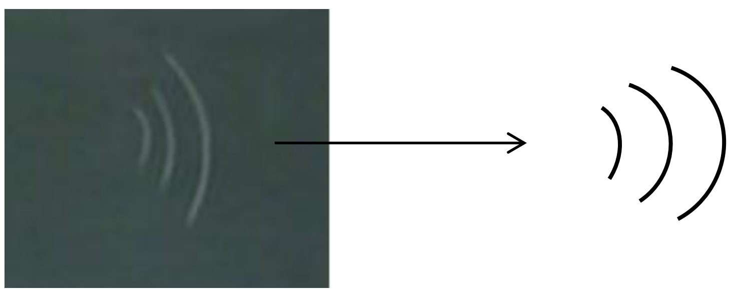


Figure 4.6. A drawing of the spreading of sound waves [CO: P5]

P6 was another PST, who made a *drawing* on the blackboard to explain a scientific concept. She taught the 'particulate nature of matter' concept to sixth graders in her classroom practice, and showed the distances (free space) between the atoms in solids, liquids and gases through drawings. She did not mention about the drawings in her lesson plan but a screenshot from her instruction is provided below (Figure 4.7).

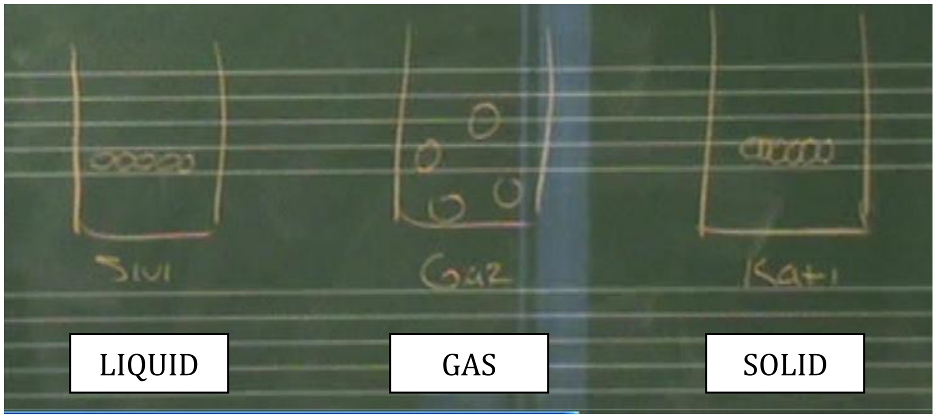


Figure 4.7. A drawing of the free spaces between the atoms of solids, liquids and gases [CO: P6]

During their teaching practices, the PSTs also used animations and simulations, besides drawings, graphics and tables. In the following section, their use of these types of models is reported.

Animations and Simulations

Animations are the modeling of the real thing, aiming at understanding and representing some characteristics of the real thing in focus. Simulations, on the other hand, give the chance to manipulate the variables, and observe the changes or effects of the manipulation on the real thing. Some PSTs in this study used animations/simulations in their classroom practices in the cooperating schools.

P6, for instance, instructed 'particulate nature of matter' to sixth graders in her teaching practice. Before the instruction, she distributed a worksheet, where students were asked to take notes about their predictions, observations or inferences about the activities done throughout the lesson. Then, P6 started the lesson with an animation that showed how solids, liquids and gases are compressed under certain pressure. Before the animation plays, however, she showed the setting in the animation (where three enclosed tubes are filled with solid, liquid and gas; see Figure 4.8) and asked students to write their predictions about the behaviors of solids, liquids and gases as the piston is compressed. As the students are complete with writing their predictions, P6 asked them to reflect their ideas. Then, she played the animation and showed how compressible solids, liquids and gases are. Below is a screenshot from the animation she used (Figure 4.8).

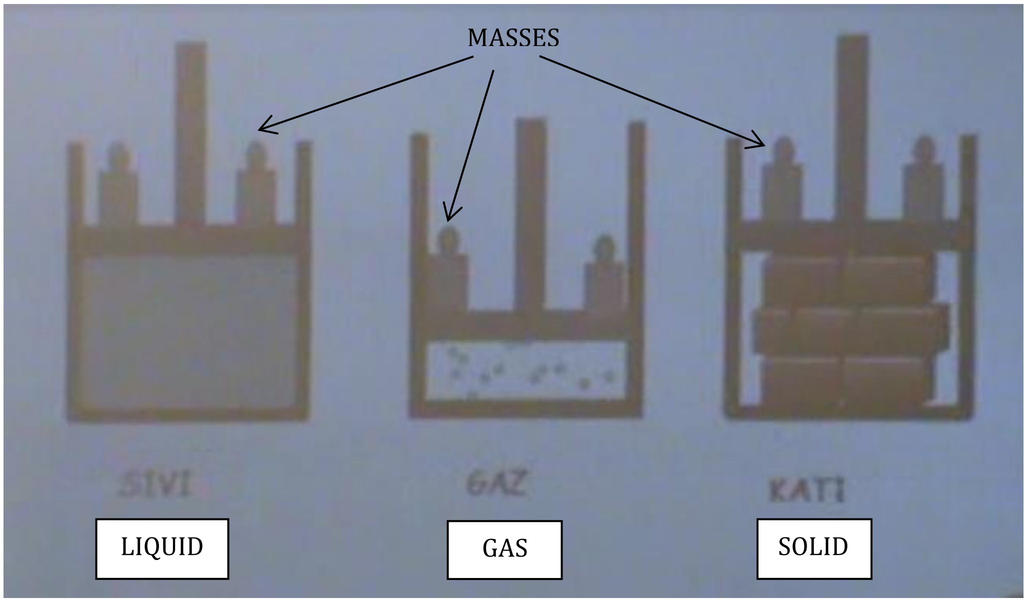


Figure 4.8. An animation of the behaviors of solids, liquids and gases under pressure [CO: P6]

Similarly, P2 also showed a simulation to explain the particulate nature of matter. In her lesson plan, she stated that:

> I [as a teacher] am going to show a simulation assuming that students will understand the particulate nature of matter and the spaces among the particles in the matter. [LP: P2]

Below is a screenshot from the simulation she used (Figure 4.9).

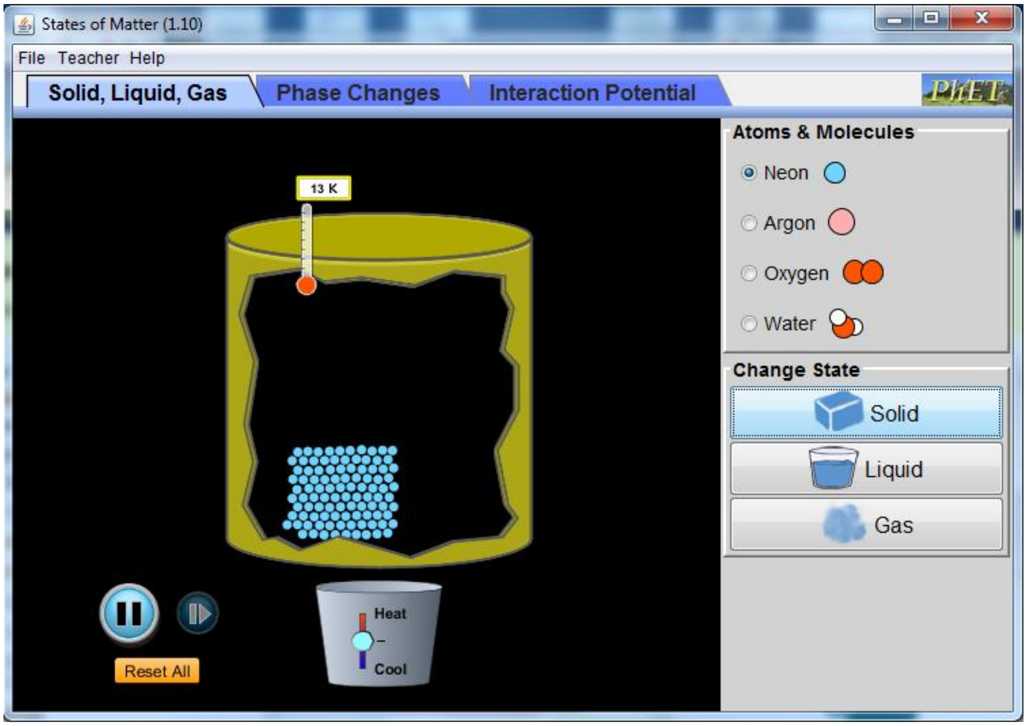


Figure 4.9. A simulation of the particulate nature of matter (http://phet.colorado.edu/en/simulation/states-of-matter) [CO: P2]

P9 instructed 'electromagnets' topic to eighth graders in his teaching experience in the cooperating school. He used two animations to show the properties of electromagnets. In his lesson plan, he stated that he intended to use animations for the purpose of showing abstract concepts in three dimensional forms. He said that:

> Animations will be used in order for the students to see three-dimensional presentations of the abstract concepts that students have difficulty in understanding. [LP: P9]

In one of the animations, he showed a nail, wrapped with a copper wire and attached to a battery (so that a simple electric circuit is formed), and a paper clip is placed near next to the nail (See Figure 4.10). As the animation started, the circuit is closed and the nail behaved like a magnet – pulling the paper clip. Below is a screenshot from the animation.

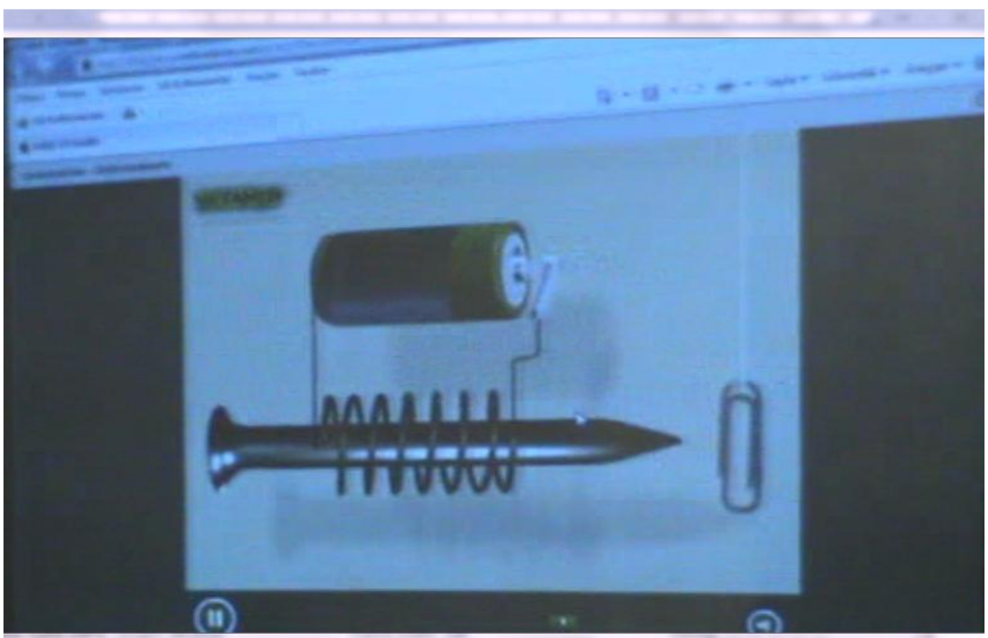


Figure 4.10. An animation of an electromagnet [CO: P9]

Similarly, P12 also used several animations (a total of five) about 'magnetic properties of electric current' (grade 8) to support his teaching:

> I will use animations from TTNet Vitamin. In order to emphasize the concepts represented through the animations, I will recite and repeat them with my own sentences. I will stop the animations at certain points and ask students about their ideas on the concept in focus in order to avoid a teacher-centered approach. [LP: P12]

Below (Figure 4.11) is a screenshot from an animation about the mechanism of the doorbell that P12 showed during his instruction.

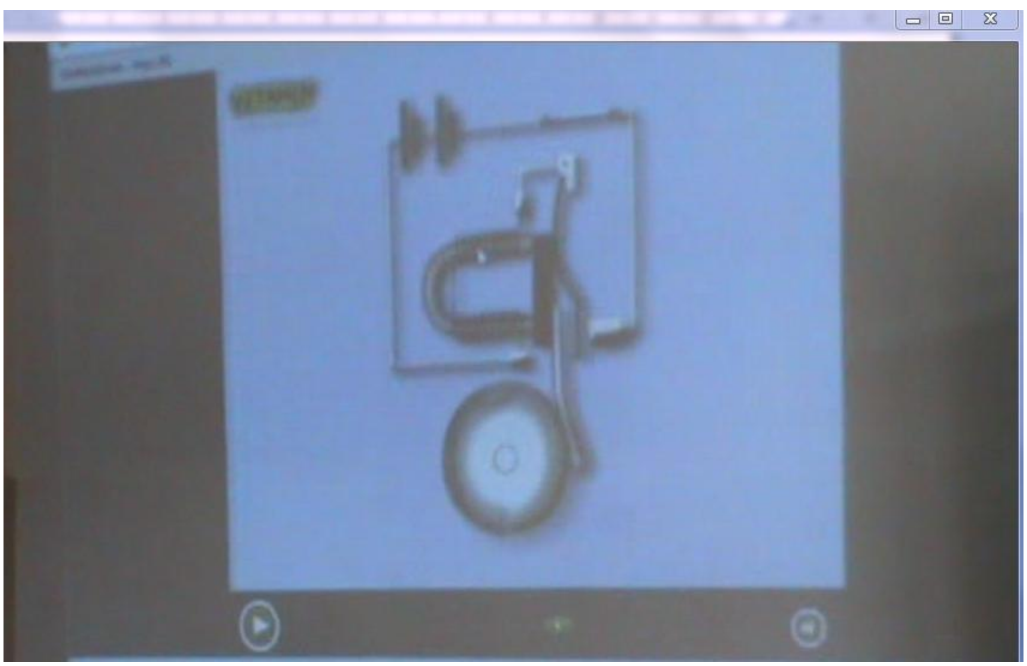


Figure 4.11. An animation of the mechanism of the doorbell [CO: P12]

Apart from animations and simulations, the PSTs also used concept maps in their teaching practices. Their use of concept maps is presented in the following section.

Concept maps

Concept maps were another type of models used by the PSTs during their instructions. They generally preferred to use concept maps at the end of the class hours to summarize the topics they have taught.

P2, for instance, constructed a concept map as a PowerPoint presentation to summarize her instruction on the 'particulate nature of matter'. In her lesson plan, she stated several times that she planned to use a concept map to summarize the concepts. She said that:

> The subject is summarized through a concept map. (…) I [as a teacher] will summarize the lesson by using a concept map. (…) I will use a concept map to summarize the lesson. [LP: P2]

Below (Figure 4.12) is the concept map she attached to her lesson plan.

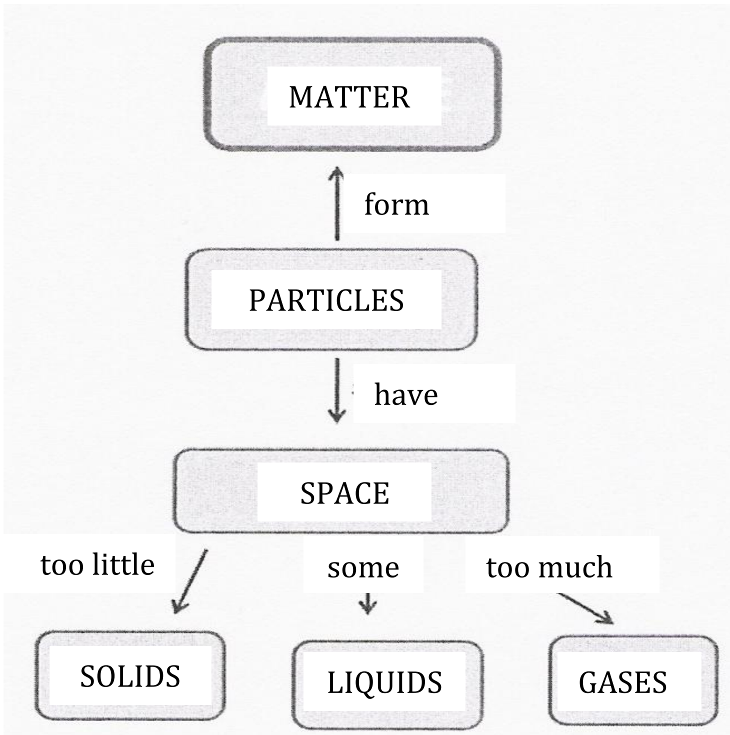


Figure 4.12. A concept map of the particulate nature of matter [LP: P2]

Similarly, P6 also taught the particulate nature of matter in her lesson and summarized her lesson with a concept map. In the lesson plan, she said that:

> I [as a teacher] will shortly summarize the activities conducted throughout the lesson by using a concept map. [LP: P6]

The concept map she presented in her lesson plan is below (Figure 4.13).

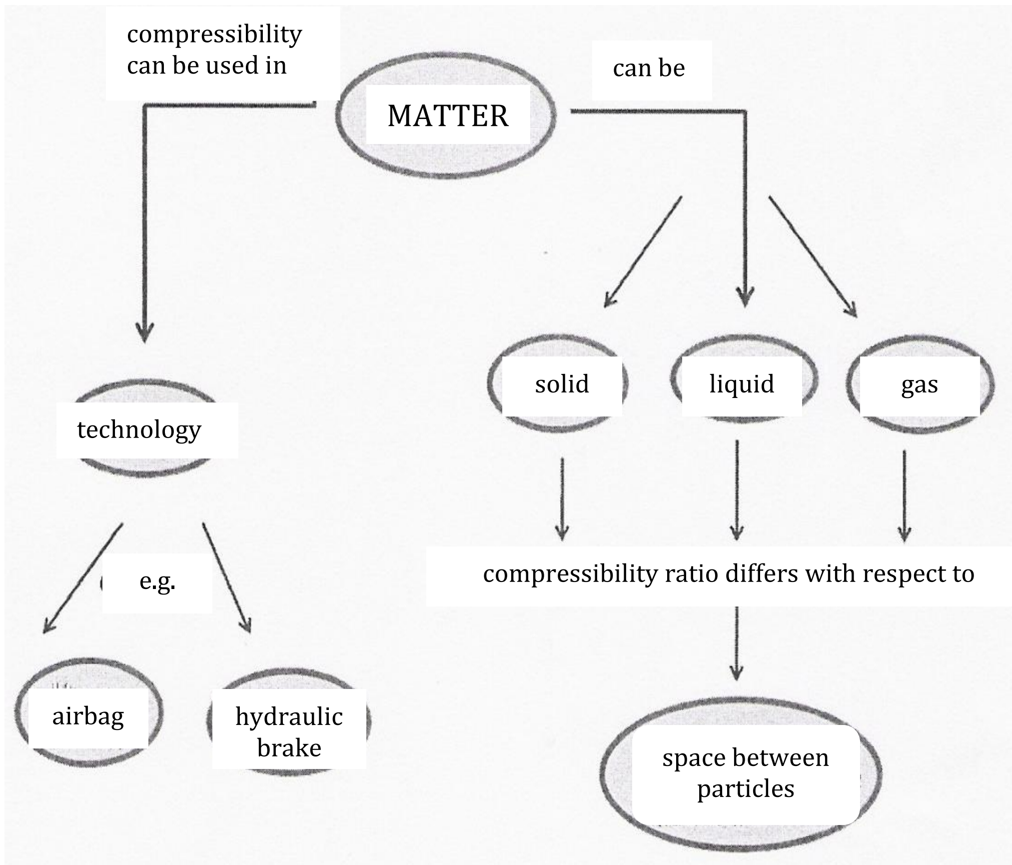


Figure 4.13. A concept map on the particulate nature of matter [LP: P6]

In her lesson plan about 'insulators and conductors' concept, P10 presented the concept map as a teaching material:

> Concept map: I will use it for summarizing the subject discussed throughout a lesson. [LP: P10]

Below is her concept map she gave in her lesson plan (Figure 4.14).

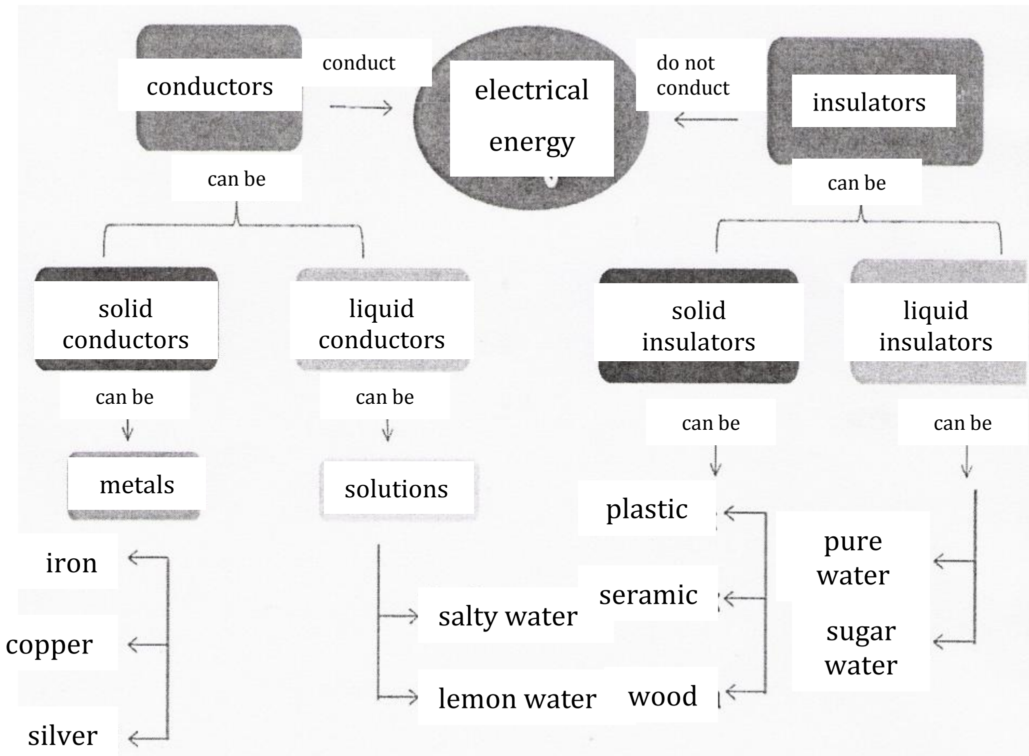


Figure 4.14. A concept map of conductors and insulators (LP: P10)

In sum, it was seen that the PSTs made use of different types of teaching models in their instructions. They mostly preferred to use drawings, graphs and tables. Some of them also used concept maps to summarize the topics they taught. The use of simulations was also common. As mentioned previously; the PSTs stated in their lesson plans that, simulations and animations motivate students towards the course and increase the retention of the concepts taught.

4.3. Summary of the Findings

Investigating PSTs' understandings of scientific models was one of the purposes of this study; and it was observed that the PSTs described scientific models as explanations and representations of unobservable/inaccessible scientific phenomena. PSTs' awareness about the explanatory and representative nature of models was sound; however, most of them also reasoned in terms of logical positivism by stating that models should be close the real things. Apart from descriptions, the PSTs in this study mentioned different roles of scientific models, among which 'simplifying' and 'visualizing' were the commonly stressed ones. PSTs believed that by simplifying and visualizing, models facilitate understanding of scientific concepts. The data further evidenced that subjectivity, creative and imaginative nature, social-cultural embeddedness, tentativeness, and empirical-basedness were emerged as aspects of nature of scientific models. All of the PSTs mentioned about the dynamic nature of scientific models and shared the idea that models can change. Most of them also mentioned about the subjectivity, and social and cultural embeddedness of the development of scientific models. Some were also of the opinion that models are constructed based on evidence, and scientists' creativity and imagination also take place in this construction process.

PSTs' perceptions about the models used in science education were also investigated for the purpose of this study. The findings revealed that, the PSTs characterized these models as being simple, appropriate to grade level, explanatory, accurate and visual, where 'simplicity' was the most commonly addressed characteristic. This finding was in line with the findings of the first research question, where 'simplifying' was emerged as a role of scientific models. Likewise, 'visuality' was also observed as a characteristic of models that is similar to the understandings about roles of scientific models (i.e., reifying, visualizing). The findings also showed that, the PSTs were quite certain about the necessity of using models in science teaching. They considered models as visual/physical structures, and by referring to 'visuality', they believed that models facilitate teaching and learning, increase retention and interest, and appeal to concrete thinking and visual intelligences since they visualize/reify scientific concepts. In respect of the use of models, on the other hand, the PSTs showed willingness towards the use of models by mentioning that they would make use of all possible models they can reach or construct. Most of them stated that they would use physical/material models in their teaching practices. Interestingly, however, none of the PSTs used any physical models in their teaching practices. They usually preferred to use drawings, graphics and tables in order to explain several scientific concepts, and some showed simulations/animations to their students for the purpose of representing some scientific processes. Concept maps were also used at the end of the class hours to summarize the topics they taught.

CHAPTER V

DISCUSSION AND RECOMMENDATIONS

This chapter provides the discussion of the findings of the present study which aimed to examine pre-service science teachers' understandings of scientific models and their perceptions about models used in science education. Discussion of the findings is followed by recommendations for further research.

5.1. Discussion of the Findings

There is no doubt that models play important roles not only in science but also in science education. While helping scientists describe and explain natural phenomena (Mashhadi, 1999) and make predictions as well as obtain information about the real thing that is inaccessible for direct observation (Van Driel & Verloop, 1999), models improve students' understanding of both scientific ideas and particular content area (Treagust, Chittleborough & Mamiala, 2002). Despite their importance, the findings of the current dissertation corroborated the related literature's call for developing a better understanding of models and supported the need for appropriate pedagogical training of pre-service teachers regarding the use of models in classroom settings. Although the sample size is limited, findings of the current study led us to offer that teacher training programs in Turkey should find ways to help pre-service teachers develop contemporary views of models as well as skills necessary for using it in their teaching effectively. The PSTs in our study, although perceived models as useful for teaching science concepts to elementary level students and showed strong willingness towards the use of them in their future classroom practices, they harbored some doubts concerning the integration of models to their instructions. This finding further supported the apparent intention-implementation gap. Thus, it was obvious that they were in need of support in terms of content knowledge and pedagogical content knowledge (PCK) about models (Justi & Van Driel, 2005c). More concentrated efforts, therefore, are needed to develop pre-service teachers' PCK regarding models.

In fact, pre-service science teachers' responses to interview questions demonstrated a lack of coherence in their views of the nature of models. Concerning the content knowledge they possess, for example, the findings along with the related literature clearly indicated pre-service science teachers' *fragmented* views about models. In other words, while having naïve views in some aspects of models, they had informed views on the other aspects. For instance, they displayed a "constructivist orientation" by acknowledging the presence of multiple models for the same phenomenon depending on scientists' perspective or creativity involved in the production of scientific knowledge, while at the same time they expressed so called "logical positivism" believing that models should be close to the real phenomena that they are explaining/representing (Van Driel & Verloop, 1999, p.1147). In detail, appreciating the importance of subjectivity, social and cultural context, and creativity involved in the development of scientific models, as well as recognizing the multiplicity of methodologies in explaining same scientific phenomena and being certain that a model cannot be an exact copy of the real thing, the PSTs possessed informed views about the nature of scientific knowledge, and thus models (See Table 4.3). We can infer from the findings that, holding informed views of many aspects of NOS (i.e., subjective, social-cultural, creative-imaginative, tentative and empirical nature) most probably helped PSTs gain a better understanding about the nature of models, as well as realize the relation between the model and the real thing. For instance, the findings demonstrated that dynamic nature of scientific models was mentioned by all of the PSTs in our study (See Table 4.3). They thought that scientists change models in the light of new evidence, and in response to new developments in technology. They also recognized that models can be changed if they have limitations by means of not being accurate anymore and having deficiency in explaining the phenomenon.

Concerning the relation between the model and the real thing, on the other hand, the PSTs believed that a direct relation between a model and the real phenomenon is impossible due to the unavailable nature of the real phenomenon (such as atoms, black hole) and the creativity involved in the construction of models. Depending on this knowledge, they concluded that a photograph (such as a photograph of DNA) could not be labelled as a model. Supporting this finding, a prior study by Van Der Valk et al., (2007) reported that a photograph or a spectrum is not considered as a scientific model, since they do not exist independently of the target although being very helpful in obtaining information about the target. These promising findings might be mainly attributed to the education that PSTs took at the university, where nature of scientific knowledge was integrated in many of the courses offered by the program they are enrolled in. Most of the courses such as methods, school experience and laboratory courses were further enriched by activities related to NOS. Current findings are quite encouraging when compared with earlier studies reported in the literature (i.e., Akerson, Khalick & Lederman, 2000; Berber & Güzel, 2009; Van Driel & Verloop, 1999). For example, most of the undergraduates and graduates in Akerson, Khalick and Lederman's (2000) study did not demonstrate adequate understandings of the role of human inference, imagination, and creativity in the development of scientific knowledge. As the researchers stated, although the participants indicated that scientists use creativity in their work, they did not seem to recognize the role of imagination and creativity in constructing scientific models and theories. Their participants used the term 'creativity' to refer to scientists' ability to come up with good designs, rather than to indicate that science involves the invention of theories and explanations. In another study by Van Driel and Verloop (1999), most of the teachers were found to be aware of the existence of multiple models for the same phenomenon and considered creativity as the major factor in the development of models, yet they classified photographs as models (63%). Studying with pre-service science and mathematics teachers, Berber and Güzel (2009) reported that, 34% of the participants believed that models do not change since models are based on facts and facts do not change, or models are designed so as not to change. Berber and Güzel suggested that history of science should be integrated in courses and students should be given the opportunity to build and test their own models. We agree with Berber and Güzel's suggestion that not only history of science but also nature of scientific knowledge should become integrated part of science courses as *contextualized (integrated)* applications. In other words, nature of model should not be presented implicitly; rather, integrated or embedded in modeling activities (like developing models), or should be taught by re-constructing some historical contexts in the classroom (like revisiting the development of atomic models by referring to the tentative and inferential nature of models, and the role of subjectivity and creativity in the development of scientific models). Specifically, science teaching should be enriched by the use of scientific models, especially for the processes that are inaccessible for direct observation (Dolphin, 2009). A promising outcome of the integrated NOS instruction was reported in a recent study by Wahbeh and Abd-El-Khalick (2013) which assessed the influence of such an intervention on in-service science teachers' NOS understandings. It was reported that the integrated NOS course was effective in helping teachers develop informed NOS conceptions, including nature of models. For instance, although the teachers previously held the notion that 'scientists are certain about the structure of the atom and they do experiments to show it', after the intervention they realized that 'scientists construct models to explain scientific concepts especially in those cases where they can't make experiments'. Moreover, after the intervention they defined models as 'reliable explanations' where imagination and creativity play important roles in their construction, although they previously considered models as realities.

Contrary to the constructivist views, most of the PSTs in our study also displayed '*logical positivist*' ideas by stating that models should be close to the real things (Van Driel & Verloop, 1999; see Table 4.1)) rather than recognizing that their closeness to real things should just include important points about how the object works (Gobert & Discenna, 1997). Science involves the invention of explanations and theoretical entities, such as atoms and species which are functional theoretical models rather than faithful copies of reality (Lederman, Abd-El-Khalick, Bell & Schwartz, 2002). However, since scientific models are idealized structures that are constructed for the purpose of developing and testing ideas rather than aiding as copies of reality (Grosslight et al., 1991), it is likely to confuse a model with the real thing. In fact, model's being an exact copy of the real thing is a naïve understanding that *students* usually hold (Chittleborough et al., 2005; Grosslight et al., 1991; Harrison & Treagust, 2000a; Treagust et al., 2002; Van Driel & Verloop, 1999). For example, a cross-age study conducted by Harrison and Treagust's (1996) reported that, students spanning grades 8 to 10 believed that models of atoms and molecules represent the actual external shape, structure and colors of the atoms and molecules. However, it was also reported in the literature that with increasing age and experience, such realist model understandings are diminished and more sound understandings of scientific models are developed (Chittleborough et al., 2005; Crawford & Cullin, 2004; Grosslight et al., 1991). In Crawford and Cullin's (2004) study, none of the pre-service science teachers believed in the presence of one-to-one correspondence between a model and the real thing. Similarly, in our study, almost all PSTs were certain that a model cannot be an exact copy of the real thing; however, they thought that a model should be as close to the real thing as possible. Some of the PSTs also thought that it is better for a model to include every detail/element of the real thing. It was interesting to note that, while they realized the inaccessible nature of the real thing (by describing models as explanations or representations of scientific phenomena which are inaccessible/ unobservable by their nature), the PSTs supported the idea that a model should be close to the real thing. From this finding, one may easily conclude that the PSTs did not embrace a purely epistemological view yet held mixed views and inconsistent understandings about models, since neither the curriculum nor the textbooks do not specifically clarify and concentrate on the concept of models, and students as well as teachers rarely find the chance to build clear ideas about nature of models. The national science education curriculum in Turkey started to adopt constructivist approaches in the 2005–2006 academic year (after being piloted in 2004-2005 academic year), and the main aim of the new curriculum was to prepare students to be scientifically literate citizens (MoNE, 2005) by putting emphasis on the aspects of science, scientists and nature of science. The PSTs in our study, however, experienced the previous curriculum which embraced traditional approach that included teacher-centered instruction (both in elementary and high schools). Teachers implemented direct instruction and they were to cover all the concepts in the heavily loaded curricula. Further, Turkish teachers are under the pressure to prepare students for high school/university entrance examinations while they are also to teach the regular curricula. That is, there is an exam-oriented educational system in Turkey. In such classroom environments, however, students hardly find an opportunity to use or develop models which would actually result in a better understanding of models. Findings of our study are promising in some aspects but are also compatible in other aspects related to the relation between models and the related scientific phenomena. None of the PSTs in our study believed that models are exact copies of real phenomena but such understandings are common in the literature. For instance, although majority of the pre-service teachers in Berber and Güzel's (2009) study defined models as representations of scientific phenomena, a considerable number (15%) defined them as exact copies of the real thing. In a recent study, as Aslan and Taşar (2013) reported, the view that scientific models are the copies of the reality is the one mostly supported (64.9%) view shared by the science teachers. Majority of the teachers (more than 66%) in Dogan and Khalick' (2008) study, on the other hand, believed scientific models to be copies of reality since scientists say they (models) are true or because much scientific observations and/or research have shown them to be true. Similarly, the PSTs in Erdoğan's (2004) study held a naïve view of the nature of scientific models by believing that scientific models are copies of reality rather than human inventions. By using Views on Science-Technology-Society (VOSTS) instrument, those PSTs were asked to indicate their position to the statement of 'many scientific models used in research laboratories (such as the model of heat, the neuron, DNA, or the atom) are copies of reality', and 47.2% of them held "naïve realist" views by indicating their agreement with that idea and saying that 'scientists say models are true, so models must be true'; 'much scientific evidence has proven models true'; and 'models are true to life, their purpose is to show us reality or teach us something about it'. About 21.8%, on the other hand, found to believe that models come close to being copies of reality because they are based on scientific observations and research. Author claimed that these participants did not embrace a purely epistemological viewpoint, yet vestiges of ontological thinking (naive realism) remained. Only 30.9% of the participants in Erdoğan's study described models as not being copies of reality by stating that 'models are simply helpful for learning and explaining, within their limitations'; 'they change with time and with the state of our knowledge, like theories do' and 'these models must be ideas or educational guesses, since you can't actually see the real thing'. Besides the understandings about models as exact copies of real phenomena, regarding the closeness of a model to the real thing, findings similar to ours are reported in the literature. Güneş, Gülçiçek and Bağcı (2004), for instance, reported that 36 percent of the university instructors supported the idea that a model should resemble to the real thing. In Van Driel and Verloop's (1999) study, some teachers also stated that a model needs to be as close to the real thing as possible. Justi and Gilbert (2002b), on the other hand, reported that the teachers in their study also claimed the necessity of a degree of similarity between the model and the real phenomenon. The teachers in that study also thought that it is desirable for a model to be complete as possible and represent all facets of the phenomenon.

Another important outcome of this study is that, PSTs generally conceptualized models' *materialistic uses*, yet they did not think much about their theoretical and *conceptual* uses (See Table 4.2). This finding provides further evidence for their *fragmented* views about models. Although some of the PSTs in our study realized models' role in describing and explaining scientific phenomena and thus referred to models' conceptual uses, it was observed that roles like reifying and visualizing were overestimated and models were dominantly characterized as visual and three-dimensional representations or *materialistic objects* (although they can be in visual, verbal, concrete and mathematical forms). To illustrate, although some accepted representations like chemical formulae (i.e., CO_2) and drawings as models, most of the PSTs in our study favored materialistic models and believed that they are the *real* models. These PSTs believed that "pedagogical analogical models" (Harrison & Treagust, 2000b) like ball-and-stick models of molecules are more likely to be models than chemical formulae since ball-and-stick models represent the structure of the molecules. Such models (ball-and-stick models as well as the chemical formulae) are actually explanatory and communicative aids that are developed for/by teachers for the purpose of making unobservable entities like atoms and molecules accessible to students (Harrison & Treagust, 2000b). PSTs' materialistic views of models are possibly stemmed from their previous experiences with the use of the term ‘model’, more specifically, from their early science education and daily life experiences. As a matter of fact, it is inevitable that their prior experiences with models potentially influence their understandings of models. Teachers, usually show limited understandings of models and use them ineffectively in their instructions. As research reported, there are links between the way textbooks use models and the way teachers teach with models (Harrison, 2001), but textbooks do not clearly discuss models by usually presenting scientific concepts episodically without relating them to one another in the context of appropriate models (Halloun, 2007). Textbooks usually identify physical representations like DNA or atom models as ‘models’ yet rarely use the term model for other types of models which would result in the false impression that atom models are the only scientific ‘models’ (Halloun, 2007). In other words, the more abstract forms of models such as graphs, tables and equations, which are the preference in professional scientific publications, were rarely used (Roth, Bowen & McGinn, 1999, as cited in Al-Balushi, 2011) and labeled as ‘models’ in science textbooks. In fact, textbooks are influential in shaping model understandings that, when students were asked what color atoms were, their answer was closely linked to the textbook in use by those students (McComas, 1998). That is, if the book illustrated atoms as blue, then blue was the color students would assign to atoms (McComas, 1998). Research has shown that conceptualizing models as ‘materialistic objects’ is a common understanding (Aktan, 2005; Gilbert, 1991; Gülçiçek & Bağcı, 2004; Justi & Gilbert, 2003, Schwartz & Skjold, 2012) but overestimating the roles like ‘reifying’ or ‘visualizing’ while underestimating some important roles like predicting or obtaining information is seldom reported in the literature. In Aktan’s (2005) study, for example, the PSTs favored three-dimensional models, and referred to physical objects and schematic representations as models. Similar findings were reported by Justi and Gilbert (2003) where slightly more than half (59%) of the teachers considered models as 3-D objects. Among the model examples that university instructors mostly mentioned in Güneş, Gülçiçek and Bağcı’s (2004) study were scale models (i.e., mock ups) and theoretical models (i.e., atom models). In a more recent study by Schwartz and Skjold’s (2012), pre-service teachers considered models as physical representations of phenomena, by describing models as visible, and the role of models as to make something that cannot normally be seen, visible. Marquez, Izquierdo and Espinet (2006) stated that, in science education there is a shift from “monomodal view of communication” which is based on verbal language, to a “multimodal view of communication” that covers interactions of different communicative modes. As the researchers reported, on the other hand, teachers often use verbal language, written texts or visual representations on the blackboard during their instructions as predominant modes of communication. However, the use different communicative modes would play significant roles in the classroom practice (Marquez et al., 2006). In line with Marquez and his colleagues' views, we suggest that use of models in science education should be encouraged since models provide a variety of modes including physical (like three-dimensional models), visual (like pictures, diagrams or maps), symbolical (like equations or formulae), or verbal (like oral descriptions) models (Gilbert, Boulter & Rutherford, 1998). Depending on the scientific concept taught, the appropriate form of models may be integrated into the science classes. Use of multiple forms of models would both support student learning and their views about roles and characteristics of models.

The findings of the present study further demonstrated that although having fragmented views of models, PSTs valued models as important parts of science education and indicated their intention to use models in their instructions. However, although use of models in science teaching was praised in theory, it was not widely practiced in their instructions. Interestingly, eventhough PSTs agreed that they were planning to use the physical models (like model of solar system) in their teaching practices; classroom observations showed that none of them used any physical models during their instructions. Moreover, although they mentioned in the interviews that they would use all possible models and would develop models they would not find any, classroom observations indicated that their use of models was limited to drawings-graphics-tables, simulations, and concept maps (See Table 4.6). In their instructions, the PSTs usually represented the concepts through drawings, tables or graphics on the blackboard, and occasionally showed simulations/animations to represent the effects of manipulations on the scientific phenomena which cannot be observed by naked eye, or constructed concept maps to summarize the the topics taught by indicating the relationships among concepts with the help of short linking words. One possible reason for the non-use of physical models may be the difficulty of developing such models. Since they did not take any education/training on developing models, it could be a difficult task for them to develop models for their instructions. Most probably, due to the fact that such models are difficult to construct, they did not intend to construct any model, instead, preferred to use mainly drawing, graphics and tables which are practical and easy to construct. Another interesting point related to PSTs' use of models in their instructions was that although they used models like animations, concept maps, or graphs in their teaching practices, the PSTs did not call these models as 'models' in their lesson plans or instructions.

Overall, these findings verify the previously mentioned assertion that PSTs needed further education in terms of *pedagogical content knowledge (PCK)* about models (Justi & Van Driel, 2005c) for succesfully using, and engaging their students in scientific modelling (Davis, Nelson, & Beyer, 2008). Schwarz and White (2005) call the understandings about the nature and purposes of scientific models and modeling practice as “metamodeling knowledge”. PCK for the use of models requires meaningful integration of teachers’ metamodeling knowledge, their knowledge of instructional strategies that can promote students' engagement in modeling practices, and their knowledge of students' ideas and challenges associated with scientific modeling (Davis, Nelson, & Beyer, 2008). By stressing ‘reifying’ and ‘visualizing’ as roles of models, it is obvious that the PSTs in our study held less sophisticated metamodeling knowledge. Their limited use of models during instruction and not recognizing that they were using models, on the other hand, revealed that they did not possess required knowledge of models as pedagogical tools. These PSTs, as beginning teachers, must develop sound understandings of models, and learn how to apply these understandings for pedagogical purposes (Justi & Van Driel, 2005; Kenyon, Davis, & Hug, 2011; Windschitl, 2003; Windschitl & Thompson, 2006). In other words, besides understanding models themselves, PSTs should also learn to effectively use them in classroom practices and help students develop sound understandings about models. The recognition about models would obviously result in better use of them, since teachers’ use can improve students’ understanding in the development of scientific ideas and the development of a better understanding of the particular content area (Treagust et al., 2002). Teachers should help students not only conceptually understand the scientific content, but also help them see how models can be useful in developing and enhancing their own science content understandings (Nelson & Davis, 2012). One of the possibilities for pre-service teachers to develop such higher-order PCK for models can be carefully designed methods courses (Nelson & Davis, 2012). Although not being the single choice, adding an emphasis on scientific models in such courses would support novice teachers in becoming well-started beginning science teachers (Nelson & Davis, 2012). Such courses may provide rich opportunities for them to engage in multiple authentic scientific practices themselves, and to develop proficiency in engaging their students in those same scientific practices (Nelson & Davis, 2012). To be brief, such applications should be beneficial for pre-service teachers not for only to gain the adequate understanding of models but also provide with assistance in how to use or entegrate models to their instructions.

It is hoped that current study might provide insights for further investigation of pre-service science teachers' understanding model and their classroom practices.

5.2. Recommendations for Future Research

PSTs' understandings of scientific models and their perceptions about use of models in science education were investigated in this study. However, further studies into conceptions of models could make a valuable contribution to science education. As an extention of this study, for example, it would be desirable to investigate PSTs' understandings of models with higher number of participants since the number of participants in this study was limited to fourteen senior PSTs. Moreover, PSTs may be given much more opportunity to teach in classroom settings in order to better examine their practices with models since the observations of the teaching practices for each PST was limited to one class hour.

During their teaching practices, it was observed that the PSTs did not effectively entegrate models in their teaching practices, although they showed strong willingness towards the use of them. In other words, the PSTs did not really use models in their instructions the way they claimed in the interviews and they did not let their students build their own models. Thus, in addition to pre-interviews, after their classroom practices, post-interviews can be conducted with PSTs to shed light on the reasons of use or non-use of models. The underlying causes for not using models (e.g., low self-efficacy) and for not letting students construct their own models may be the purpose of a further research. The obstacles about the non-use of models can thereby be investigated.

Moreover, how PSTs/teachers select the models that they use in class is also unclear. It is reported in the literature that there are links between the way textbooks use models and the way teachers teach with models (Harrison, 2001). Further research, therefore, may also include the examination of the textbook models (in Turkey) together with the interviews conducted with teachers and the observations of their classroom teaching. Additionally, the sources of models they preffered to use may also be questioned in the interviews.

The data obtained in this study did not allow categorizing PSTs as naïve or sophisticated modelers due to the homogeneous nature of the group sharing a similar educational background. A further study, therefore, can be conducted with a heterogeneous group to identify the differences between naïve and sophisticated views about models.

The researcher of the study looked for possible patterns between PSTs' understandings of models and model use in science teaching; however, no pattern was observed. In a further study, therefore, it should also be questioned whether possible patterns between understandings of models and model use exist. Through examining the related literature and employing the related analyses, possible patterns may be investigated.

How the PSTs develop understandings of models might be another concern for future research. In this study, it was observed that some of the PSTs referred to the historical development of some models, like models of atom, to reflect their understandings. Therefore, it may be concluded that such examples are influential in framing their understandings. A further exploration of possible reasons for the development of understandings of models would also be beneficial as a further study.

During the interviews, no feedback is given in response to participants' statements and reflections. However, it was observed that they looked for some feedback from the researcher to shape their understanding and state a clearer response. Therefore, as a future research, the participants can be given feedback, and the development of their understandings of models can be examined accordingly.

Finally, enhancing model understanding should also be part of science teacher education programs. Therefore, examining the alternatives offered by the researchers to enhance model understanding, and investigating their effectiveness in longitudinal studies may also be beneficial. The outcomes of learning with model applications and modeling instructions would be helpful in improving PSTs' understandings of models.

REFERENCES

Abd-El-Khalick, F., Lederman, N. G., Bell, R. L., & Schwartz, R. S. (2001). Views of nature of science questionnaire (VNOS): Toward valid and meaningful assessment of learners' conceptions of nature of science. In P. Rubba, J. Rye, W. DiBiase, & B. Crawford (Eds.), Proceedings of the 2001 Annual International Conference of the Association for the Education of Teachers in Science (pp. 212-277). Pensacola, FL: Association for the Education of Teachers in Science.

Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching, 37*(4), 295-317.

Al-Balushi, S. M. (2011). Students' evaluation of the credibility of scientific models that represent natural entities and phenomena. *International Journal of Science and Mathematics Education, 9,* 571-601.

Aktan M. B. (2005). Investigation of prospective teachers' knowledge and understanding of models and modeling and their attitudes towards the use of models in science education. Unpublished doctoral dissertation, Purdue University, Indiana.

AAAS. (1990). *Science for all Americans.* New York: Oxford University Press.

Apaydın, Z., Çobanoğlu, E.O., & Taşkın, Ö. (2006). Evrim öğretimi için model önerisi: Soyağacı, hat modeli ve el modeli oluşturma. *Ondokuz Mayıs Üniversitesi Eğitim Fakültesi Dergisi, 22,* 95-108.

Aslan, O. & Taşar, M. F. (2013). How do science teachers view and teach the nature of science? A classroom investigation. *Education and Science, 38*(167), 65-80.

Bent, H. (1984). Uses (and abuses) of models in teaching chemistry. *Journal of Chemical Education, 61*, 774-777.

Ben-Zvi, N., & Genut, S. (1998). Uses and limitations of scientific models: the Periodic Table as an inductive tool. *International Journal of Science Education, 20*(3), 351-360.

Berber, N. C., & Güzel, H. (2009). Fen ve matematik öğretmen adaylarının modellerin bilim ve fendeki rolüne ve amacına ilişkin algıları. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi, 21,* 87-97.

Bokulich, A. (2011). How scientific models can explain. *Synthese, 180*, 33-45.

Byrne, J. (2011). Models of micro-organisms: Children's knowledge and understanding of micro-organisms from 7 to 14 years old. *International Journal of Science Education*, *33*(14), 1927-1961.

Cartier, J. (2000). Using a modeling approach to explore scientific epistemology with high school biology students. Research Report. University of Wisconsin–Madison, Report No. 99-1. National Center for Improving Student Learning and Achievement in Mathematics and Science.

Cartier, J., Rudolph, J., & Steward, J. (2001), The nature and structure of scientific models, *The National Center for Improving Student Learning and Achievement in Mathematics and Science (NCISLA).*

Cartier, J. L., Stewart, J., & Zoellner, B. (2006). Modeling and inquiry in a high school genetics class. *The American Biology Teacher, 68*(6), 334-340.

Chittleborough, G. D. (2004). The role of teaching models and chemical representations in developing students' mental models of chemical phenomena. Unpublished doctoral dissertation, Curtin University of Technology, Australia.

Chittleborough, G. D., Treagust, D. F., Mamiala, T. L., & Mocerino, M. (2005). Students' perceptions of the role of models in the process of science and in the process of learning. *Research in Science and Technological Education, 23*(2), 195-212.

Christofilis, T., & Kousathana, M. (2005). Models in science teaching. Paper presented at International History, Philosophy, Sociology and Science Teaching Conference, Leeds, England.

Coll, R. K. (2006). The role of models, mental models and analogies in chemistry teaching. In Aubusson, P. J., Harrison, A. G. & Ritchie, S. M., *Metaphor and Analogy in Science Education.* Science and Technology Education Library (30), 65-77.

Coll, R. K., France, B., & Taylor, I. (2005). The role of models/and analogies in science education: implications from research. *International Journal of Science Education, 27*(2), 183-198.

Coll, R. K., & Treagust, D. F. (2003). Investigation of secondary school, undergraduate, and graduate learners' mental models of ionic bonding. *Journal of Research in Science Teaching, 40*(5), 464-486.

Cook, M. P. (2006). Visual representations in science education: the influence of prior knowledge and cognitive load theory on instructional design principles. *Science Education, 90*, 1073-1091.

Crawford, B. A., & Cullin, M. J. (2004). Supporting prospective teachers' conceptions of modeling in science. *International Journal of Science Education, 26*(11), 1379-1401.

Crawford, B. A., & Cullin, M. J. (2005). Dynamic assessment of preservice teachers' knowledge of models and modeling. In Boersma, K., Goedhart, M., de Jong, O. & Eijkelhof, H. Research and Quality of Science Education, 309-323.

Cresswell, J. W. (2007). *Qualitative inquiry and research design: Choosing among five traditions* (2nd ed.). Thousand Oaks, CA: Sage.

Cullin, M., & Crawford, B. A. (2003). Using technology to support prospective science teachers in learning and teaching about scientific models. *Contemporary Issues in Technology and Teacher Education*, *2*(4), 409-426.

Danusso, L., Testa, I., & Vicentini, M. (2010). Improving prospective teachers' knowledge about scientific models and modeling: Design and evaluation of a teacher education intervention. *International Journal of Science Education, 32*(7), 871-905.

Davis, E. A., Kenyon, L., Hug, B., Nelson, M., Beyer, C., Schwarz, C., & Reiser, B. J. (2008). MoDeLS: Designing supports for teachers using scientific modeling. Paper presented at the Association for Science Teacher Education, St. Louis, MO, January, 2008.

Davis, E. A., Nelson, M., Hug, B., Kenyon, L., Cotterman, B., Teo, T. W., & Reiser, B. J. (2010). Preservice teachers and scientific modeling: Synthesizing results of a multi-year, multi-site Project. Paper presented at the Association for Science Teacher Education, Sacramento, CA, January, 2010.

Davis, E. A., Nelson, M. & Beyer, C. (2008). Using educative curriculum materials to support teachers in developing pedagogical content knowledge for scientific modeling. Proceedings of the 2008 Annual Meeting of the National Association for Research in Science Teaching (NARST), Baltimore, MD

Davies, T., & Gilbert, J. (2003). Modeling: Promoting creativity while forging links between science education and design and technology education. *Canadian Journal of Science, Mathematics and Technology Education, 3*(1), 67-82.

Dogan, N. & Abd-El-Khalick, F. (2008). Turkish grade 10 students' and science teachers' conceptions of nature of science: A national study. *Journal of Research in Science Teaching, 40*(10), 1083-1112.

Dolphin, G. (2009). Evolution of the theory of the earth: A contextualized approach for teaching the history of the theory of plate tectonics to ninth grade students. *Science and Education, 18*, 425-441.

Erdoğan, R. (2004). Investigation of the preservice science teachers' views on nature of science. Unpublished master's thesis, Middle East Technical University, Ankara.

Etkina, E., Warren, A., & Gentile, M. (2006). The role of models in physics instruction. *The Physics Teacher, 44(*1), 34-39.

Falcao, D., Colinvaux, D., Krapas, S., Querioz, G., Alves, F., Cazelli, S., Valente, M. E., & Gouvea, G. (2004). A model-based approach to science exhibition evaluation: a case study in Brazilian astronomy museum, *International Journal of Science Education*, *26*(8), 951-978.

Fredericksen, J. R., White, B., & Gutwill, J. (1999). Dynamic mental models in learning science: the importance of constructing derivational linkages among models. *Journal of Research in Science Teaching, 36*(7), 806-836.

Frigg, R. (2002). Models and representation: why structures are not enough. *Measurement in Physics and Economics Project Discussion Paper Series*, DP MEAS 25/02, London School of Economics.

Frigg, R., & Hartmann, S. (2005). Scientific Models. In Sarkar, S. and Pfeifer, J. (Eds.), *The Philosophy of Science: An Encyclopedia, Vol. 2*. (pp.740-749) Routledge, New York. USA.

Giere, R. N. (1988). *Explaining science: a cognitive approach.* Chicago University Press, Chicago.

Giere, R. N. (2004). How models are used to represent reality. *Philosophy of Science*, *71*(5), 742-752.

Gilbert, S.W. (1991). Model building and a definition of science. *Journal of Research in Science Teaching, 28*(1), 73-79.

Gilbert, J. K. (Ed.). (1993). *Models and modeling in science education*. Hatfield, Herts: Association for Science Education.

Gilbert, J. K. (2004). Models and modeling: routes to more authentic science education. *International Journal of Science and Mathematics Education, 2*, 115-130.

Gilbert, J. K., Boulter, C., & Rutherford, M. (1998). Models in explanations, part 1: Horses for courses? *International Journal of Science Education, 20*(1), 83-97.

Gilbert, J. K., Boulter, C. J., & Rutherford, M. (2000). Explanations with models in science education. In Gilbert, J.K. & Boulter, C.J. (Eds.), Developing models in science education (pp. 193–208). Dordrecht, The Netherlands: Kluwer.

Gobert, J. D., & Buckley, B. C. (2000). Introduction to model-based teaching and learning in science education, *International Journal of Science Education*, *22*(9), 891-894.

Gobert, J., & Discenna, J. (1997). The relationship between students' epistemologies and model-based reasoning. Paper presented at the Annual Meeting of the American Educational Research Association, Chicago.

Gobert, J. D., O' Dwyer, L., Horwitz, P., Buckley, B. C., Tal Levy, S., & Wilensky, U. (2010). Examining the relationship between students' understanding of the nature of models and conceptual learning in biology, physics, and chemistry. *International Journal of Science Education, (iFirst)*, 1-32.

Godfrey-Smith, P. (2006). The strategy of model-based science. *Biology and Philosophy, 21*, 725-740.

Grosslight, L., Unger, C., Jay, E., & Smith, C. L. (1991). Understanding models and their use in science: conceptions of middle and high school students and experts. *Journal of Research in Science Teaching, 28*(9), 799-822.

Güneş, B., Gülçiçek, Ç., & Bağcı, N. (2004). Eğitim fakültelerindeki fen ve matematik öğretim elemanlarının model ve modelleme hakkındaki görüşlerinin incelenmesi. *Türk Fen Eğitimi Dergisi, 1*(1), 35-48.

Halloun, I. (1996). Schematic modeling for meaningful learning of physics. *Journal of Research in Science Teaching, 33*(9), 1019-1041.

Halloun, I. (1998). Schematic concepts for schematic models of the real world: the Newtonian concept of force. *Science Education, 82*, 239-263.

Halloun, I. (2007). Mediated modeling in science education. *Science & Education, 16*, 653-697.

Harrison, A. G. (2001). How do teachers and textbook writers model scientific ideas for students? *Research in Science Education, 31*(3), 401-435.

Harrison, A. G., & Treagust, D. F. (1998). Modeling in science lessons: Are there better ways to learn with models? *School Science and Mathematics*, *98*(8), 420-429.

Harrison, A. G., & Treagust, D. F. (2000a). Learning about atoms, molecules and chemical bonds: A case study of multiple-model use in grade 11 chemistry. *Science Education*, *84*, 352-381.

Harrison, A. G., & Treagust, D. F. (2000b). A typology of school science models. *International Journal of Science Education, 22*(9), 1011-1026.

Hestenes, D. (1996), Modeling methodology for physics teachers, *Proceedings of the International Conference on Undergraduate Physics Education.* College Park, August 1996.

Hitt, A. (2004). Perceptions of models in life science research and implications for science education. Unpublished doctoral dissertation, Indiana University, Indiana.

Hitt, A., White, O., & Hanson, D. (2005). Popping the kernel: Modeling the states of matter. *Science Scope 28*(4), 39-41.

Hodgson, T. (1995). Secondary mathematics modeling: Issues and challenges. *School Science and Mathematics, 95*, 351 – 358.

Justi, R. S., & Gilbert, J. K. (2000). History and philosophy of science through models: some challenges in the case of 'the atom'. *International Journal of Science Education, 22*(9), 993-1009.

Justi, R. S., & Gilbert, J. K. (2002a). Science teachers' knowledge about and attitudes towards the use of models and modeling in learning science. *International Journal of Science Education*, *24*(12), 1273-1292.

Justi, R. S., & Gilbert, J. K. (2002b). Modeling, teachers' views on the nature of modeling, and implications for the education of modelers. *International Journal of Science Education*, *24*(4), 369-387.

Justi, R. S., & Gilbert, J. K. (2003). Teachers' views on the nature of models. *International Journal of Science Education*, *25*(11), 1369-1386.

Justi, R. S., & Van Driel, J. (2005a). The development of science teachers' knowledge on models and modeling: promoting, characterizing, and understanding the process. *International Journal of Science Education*, *27*(5), 549-573.

Justi, R. S., & Van Driel, J. (2005b). A case study of the development of a beginning chemistry teacher's knowledge about models and modeling. *Research in Science Education*, *35*, 197-219.

Justi, R. S., & Van Driel, J. (2005c). Developing science teachers' knowledge on models and modeling. In Beijaard, D., Meijer, P. C., Morine-Dershimer, G. & Tillema, H. (Eds.), Teacher Professional Development in Changing Conditions, (pp. 165-180). Dordrecht, The Netherlands: Kluwer.

Kenyon, L., Davis, E. A. & Hug, B. (2011). Design approaches to support preservice teachers in scientific modeling. *Journal of Science Teacher Education, 22*, 1-21.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching, 29*, 331–359.

Lederman, N. G., Abd-El-Khalick, F., Bell, R. L., & Schwartz, R. S. (2002). Views of nature of science questionaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.

Loper, S. J. (2005). Struggles with learning about scientific models in a middle school science classroom**.** Unpublished doctoral dissertation, University of California, Berkeley.

Marquez, C., Izquierdo, M., & Espinet, M. (2006). Multimodal science teachers' discourse in modeling the water cycle. *Science and Education, 90*, 202–226.

Mashhadi, A. (1999). Enhancing students' understanding of the nature of science. *Teaching and Learning, 19*(2), 84-89.

McComas, W. F. (1998). The principal elements of the nature of science: Dispelling the myths. *The nature of science in science education*. Kluwer Academic Publishers. Printed in Netherlands.

Merriam, S. B. (1998). *Qualitative research and case study applications in education (Rev. ed.)*. San Francisco: Jossey-Bass Publishers.

Merriam, S. B. (2009). *Qualitative research. A guide to design and implementation*. San Francisco: Jossey-Bass Publishers.

Merriam, S. B., & Associates (2002). *Qualitative research in practice: Examples for discussion and analysis*. San Francisco: Jossey-Bass Publishers.

Ministry of National Education (MoNE). (2005). Elementary Science and Technology Education Course Program. Ankara, Turkey: Ministry of Education.

National Research Council. (1996). *National science education standards.* Washington, DC: National Education Press.

Nelson, M. M., & Davis, E. A. (2012). Preservice elementary teachers' evaluations of elementary students' scientific models: An aspect of pedagogical content knowledge for scientific modeling. *International Journal of Science Education, 34*(12), 1931-1959.

Norman, D.A. (1983). Some observations on mental models. In D. Gentner & A.L. Stevens (Eds.), *Mental Models* (pp. 7-14). Hillsdale, NJ: Lawrence Erlbaum Publishers.

Patton, M. Q. (2002). *Qualitative evaluation and research methods* (3rd ed.). Thousand Oaks, CA: Sage Publications, Inc.

Petridou, E., Psillos, D., Hatzikraniotis, E., & Viiri, J. (2009). Design and development of a microscopic model for polarization. *Physics Education, 44*(6), 589-598.

Prins, G. T., Bulte, A. M. W., Van Driel, J., & Pilot, A. (2008). Selection of authentic modeling practices as contexts for chemistry education. *International Journal of Science Education*, *30*(14), 1867-1890.

Roth, W. M., Bowen, G. M., & McGinn, M. K. (1999). Differences in graph-related practices between high school biology textbooks and scientific ecology journals. *Journal of Research in Science Teaching, 36*, 977–1019.

Saari, H., & Viiri, J. (2003). A research-based teaching sequence for teaching the concept of modeling to seventh-grade students. *International Journal of Science Education, 25*(11), 1333-1352.

Sarıkaya, R., Selvi, M., & Doğan Bora, N. (2004). Mitoz ve mayoz bölünme konularının öğretiminde model kullanımının önemi. *Kastamonu Eğitim Dergisi 12*(1), 85-88.

Shwartz, Y., Rogat, A., Merritt, J., & Krajcik, J. (2007). The effect of classroom practice on students understanding of models. Paper presented at the annual meeting of the National Association of Research in Science Teaching, New Orleans, LA.

Schwartz, R. S., & Skjold, B. (2012). Teaching about scientific models in a science content course. *Educacion Quimica, 23*(4), 451-457.

Schwarz, C. V. & White, B. Y. (2005). Metamodeling knowledge: Developing students' understanding of scientific modeling. *Cognition and Instruction, 23*(2), 165-205.

Sins, P. H. M., Savelsbergh, E. R., van Joolingen, W. R., & van Hout-Wolters, B. H. A. M. (2009). The relation between students' epistemological understanding of computer models and their cognitive processing on a modeling task. *International Journal of Science Education, 31*(9), 1205-1229.

Taber, K. S. (2001). When the analogy breaks down: Modeling the atom on the solar system. *Physics Education, 36*, 222-226.

Taber, K. S. (2008). Towards a curricular model of the nature of science. *Science and Education, 17*, 179-218.

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2002). Students' understanding of the role of scientific models in learning science. *International Journal of Science Education, 24*(4), 357-368.

Treagust, D. F., Chittleborough, G., & Mamiala, T. L. (2004). Students' understanding of the descriptive and predictive nature of teaching models in organic chemistry. *Research in Science Education, 34*, 1-20.

Wahbeh, N. & Abd-El-Khalick, F. (2013). Revisiting the translation of nature of science understandings into instructional practice: Teachers' nature of science pedagogical content knowledge. *International Journal of Science Education,* DOI: 10.1080/09500693.2013.786852.

Wells, M., Hestenes, D., & Swackhamer, G. (1995). A modeling method for high school physics instruction. *American Journal of Physics*, *63*(7), 606-619.

Windschitl, M. (2003). Inquiry projects in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice*? Science Education, 87*, 112-143.

Windschitl, M. & Thompson, J. (2006). Transcending simple forms of school science investigation: The impact of preservice instruction on teachers' understandings of model-based inquiry. *American Educational Research Journal, 43*(4), 783-835.

Valanides, N., & Angeli, C. (2008). Learning and teaching about scientific models with a computer-modeling tool. *Computers in Human Behavior*, *24*, 220-233.

Van Der Valk, T., Van Driel, J. H., & De Vos, W. (2007). Common characteristics of models in present-day scientific practice. *Research in Science Education*, *37*, 469-488.

Van Driel, J. H., & Verloop, N. (1999). Teachers' knowledge of models and modeling in science. *International Journal of Science Education*, *21*(11), 1141-1153.

Van Driel, J. H., & Verloop, N. (2002). Experienced teachers' knowledge of teaching and learning of models and modeling in science education. *International Journal of Science Education*, *24*(12), 1255-1272.

Yager, R. E. (1991). The constructivist learning model: Towards real reform in science education. *The Science Teacher*, *58*(6), 52-57.

APPENDICES

APPENDIX A

BİLİMDE MODELLER VE MODELLEME HAKKINDAKİ GÖRÜŞLERİM

Bu ankette bilimde modeller ve modelleme hakkındaki düşüncelerinize yönelik ifadeler olacaktır. Size uyan iki seçenekten birini tercih ediniz ve verilen boşluğa neden o seçeneği seçtiğinize dair bir açıklama yazınız.

1- Bilimde modeller ve modelleme bilimin anlaşılması açısından önemlidir. Modeller:

a) düşüncelerin ya da nesnelerin nasıl çalıştığını gösterir.

b) gerçeğin tam bir kopyasıdır.

Açıklama: -

____

____

____

____

____

____

2- Bilimsel düşünceler;

a) sadece bir modelle açıklanır, başka bir modelle açıklamak yanlış olur.

b) bir modelle açıklanır ancak başka modeller de kullanılabilir.

Açıklama: -

____

____

____

____

____

____

3- Bilim adamları modelleri ve modellemeyi kullanarak bir bilimsel olguyu açıklarken,

a) sadece bir model kullanabilirler.

b) birçok model kullanabilirler.

Açıklama: -

____

____

____

____

____

____

4- Yeni bir bilimsel teori için yeni bir model önerildiğinde, bilim adamları bu modeli kabul edip etmeyeceklerine karar verirler. Bu kararları;

a) modeli ve teoriyi destekleyen gerçeklere bağlıdır.

b) kişisel duygu ve düşüncelerinden etkilenir.

Açıklama: -

____
____
____
____
____
____

5- Yeni bir bilimsel modelin kabulü;

a) birçok bilim adamı tarafından desteklenmesini gerektirir.

b) açıklaması gereken şeyi en iyi şekilde açıklarsa olur.

Açıklama: -

____
____
____
____
____
____

6- Bilimsel modeller, birçok bilim adamının bilimsel bir olguyu anlamaya yönelik, uzun zaman alan çalışmaları sonunda oluşturulur. Bu yüzden bilimsel modeller;

a) gelecek yıllarda değişmez.

b) gelecek yıllarda değişebilir.

Açıklama: -

APPENDIX B

GÖRÜŞME SORULARI

Araştırma sorusu: Öğretmen adayları, bilimde ve fen eğitiminde kullanılan modeller hakkında ne gibi anlayışlara sahiptirler?

Tarih: ...../...../........ **Saat** (Başlangıç/Bitiş): ..../...........

Giriş:

Merhaba. Adım Ayşe Yenilmez Türkoğlu. Orta Doğu Teknik Üniversitesi Eğitim Fakültesi İlköğretim Bölümünde hem Doktora öğrencisi hem de aynı anabilim dalında araştırma görevlisiyim. Öğretmen adaylarının modeller hakkındaki fikirleri konusunda bir araştırma yapmaktayım. Bu konudaki anlayışları belirlemede sizin görüşlerinizin de önemli olduğunu düşünüyorum. Katkılarınız için şimdiden teşekkür ediyorum.

Görüşmemize geçmeden önce, görüşmemizin gizli olduğunu ve görüşmede konuşulanları yalnızca benim ve bazı araştırmacıların bileceğini belirtmek isterim. Bunun yanında araştırma raporunda isimleriniz kesinlikle yer almayacak, bunun yerine takma isimler kullanılacak yada isimleriniz şifrelenecektir.

Görüşmemize başlamadan önce sormak istediğiniz soru yada belirtmek istediğiniz herhangi bir düşünceniz var mı?

Konuşmalarımızın kaydedilmesi konusunda ne düşünüyorsunuz? Görüşme sonunda istemediğiniz bazı bilgileri silebiliriz.

Görüşmeye devam etmek istiyor musunuz?

Görüşmemizin yaklaşık yarım saat süreceğini tahmin ediyorum. İzin verirseniz sorulara başlamak istiyorum.

SORULAR:

1. Model kelimesini duyduğunuzda aklınıza neler geliyor?
   Örnek verebilir misiniz?
   Modeli bilmeyen birisine modeli nasıl açıklarsınız?
2. Sizce modeller ne için oluşturulmuşlardır?
   Amacı nedir?
   Modellerle neler yapabiliriz?
3. Sizce verilen şu örnekler model midir? (mankenler, oyuncak araba, beğenilen kişiler, CO_2 kimyasal formülü, DNA sarmalı –kendisi, resmi, fotografı-, evrim teorisi)
   Sizce bu verilen örnekler bilim alanında kullanılıyor mu?
   Bilimsel model nedir?

Hangi özellikleri bir modeli bilimsel model yapar?

5. Bilimde modellerin kullanılmasının amacı nedir?
6. Bir model oluştururken nelere dikkat edilmelidir?

   Neleri aklmızdan çıkarmamamız gerekiyor?

   Nelerin önemli olduğunu nerden biliyorsunuz?

   Modeli çıkardığımız şeyle model arasında nasıl bir ilişki olmalı?
7. Sizce bilim adamları aynı şey için birden fazla model oluşturmuşlar mıdır? Yada oluşturabilirler mi?
8. Bir bilim adamı bir modeli değiştirebilir mi?

   Nasıl değiştirir?

   Örnek verebilir misiniz?
9. Fen bilgisi eğitiminde modeller kullanılıyor mu/kullanılabilir mi?

   Fen bilgisi derslerinde modellerin kullanılması neden önemlidir?

   Sizce eğitimde kullanılan modeller bilimde kullanılan modellerden farklı mıdır/farklı olmalı mıdır? Neden?

   Sizce, eğitim/ öğretim amaçlı kullanılan iyi bir model ne gibi özelliklere sahip olmalıdır?
10. Modellerin değişik çeşitleri var mıdır?

    Çeşitlilik neye göre değişir?

    Ne gibi özellikleri bir modeli diğerlerinden farklı kılar?
11. Model sayesinde daha rahat anlayabildiğiniz bilimsel kavramlar var mı? Bir tanesini anlatabilir misiniz?
12. Modellere kimler ihtiyaç duyar?

13. Kimler model geliştirebilir?

    Siz hiç geliştirdiniz mi?

14. Derslerinizde hangi tür modelleri kullanmayı düşünürsünüz?

    Sizce kullanacağınız bu modeller etkili mi / yeterli mi?

    Derslerinizde kullanacağınız hangi modelleri daha faydalı/ kullanışlı/ gerekli buluyorsunuz?

15. Derslerinizde kullanacağınız modeller geliştirilebilir mi?

    Geliştirilebileceğini düşünüyorsanız, nasıl?

    Sizden bir modeli geliştirmeniz istense nasıl yapardınız? Neleri göz önünde bulundururdunuz?

APPENDIX C

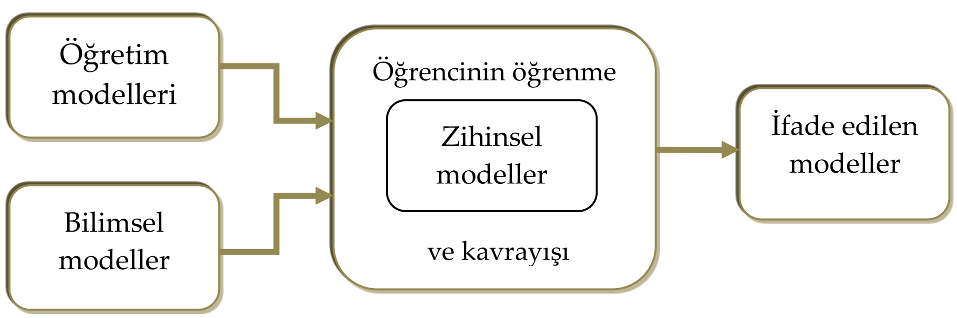
TURKISH SUMMARY

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ MODELLER HAKKINDAKİ ANLAYIŞLARI VE MODEL KULLANIMLARININ İNCELENMESİ

GİRİŞ:

Fen bilgisi öğretimi birtakım bilimsel modellere dayanmaktadır, çünkü atom, hücre ve DNA gibi bazı bilimsel kavramların anlaşılabilmesi bu bilimsel modellere bağlıdır. Doğaları gereği genellikle erişilemez veya gözlemlenemez yapıda olan bu tür kavramların anlaşılabilmesi için bilimsel modeller, bu kavramların somutlaştırılmış veya basitleştirilmiş biçimi olarak işlev görürler. Böylece bilim adamları, öğretmenler ve öğrenciler bu kavramlar hakkında açıklama yapabilir veya tahmin yürütebilirler (Harrison & Treagust, 2000b). Diğer bir deyişle, bilimsel olguların niteliklerini test veya tahmin eden bilimsel modeller; olgular hakkında açıklamalar yapan, tanımlar öneren nesneler veya düşünceler olarak işlev görürler (Aktan, 2005). Hestenes'e (1996) göre, fen bilgisi dersleri birtakım bilimsel modeller etrafında organize edildiğinde, bilimsel bilgi, öğrenciler için daha anlaşılabilir hale getirilip öğretilebilir. Örneğin, dünyanın fiziksel bir modeli olan kürenin kullanımı ile dünyanın şekli, kıtalar, eksen eğimi gibi bazı kavramlar daha açık hale getirilebilmektedir. Küre gibi fiziksel modellerin yanı sıra, çeşitli yapısal (güneş sistemi, DNA), işlevsel (ayın evreleri, kimyasal tepkimeler), veya analojik modeller (gazların bilardo topu modeli, çekirdeğin sıvı damlası modeli) yardımıyla da birtakım bilimsel kavramlar kolaylıkla açıklanabilmektedir (Schwartz & Skjold, 2012). Bu tür modellerin sınıf ortamlarında kullanılmasıyla, öğrencilerin bilimsel düşünme becerileri geliştirmeleri ve bilimsel kavramları daha iyi anlamaları sağlanmaktadır (Treagust, Chittleborough & Mamiala, 2002). Bilimsel modellerin yanı sıra, bilimsel kavramların anlaşılmasını kolaylaştırmak için öğretmenler, *öğretim modellerinden* de faydalanabilirler (Gobert & Buckley, 2000). Öğretim modelleri, "bir bilimsel kavramı anlamaya yardımcı olmak için öğretmenler tarafından kullanılan özel olarak hazırlanmış modellerdir" (Chittleborough, Treagust, Mamiala, & Mocerino, 2005, s. 197). En yaygın öğretim modelleri arasında resimler, simülasyonlar, analojiler ve somut modeller (Justi & Van Driel, 2005b) ile şekiller, diyagramlar ve resimler gibi iki boyutlu ders kitabı modelleri, ve görsel ve sözel metaforlar ile analojiler yer almaktadır (Coll, France & Taylor, 2005). Bu modeller, bilimsel konuları yalınlaştırarak, görselleştirerek veya somutlaştırarak öğrenmeyi desteklemekte (Falcao, Colinvaux, Krapas, Querioz, Alves, Cazelli, Valente & Gouvea, 2004); ve öğrenciler tarafından anlaşıldığı ve hatırlandığı takdirde, öğrenmeyi etkinleştiren öğretim araçları olarak işlev görmektedirler (Harrison & Treagust, 1998, 2000b).

Chittleborough ve arkadaşlarına (2005) göre bahsi geçen bu bilimsel modeller ve öğretim modelleri, öğrencilerin öğrenmesinde etkin rol oynamaktadırlar. Şekil 1'de, bilimsel modeller ile öğretim modelleri arasındaki ilişki ve bu modellerin öğrenme sürecindeki rolleri gösterilmektedir.



Şekil 1. Öğrenmeye ilişkin modellerin teorik çerçevesi (Chittleborough ve ark., 2005, s.197)

Chittleborough ve arkadaşlarına (2005) göre öğrenme, bilimsel ve öğretim modelleri vasıtasıyla, öğrencilerde bilimsel kavramlar hakkında zihinsel modeller oluşturmak olarak tanımlanmaktadır. Bu süreçte zihinsel modeller, öğrencilerin öğrenme eylemlerinin ürünüdürler ve kısaca öğrenme ürünü olarak kabul edilirler. Diğer yandan, 'ifade edilen modeller' ise, öğrencilerin eylem, konuşma veya yazı yoluyla zihinsel modellerini ifade edişleridir. Yeni bir kavramı anlama sürecinde öğrenciler, daha önceki bilgileri ile yeni bilgiler arasında benzerlikler kurar ve böylece, kendi zihinsel modellerini oluştururlar. Bu noktadan hareketle, Chittleborough (2004), öğrencilerin kendi zihinsel modellerini oluşturmasının 'yapılandırmacı' bir yaklaşım olduğunu savunmaktadır. Benzer şekilde, diğer bazı araştırmacılar da, modele dayalı çalışmalarının teorik temellerini yapılandırmacı öğrenme ve öğretme yaklaşımı üzerine kurmaktadırlar (Byrne, 2011; Crawford & Cullin, 2005; Harrison & Treagust, 2000a; Treagust, Chittleborough & Mamiala, 2002). Yapılandırmacı yaklaşıma göre fen öğrenimi, öğrencilerin bir fikir veya kavramı alıp, yeniden yapılandırmasını, içselleştirmesini ve sonrasında da bu fikir veya kavramı başkalarıyla paylaşabilmesini ya da başkalarına açıklayabilmesini gerektirir ki, modeller, bu süreçte çok faydalı araçlar olarak işlev görebilmektedirler (Treagust, Chittleborough & Mamiala, 2002). Bir diğer deyişle, karşılaşılan bir olgunun kişiye özgü zihinsel modellerinin oluşmasını sağladıkları için modeller, önemli bir yapılandırmacı öğretim stratejisi olarak kabul edilebilirler. Ayrıca (analojiler ve metaforlar ile birlikte) modeller, öğrencilerin aşina oldukları kavramlarla ilişkilendirebilecekleri ve üzerine yeni düşünceler inşa edebilecekleri bir temel sağladıklarından (Chittleborough, 2004), yeni düşünceler kabul edilip mevcut düşünceler ile ilişkilendirildiğinde, öğrenciler kendi zihinsel modellerini geliştirmiş olurlar ve böylece öğrenme gerçekleşmiş olur (Byrne, 2011). Modellerin fiziksel bir görüntü sağlaması ve analoji veya metaforların yeni bir olguyu öğrencilerin var olan bilgileri ile benzerlik kurarak açıklayabilmesi (Taber, 2001), öğrencilerin yeni bilgileri önceki bilgilerinin üzerine inşa edebilecekleri bir temel oluşturduğundan (Yager, 1991, akt: Chittleborough, 2004), modellerin (ve analoji ve metaforların) kullanımının yapılandırmacı yaklaşımla tutarlı olduğu söylenebilir.

Bu noktalardan hareketle, fen bilgisi derslerinde, anlamlı zihinsel modeller oluşturmasının yanı sıra, yapılandırmacı öğrenme stratejilerini de destekleyen bilimsel ve öğretim modellerinin uygun bir şekilde kullanımının, öğrenmeyi destekleyen etkili öğretim stratejileri oldukları söylenebilir. Bu ve benzeri düşünceler dikkate alındığında ise, öğrencilerin anlamlı zihinsel modeller oluşturmaları ve modelleri etkili bir şekilde kullanmaları için fırsat yaratmanın yollarını aramamız gerektiğini söylemek yanlış olmaz. Bu noktada öğretmenlere düşen görev, öğrencilerin anlamlı zihinsel modeller geliştirebilmeleri için onlara yardımcı olacak öğretim modelleri geliştirmektir (Norman, 1983). Bu nedenle, öğretmenlerin (hem hizmet öncesi hem hizmet içi) fen bilimlerinde kullanılan önemli modellerin farkında olmalarının yanı sıra, modeller ve kullanımı hakkında da yeterli bilgiye sahip olmaları önemlidir (Danusso, Testa & Vicentini, 2010). Bu açıdan bakıldığında, fen bilgisi öğretmen adaylarının (FBÖA'nın) modeller hakkındaki anlayışlarının ve modelleri derslerinde nasıl kullandıklarının araştırılmasının önemi ortaya çıkmaktadır ki, bu çalışmanın da amacı budur.

Bu çalışma FBÖA'nın bilimsel modeller hakkındaki anlayışları ve fen bilgisi eğitiminde model kullanımı hakkındaki algılarını incelemiştir. Daha spesifik olarak çalışmanın bulguları, bilimsel modellerin tanımları ve rolleri, bilimsel modellerin doğası, fen bilgisi eğitiminde kullanılan modellerin özellikleri ve faydaları, ve FBÖA'nın derslerinde modellerden nasıl faydalandıkları gibi, modeller hakkındaki anlayışlarını ve model kullanımlarını farklı açılardan açığa çıkarmayı amaçlamıştır. Çalışmanın araştırma soruları aşağıdaki gibidir:

1. Fen bilgisi öğretmen adaylarının bilimsel modeller hakkındaki anlayışları nelerdir?

2. Fen bilgisi öğretmen adaylarının modellerin fen bilgisi eğitiminde kullanılmalarına ilişkin algıları nelerdir?

Çalışmanın Önemi:

Daha önce de belirtildiği gibi, modeller fen bilgisi öğretiminde önemli bir yere sahiptirler çünkü bazı bilimsel olgular, boyut, zaman, karmaşıklık gibi çeşitli unsurlardan dolayı soyut kalmakta; ancak bu olgular ilgili modeller ile rahatlıkla öğretilebilmektedirler (Harrison, 2001). Eğer öğrenciler modelleri, rollerini, amaçlarını ve sınırlıklarını kavrayabilirler ise, söz konusu olgu ile modeli arasındaki ilişkileri kurabilir ve bu olguları daha iyi anlayabilirler (Hitt, White, & Hanson, 2005). Modeller ve modelleme uygulamaları kullanarak öğrenciler, verileri yorumlama, tahminler üretip daha sonra onları tekrar değerlendirme ve bilimsel tartışmalar yapma gibi, fen eğitimi standartları ve reform niteliğindeki fen eğitimi hedefleri ile tutarlılık gösteren pek çok bilimsel faaliyette tecrübe sahibi olabilirler (Nelson & Davis, 2012). Bu düşüncelere paralel olarak, Amerika Bilimsel Eğitim Standartları'nın (Ulusal Araştırma Konseyi, 1996) vizyonu ve başka ülkelerdeki fen eğitimi reformları, fen bilgisi öğretmenlerinin modeller hakkında bilgi sahibi olmaları gerektiğini vurgulamaktadır (akt: Crawford & Cullin, 2004). Benzer şekilde, öğrenmede yapılandırmacı bakış açılarını benimseyen Türkiye'deki Fen Eğitimi müfredatı da (MEB, 2005), modellerin sınıf ortamlarında çeşitli şekillerde kullanımını vurgulamakta; örneğin, öğretmenleri, edinebilirlik, maliyet ve emniyet gibi çeşitli sebeplerle ulaşılamayan bilimsel kavramları öğretirken, video kayıtları ve simülasyonlar gibi çeşitli araçları kullanmaya teşvik etmektedir.

Bu ve çeşitli sebeplerden dolayı fen bilgisi öğretmenleri, derslerinde etkin bir şekilde modellerden faydalanmalıdırlar. Ancak, modeller sınıf ortamlarına görsel amaçları dışında nadiren entegre edilmektedirler (Davis, Kenyon, Hug, Nelson, Beyer, Schwarz & Reiser, 2008). Bunun bir sebebi kaliteli müfredat materyallerinin eksikliği olabilir, ancak modelleri uygun bir şekilde kullanmak ve öğrencilere modelleme faaliyetleri yaptırmak için öğretmenlere de önemli görevler düşmektedir (Davis ve ark., 2008). Öğrencilerin öğrenme sürecinde öğretmenin önemli bir rol oynadığı düşünüldüğünde (Davis ve ark., 2008), fen bilgisi öğretmen adaylarının modeller konusundaki anlayışlarını ve derslerinde ne ölçüde modellerden faydalandıklarını araştırmanın önemi açıkça ortaya çıkmaktadır. Fakat modeller üzerine yapılan çoğu araştırmanın, öğrencilerin (örn. Chittleborough, Treagust, Mamiala & Mocerino, 2005; Grosslight, Unger, Jay & Smith, 1991; Treagust, Chittleborough & Mamiala, 2002; ve diğerleri), ve öğretmenlerin (örn. Harrison, 2001; Justi & Gilbert, 2002a, 2002b, 2003; Van Driel & Verloop, 1999, 2002) model anlayışlarını incelediği görülmektedir. FBÖA'nın modeller hakkındaki anlayışları üzerine yapılan çok az sayıda araştırma bulunmaktadır (örn. Aktan, 2005; Berber & Güzel, 2009; Crawford & Cullin, 2004; Valanides & Angeli, 2008). Dolayısıyla, FBÖA'nın model anlayışları konusunda daha net bir çerçeve oluşturmak için daha fazla araştırmaya ihtiyaç olduğu açıktır. FBÖA'nın modeller hakkındaki anlayışları ve model kullanımı konusundaki algıları önemlidir çünkü bu algılar ve anlayışlar öğrencilerin model anlayışlarını da etkileyebilir. Modellerin uygun bir şekilde kullanımıyla öğrencilerin bilimsel düşünce becerileri ve öğrenme düzeyleri geliştirilebilir. Öğrenciler, modellerin rolünü, amaçlarını ve sınırlıklarını fark edebildiklerinde bilimsel kavramları daha etkin bir şekilde öğrenebilirler. Bu nedenle bu çalışma, FBÖA'nın modeller hakkındaki anlayışlarını incelemeyi ve bu alanda sınırlı olan literatüre katkıda bulunmayı amaçlamıştır. Ayrıca, bildiğimiz kadarıyla Türkiye'de FBÖA'nın modeller hakkındaki anlayışlarını inceleyen yalnızca bir araştırma bulunmaktadır (Berber & Güzel, 2009). Berber ve Güzel'in araştırması, nicel verilere dayanmaktadır; ve nitel verilere dayalı olan bizim çalışmamızın bulguları ile bu çalışmada elde edilen bulguların genişletileceği, ve Türkiye'deki FBÖA'nın modeller hakkındaki anlayışlarının daha detaylı bir şekilde ortaya konulacağı düşünülmektedir. Bizim çalışmamızda, açık uçlu bir ölçeğe ek olarak mülakat yoluyla FBÖA'nın bilimsel modeller hakkındaki anlayışlarının neler olduğunu derinlemesine bir şekilde incelemek amaçlanmıştır. Çünkü mülakat yöntemi, araştırmacıya katılımcının araştırılan konu hakkındaki duygularını ve bakış açılarını derinlemesine inceleme fırsatı vermektedir. Ayrıca, yine bildiğimiz kadarıyla, FBÖA'nın fen bilgisi öğretiminde model kullanımı konusundaki anlayışları, yani modelleri nasıl algıladıkları ve nasıl kullandıkları konusu, araştırmacıların çok ilgisini çekmemiştir. Bu nedenle bu çalışma, mülakatlar, ders planları ve sınıf içi gözlemlerden elde edilen verilerin analizi ile, FBÖA'nın öğretim modelleri hakkındaki algılarını ve sınıf ortamında modelleri nasıl kullandıklarını araştırarak gelişmekte olan literatürdeki bu açığı kapatmayı amaçlamaktadır.

YÖNTEMLER:

Araştırma Deseni:

Fen bilgisi öğretmen adaylarının (FBÖA'nın) modeller hakkındaki anlayışlarını araştırmak amacıyla yapılan bu çalışmada nitel araştırma yöntemlerinin kullanılması uygun görülmüştür. Nitel araştırmalarda amaç, kişilerin oluşturdukları anlam ve anlayışları ortaya koymaktır; ve bu amaç için yüz yüze görüşmeler, gözlemler, belge incelemeleri gibi yollarla veriler toplanır ve zengin bir betimleme yöntemiyle toplanan bu veriler sunulur (Merriam, 1998). Bu çalışma, doğası ve amacına bağlı olarak, bir grup FBÖA'nın modeller konusundaki anlayışlarını ve model kullanımlarını bütünsel ve betimleme yoluyla incelemeyi amaçlamaktadır. Bu nedenle, nitel bir araştırma yönteminin, daha spesifik olarak da bir 'durum çalışması' araştırma deseninin kullanımı uygun görülmüştür.

Eğitim alanındaki nitel çalışmalarda durum çalışması araştırma deseni yaygın olarak kullanılmaktadır (Merriam ve ark., 2002). Bu çalışmalardaki durum, bir öğrenci, bir öğretmen, bir müdür, bir program, bir sınıf, bir okul, bir topluluk, veya özel bir eğitim politikası olabilir (Merriam ve ark., 2002). Sorgulanacak tek nokta, analiz edilecek birimin sınırlandırılmış olması, yani çalışmaya katılan insan sayısının sınırlı olması gerektiğidir (Merriam ve ark., 2002). Bu çalışmada analiz edilecek birim, bir devlet üniversitesinde fen bilgisi öğretmenliği bölümünde son sınıf öğrencisi olarak öğrenim gören ve 'İlköğretimde Öğretmenlik Uygulamaları' dersini alan on dört FBÖA'dır.

Katılımcılar:

Yukarıda da belirtildiği gibi, bu araştırmanın katılımcıları, Ankara'da bulunan büyük bir devlet üniversitesinde İlköğretim Fen Bilgisi Öğretmenliği (İFBÖ) programına kayıtlı on dört son sınıf öğrencisinden (dört erkek, on kadın) oluşmaktadır. Çalışmanın amacı, öğretmen adaylarının modeller hakkındaki anlayışlarını ve model kullanımlarını araştırmaktır; bu nedenle, çalışmanın ders bağlamı, İFBÖ programı tarafından verilen derslerden bir tanesi, yani İlköğretimde Öğretmenlik Uygulamaları dersi olmuştur. İlköğretimde Öğretmenlik Uygulamaları dersi, Yüksek Öğretim Kurulu tarafından belirlenen alan deneyimine ilişkin iki zorunlu dersten biridir. FBÖA bu dersi genellikle eğitimlerinin en son (sekizinci) döneminde almakta; ve dersin amacına uygun olarak, staj için seçilen okullarda çeşitli eğitim faaliyetlere aktif olarak katılmakta ve gözlem yapmaktadırlar. Dersin gerekliliklerinden biri olarak FBÖA'ndan ders planları hazırlamaları ve staj okullarındaki gerçek sınıf ortamlarında ders anlatmaları beklenmektedir. FBÖA'nın staj okullarında anlattıkları bu dersler o okullardaki rehber öğretmenleri ve üniversitede dersi veren öğretim elemanı tarafından gözlemlenip değerlendirilmektedir.

Veri Toplama Araçları:

Bu çalışmanın veri toplama araçlarını, Modeller ve Modelleme Hakkındaki Düşüncelerim (VOMMS) ölçeği ile, yarı yapılandırılmış görüşmeler, ders planları ve sınıf gözlemleri oluşturmaktadır.

Modeller ve Modelleme Hakkındaki Düşüncelerim (VOMMS) Ölçeği

'Modeller ve Modelleme Hakkındaki Düşüncelerim' (VOMMS) ölçeği, ilk olarak Treagust, Chittleborough ve Mamiala (2004) tarafından, Aikenhead ve Ryan'a (1992) ait Bilim-Teknoloji-Toplum Hakkındaki Görüşler (VOSTS) isimli anketten faydalanılarak geliştirilmiş, ve Türkçe'ye bu çalışmanın araştırmacısı tarafından çevrilmiştir. VOMMS ölçeği toplamda 6 madde içermekte ve bilimsel modellere ilişkin üç özelliğini araştırmaktadır: 'temsiller olarak modeller', 'modellerin çeşitliliği' ve 'modellerin dinamik/değişken doğası'. Ölçeğin her bir maddesi, katılımcıların bilimsel modeller hakkında verilen iki alternatif ifade arasından seçim yapmalarını ve daha sonra bu seçimlerinin gerekçesini yazılı olarak anlatmalarını istemektedir. Bu yazılı açıklamalar FBÖA'nın soruları doğru anlayıp anlamadıklarını yorumlamak ve ayrıca model ile ilgili anlayışları hakkında detaylı bilgi edinmek için kullanılmaktadır.

Yarı-Yapılandırılmış Görüşmeler

Yarı-yapılandırılmış görüşmeler bu çalışmanın başlıca veri toplama aracı olarak işlev görmüşlerdir. Görüşmeler, katılımcıların model kullanımı konusundaki anlayışları hakkında olası tema ve örüntüleri araştırmak için kullanılmıştır. Katılımcılardan deneyimleri üzerine düşünmeleri ve düşüncelerini sesli olarak ifade etmeleri istenmiş; ve yöneltilen temel soruların yanında, onlardan gelen yanıtlarına bağlı olarak irdeleyici ve ek sorular sorularak düşünceleri araştırılmıştır (Patton, 2002). Görüşme soruları ve irdeleyici sorular daha önce yapılan bazı araştırmalardan yararlanılarak geliştirilmiş (Grosslight ve ark., 1991; Gobert & Discenna, 1997; Crawford & Cullin, 2004; Aktan, 2005), ve spesifik olarak katılımcıların, modellerin tanımı, işlevleri, özellikleri ve kullanımı hakkındaki anlayışlarını ortaya çıkarmayı amaçlamıştır. Görüşme soruları tüm FBÖA'na aynı sırayla sorulmuştur, ancak, verilen yanıtlara bağlı olarak yöneltilen irdeleyici sorular değişkenlik göstermiştir. Diğer bir deyişle, katılımcıların anlayışlarını detaylı bir şekilde araştırmak için bazı sorular eklenmiş veya tekerrür eder gibi görünen bazı sorular atlanılmıştır. Tutarlılık sağlamak amacıyla, görüşmelerin tamamı araştırmacı tarafından sessiz bir odada bireysel olarak yapılmıştır ve her biri yaklaşık olarak 30-35 dakika sürmüştür. Görüşmeler araştırmacı tarafından bir ses kayıt cihazı yardımıyla kaydedilip daha sonra birebir yazıya dönüştürülmüştür.

Ders Planları

Daha önce söz edildiği üzere, her fen bilgisi öğretmen adayı, İlköğretimde Öğretmenlik Uygulamaları dersinin bir gerekliliği olarak uygulama yaptıkları okuldaki dersleri için ders planları hazırlayıp teslim etmişlerdir. Hazırlanan bu ders planları, bu çalışmanın veri kaynaklarından biri olmuştur çünkü bu okullardaki öğretmenlik uygulamaları ile, öğretmen adayları, gerçek bir sınıf ortamında birer öğretmen olarak ders anlatmışlardır. Bu ders planları aracılığıyla elde edilen veriler, onların modeller hakkındaki algıları ile derslerinde modelleri kullanıp kullanmadıkları ve kullandılarsa nasıl kullandıkları hakkında bilgi vermiştir. Tipik olarak bir ders planının içeriği, tarih, okulun adı, öğrencilerin sınıf düzeyi, konu, zamanlama, gereken temel bilgiler, kazanımlar, kullanılacak öğretim materyalleri, eğitsel teknoloji ve medya, öğretim yöntemleri, ön hazırlıklar, öğrenci ve öğretmen hazırlıkları, kazanımlarının entegre edildiği konunun sunumu, öğretim araçları ve öğretim yöntemleri, ders sonrası ödevler, ve değerlendirme kısımlarından oluşmuş; ve FBÖA'ndan fen bilgisi müfredatında geçen *Bilimsel Süreç Becerileri* (BSB), *Bilim-Teknoloji-Toplum ve Çevre (*BTTÇ), ve *Bilimin Doğası* (BD) kazanımlarının elde edilmesine özel ilgi göstermeleri beklenilmiştir. FBÖA'nın hazırladığı bu ders planlarının birer kopyası araştırmacı tarafından alınmış ve daha sonra bu çalışmanın amacına yönelik olarak incelenmiştir.

Sınıf İçi Gözlemler

FBÖA'nın staj okullarında gerçekleştirdiği öğretmenlik uygulamaları sırasında yapılan sınıf içi gözlemlerden elde edilen veriler onların model kullanımları hakkında bilgi sağlamıştır. FBÖA'nın ders planlarında bahsettikleri modelleri nasıl kullandıklarını teyit etmek ve gözlemlemek amacıyla dersler video kaydına alınmıştır. Tüm kayıtlar araştırmacı tarafından yapılmış ve araştırmacı kayıtlar sırasında FBÖA'nın model kullanma faaliyetleri üzerine yoğunlaşmıştır. Tipik olarak öğretmenlik uygulamaları ve dolayısıyla video kayıtları bir ders saati, yani 35-40 dakika kadar sürmüştür.

Veri Toplama Süreci:

2009-2010 sonbahar döneminde, İFBÖ programına kayıtlı olan tüm son sınıf FBÖA'na VOMMS ölçeğini doldurmaları teklif edilmiş, ancak bunlardan 35'i gönüllü olmuş ve ölçeği doldurmuşlardır. Daha sonra bu 35 FBÖA'na e-posta ile ulaşılarak araştırmanın geri kalan kısmı hakkında bilgi verilmiş ve bu kısma da katılmaları teklif edilmiştir. Bu FBÖA'ndan 14'ü gönderilen e-postaya yanıt vermiş ve çalışmanın geri kalan kısmına katılmak konusunda gönüllü olmuşlardır. Bu FBÖA ile yüz yüze görüşmeler (mülakatlar) yapmak üzere tarih ve zamanlar ayarlanmış, ve bu görüşmeler 2009-2010 bahar dönemi başlamadan önce gerçekleştirilmiştir. 2009-2010 bahar döneminde ise, İlköğretimde Öğretmenlik Uygulamaları dersinin bir gerekliliği olarak, öğretmen adayları staj yapacakları okullara yönlendirilmişlerdir. Daha önce de belirtildiği gibi, bu okullardaki öğretmenlik uygulamaları, araştırmacı tarafından izlenmiş ve hazırlanan ders planlarının birer kopyası alınmıştır.

Verilerin Analizi:

VOMMS ölçeği ile elde edilen veriler nitel veri analizi yöntemleri ile analiz edilmiştir. Her bir VOMMS maddesi için, FBÖA'ndan verilen iki alternatif cevaptan birini seçmeleri ve daha sonra seçimlerini yazılı olarak açıklamaları istenmiştir, ve hemen hemen tüm katılımcılar seçimlerini gerekçelendiren yazılı yanıtlar vermişlerdir. Bu yazılı yanıtlar araştırmacı tarafından tekrar tekrar okunmuş, ve verilerdeki benzerlikler ortaya çıktıkça kodlar ve kategoriler oluşturulmuştur. Araştırmanın güvenilirliğini artırmak için ise, araştırmacı bir meslektaşından yapılan analizi kontrol etmesini istemiş ve problemli görülen noktalarda araştırmacı ve meslektaşı bir araya gelip görüş birliği sağlanana dek tartışmışlardır. Sonuçta elde edilen kodlar ve kategoriler katılımcıların modeller hakkındaki anlayışları ile ilgili bilgi vermiştir.

VOMMS ölçeğinde olduğu gibi, mülakatlardan elde edilen veriler de ilgili tema ve örüntüleri ortaya çıkarmak amacıyla nitel kodlama tekniği ile de analiz edilmiştir. Öncelikle, ses kayıtları birebir olacak şekilde yazıya dönüştürülmüş, ve daha sonra araştırmacı oluşturulan bu transkripsiyonları tekrar tekrar okuyarak katılımcıların modeller hakkındaki anlayışlarına ilişkin önemli kelime veya ifadeleri aramıştır. Bu sürecin bir kaç kez tekrarını takiben araştırmacı, sıkça ortaya çıkan ifadelere ulaşmış ve verileri anlamlı kodlara dönüştürmüştür. Bu esnada, bir meslektaştan da aynı süreci takip etmesi ve verileri kodlaması istenmiştir. Kodlama işlemleri tamamlandığında her iki araştırmacı da bir araya gelmiş ve nihai kodları görüş birliğine varıncaya kadar tartışmışlardır. Ayrıca, sürecin güvenilirliğini teyit etmek amacıyla oluşturulan bu kodlar ve kategoriler, bir profesör, bir doçent ve bir yardımcı doçentten oluşan bir grup tarafından da kontrol edilmiştir.

Diğer bir veri kaynağı olan ders planları ise, doküman analizi yöntemiyle incelenmiştir. FBÖA'nın model kullanımı ile ilgili algılarını ortaya çıkarmak ve öğretmenlik uygulamalarında modellerden ne şekilde faydalanacaklarını araştırmak için her bir ders planı araştırmacı tarafından birkaç kez okunmuştur. FBÖA'nın derslerinde ne tür modeller kullanacağı bu incelemeler sonucunda ortaya konulmuştur. Ayrıca, ders planlarında model kullanımı ile ilgili algılar da araştırılmıştır, çünkü FBÖA derslerinde kullanmayı planladıkları modellerin olası faydalarından ve onları kullanmanın gerekliliğinden ders planlarında da söz etmişlerdir.

Son olarak, FBÖA'nın staj için gittikleri okullardaki gerçek sınıf ortamlarında video kaydına alınan öğretmenlik uygulamaları, ilgili ders planları incelendikten sonra araştırmacı tarafından birkaç kez izlenmiştir. Araştırmacı, FBÖA'nın ders planlarında bahsettikleri modelleri derslerinde kullanıp kullanmadıklarını ve nasıl kullandıklarını incelemiştir. Ayrıca, video kayıtları ders planlarında söz edilmeyen muhtemel model kullanımları açısından da incelenmiştir.

BULGULAR:

1. Fen Bilgisi Öğretmen Adaylarının Bilimsel Modeller Hakkındaki Anlayışları

Bulgular, FBÖA'nın bilimsel modeller hakkındaki anlayışlarının 'bilimsel modellerin tanımı ve işlevleri' ve 'bilimsel modellerin doğası' olmak üzere iki ana kategoride toplandığını göstermiştir.

1.1. Bilimsel Modellerin Tanımları ve İşlevleri

1.1.1. Bilimsel Modellerin Tanımları

Mülakatlardan ve VOMMS ölçeğinden elde edilen veriler, FBÖA'nın modeller hakkındaki tanımlamalarının, 'açıklamalar niteliğinde modeller', 'temsiller niteliğinde modeller' ve 'tam kopya niteliğinde modeller' olmak üzere 3 temada toplandığını göstermiştir. Bilimsel modellerin tanımlarına ilişkin kodlama planı ve ilgili frekans dağılımları Tablo 1'de sunulmuştur.

Tablo 1. Bilimsel modellerin tanımlarına dair kodlama planı ve frekans dağılımları

Tanım	Açıklama	Frekans dağılımları (N=14)
Açıklamalar Niteliğinde Modeller	FBÖA bilimsel modelleri, görünmez, bilinmez, veya ulaşılamaz gibi birtakım sınırlayıcı özellikleri olabilen bilimsel olguları açıklamak için geliştirilen araçlar olarak tanımlarlar.	11
Temsiller Niteliğinde Modeller	FBÖA bilimsel modelleri, genellikle, doğrudan gözlemlenemeyen bilimsel olguları temsil eden araçlar olarak tanımlarlar.	10
Tam Kopya Niteliğinde Modeller	FBÖA modellerin gerçek olguya yakın veya benzer olması gerektiğine inanırlar.	1

Modellerin 'açıklayıcı' veya 'temsili' doğasını vurgulayan FBÖA, genellikle gerçek olgunun sınırlayıcı özelliklerine değinip; soyut, gözlemlenemeyen veya ulaşılamayan olguları açıklamak veya temsil etmek için modellere ihtiyaç duyulduğunu düşünmüşlerdir. Çoğu, modellerin, gerçek olgunun yapısını detaylı ve görsel bilgiler sunarak gösterdiği düşüncesini taşımıştır. Bu bulguyla ilintili olarak, FBÖA genellikle modellerin, görsel veya üç boyutlu olduğu görüşündedirler. Örneğin, bazı FBÖA çizimleri model olarak kabul ederken, çoğu, üç boyutlu modelleri *gerçek* modeller olarak adlandırmıştır. Genel olarak, FBÖA'nın modellerin açıklayıcı ve temsili doğası hakkında yeterli bilgiye sahip olduğu düşünülse de, çoğunun, modellerin açıkladıkları veya temsil ettikleri gerçek olgulara yakın olmaları gerektiğini savunması ilginçtir. Diğer yandan, bazı FBÖA, modellerin gerçek olgunun tüm özelliklerini yansıtması gerektiğini savunurken, diğer bazıları amaca bağlı olarak modellerin, gerçek olgunun her detayını içermesi gerekmediğini düşünmüşlerdir.

1.1.2. Bilimsel Modellerin İşlevleri

FBÖA'na göre modeller, karmaşık kavramları yalınlaştırarak, soyut kavramları somutlaştırarak ve kavramları zihinde görselleştirerek bu kavramları anlamayı kolaylaştırır, ve ayrıca bilimsel gelişmelere katkıda bulunurlar. Bilimsel modellerin işlevlerine ilişkin kodlama planı ve ilgili frekans dağılımları Tablo 2'de sunulmuştur.

Daha önce de ifade edildiği gibi, bu çalışmadaki FBÖA, modelleri oluşturulan gerçek olguların, gözlemlenemeyen, ulaşılamayan veya karmaşık yapıda olduklarının farkındalardır. Bu bulguyla ilintili olarak da, modelleri, bu tür kavramları yalınlaştırarak, somutlaştırarak veya görselleştirerek, anlaşılmalarını kolaylaştıran araçlar olarak tanımlarlar.

Tablo 2. Bilimsel modellerin işlevlerine dair kodlama planı ve frekans dağılımları

Bilimsel Modellerin İşlevleri	Açıklama	Frekans dağılımları (N=14)
anlamayı kolaylaştırmak	FBÖA bilimsel modellerin, bilimsel kavramları yalınlaştırarak ve/veya görselleştirerek anlaşılmalarını kolaylaştırdıklarını ifade ederler.	9
yalınlaştırarak (basitleştirerek)	FBÖA bilimsel modellerin, bilimsel olguları yalınlaştırdığı ve karmaşıklıklarını azalttığı düşüncesindedirler.	4
somutlaştırarak	FBÖA gerçek olgunun gözlemlenemeyen veya soyut doğasına değinir, ve bilimsel modellerin bu olguları somutlaştırdığından bahsederler.	8
kavramları zihinde görselleştirerek	FBÖA modellerin zihnimizde bilimsel olguyla ilgili görseller oluşturmamıza yardımcı olduklarından bahsederler.	7
bilimsel gelişime katkıda bulunmak	FBÖA bilimsel modellerin, bilimsel bilginin süreci, gelişimi ve üretiminde kullanılan araçlar olduklarını düşünürler.	6

Ayrıca bazı FBÖA, bilimsel modellerin bilimsel bilginin gelişimine katkıda bulunduğunu düşünmüşlerdir. Bu FBÖA, modellerin, bilimde önemli işlevlere sahip olduklarını ve hatta bilimin bir parçası olduğunu savunmuşlardır. FBÖA'nın modellerin bilimsel çalışmalardaki önemine ilişkin yeterli anlayışlara sahip oldukları düşünülebilir; ancak, modellerin bilimsel olgular hakkında tahmin yürütme aracı olarak kullanılması gibi birtakım önemli işlevlerinin FBÖA tarafından hiç bahsedilmemiş olması dikkat çekicidir.

1.2. Bilimsel Modellerin Doğası

Bulgular, FBÖA'nın bilimsel modellerin öznel, sosyal-kültürel, değişken, deneysel ve yaratıcı doğasının farkında olduklarını göstermiştir. Bilimsel modellerin doğasına ilişkin kodlama planı ve ilgili frekans dağılımları Tablo 3'te sunulmuştur.

Tablo 3. Bilimsel modellerin doğasına dair kodlama planı ve frekans dağılımı

Bilimsel Modellerin Doğası	Açıklama	Frekans dağılımı (N=14)
öznel doğası	FBÖA, bilimsel modellerin öznel doğasına değinerek, bilim adamlarına ait yorumların, bakış açılarının, ve inançların onların geliştirdikleri modelleri etkilediğini ve böylece birden çok modelin ortaya çıktığını söylerler.	11

Tablo 3. Continued.

sosyal ve kültürel gömülmüşlük	FBÖA, bir olgu için birden çok modelin varlığını gerekçelendirirken, bilimsel modellerdeki sosyal ve kültürel konulara (yani din, kültür, toplumsal çevre) değinir; ve yeni bir model ortaya konulduğunda bilim adamlarının bu modeli kabul edip etmeme konusundaki kararlarının onların toplumsal-kültürel inançlarından etkilendiğinden söz ederler.	6
deneysel doğası	FBÖA, modellerin kanıtlara dayalı olduğunu veya çıkarımlar sonucu geliştirildiğini düşünürler; ve yeni bir modeli kabul ederken bilim adamlarının modelin geçerli veri, test ya da kanıta dayalı olup olmadığını değerlendirdiklerini söylerler.	7
dinamik (geçici) doğası	FBÖA, bilimsel modellerin kesin olmadıklarını; ilgili bilimsel olguları daha iyi açıklayan modeller geliştirildiğinde (örn. atom modelleri) değişebileceklerini ifade ederler.	14
yaratıcı ve hayali doğası	FBÖA, bir olgu için birden çok modelin varlığını açıklarken yaratıcılıktan söz ederler; ve model geliştirmek için yaratıcılığın ve hayal gücünün gerekli beceriler arasında olduğuna inanırlar.	9

Araştırma verileri, çalışmaya katılan FBÖA'nın bilimsel modellerin doğası hakkında bilgili olduklarına dair güçlü kanıtlar vermiştir. FBÖA, bilim adamlarının farklı özgeçmişlerinin, bakış açılarının, sosyo-kültürel inançlarının ve bunlara bağlı olarak verileri farklı yorumlarının, aynı olgu için birçok modelin geliştirilmesine sebep olabileceğini düşündüklerini göstermektedir. Ayrıca FBÖA, bilimsel modellerin geliştirilmesinde bilim adamlarının yaratıcılıklarının ve hayal güçlerinin de rol oynadığına inanmaktadırlar. FBÖA, model geliştirmek için gereken beceriler arasında yaratıcılığın ve hayal gücünün de yer aldığını iddia etmektedirler. Çoğu FBÖA, modellerin gözlemlenemez veya soyut olgular için geliştirildiğini kabul ettiğinden, bir olguya ait fotoğrafın (örneğin, bir DNA fotoğrafının) model olarak kabul edilemeyeceğini, aksine, modellerin geliştirilmesinde bilim adamlarının yaratıcılığının rol oynadığını savunmuşlardır. Ayrıca FBÖA, modellerin toplumsal bağlamlarda oluşturulduklarının ve kullanıldıklarının da farkındadırlar. Yeni geliştirilen bir modelin kabulünde bilim adamlarının sosyo-kültürel inançlarının etkili olduğunu ve bir modelin kabul edilişinin başka bilim adamlarının desteğine ihtiyaç duyulduğunu da vurgulamışlardır. Ayrıca bulgular, tüm FBÖA'nın bilimsel modellerin değişken doğasının farkında olduğunu; sözkonusu alanda yapılan araştırmaların sonucunda ve teknolojideki yeni gelişmelere cevaben yeni kanıt ve bulgular ışığında, bilim adamlarının modelleri değiştirebildiğini düşündüklerini göstermiştir.

2. Fen Bilgisi Öğretmen Adaylarının Fen Eğitiminde Kullanılan Modeller Hakkındaki Algıları

Bulgular, FBÖA'nın fen eğitiminde kullanılan modeller hakkındaki algılarının, bu modellerin özellikleri, kullanımlarının gerekliliği ve yararları, ve FBÖA'nın bu modelleri kullanım konusundaki eğilimleri olmak üzere üç ana kategoriye düştüğünü göstermiştir.

2.1. Fen Eğitiminde Kullanılan Modellerin Özellikleri

Bulgular, FBÖA'nın fen eğitiminde kullanılan modellerin, yalın (basit), sınıf düzeyine uygun, üç boyutlu, açıklayıcı ve doğru olması gerektiğini düşündüklerini göstermiştir. Fen eğitiminde kullanılan modellerin özelliklerine ilişkin kodlama planı ve frekans dağılımı Tablo 4'te verilmiştir.

Bulgular, FBÖA'nın çoğunun, fen eğitiminde kullanılan modellerin 'basit' olması, yani kolay anlaşılması ve karmaşık olmaması gerektiğine inandığını göstermiştir. Bu bulgu, bilimsel modellerin bir işlevi olarak 'basitleştirme'nin ortaya çıktığı ilk araştırma sorusuna ait bulgular ile paraleldir. Ayrıca, modellerin basit olması ile ilintili olarak FBÖA, ilköğretim öğrencilerinin sınıf düzeylerine de atıfta bulunmuş ve öğrenciler tarafından kolayca anlaşılabilmesi için de modellerin yeterince basit olmaları gerektiği savunmuşlardır. Diğer taraftan, açık ve anlaşılır olmaları, FBÖA tarafından modellere dair ifade edilen bir diğer özelliktir.

Tablo 4. Fen eğitiminde kullanılan modellerinin özelliklerine ilişkin kodlama planı ve frekans dağılımı

Özellik	Açıklama	Frekans dağılımı (N=14)
yalın (basit)	FBÖA, bilim adamlarının kullandıkları modellere kıyasla, fen eğitiminde kullanılan modellerin daha basit olmaları gerektiğini vurgularlar.	9
sınıf düzeyine uygun	FBÖA, öğrencilerin onları daha rahat anlayabilmeleri için, modellerin, sınıf düzeyine uygun olmaları gerektiğini düşünürler.	5
açıklayıcı	FBÖA, modellerin gerçek olguyu iyi bir şekilde açıklamaları gerektiğini ifade ederek, modellerin bir özelliği olarak açıklayıcılığa atıfta bulunurlar.	5
doğru (hatasız)	FBÖA, kavram yanılgılarını önlemek için, modellerin, gerçek olguyu doğru bir şekilde açıklamaları/temsil etmeleri gerektiğine inanırlar.	4
üç boyutlu	FBÖA, modellerin üç boyutlu olmaları gerektiğine inanırlar.	3

FBÖA, modellerin gerçek olguyu iyi ve doğru bir şekilde açıklamaları gerektiğini düşünmektedirler. Burada modellerin doğru olması, gerçek olguyu bilimsel açıdan kabul edilebilir bir şekilde açıklaması ya da temsil etmesi anlamına gelmektedir. Son olarak, bilimsel modellerin işlevleri konusundaki düşüncelere (yani somutlaştırma, görselleştirme) benzer bir şekilde, üç boyutlu olmak da, fen eğitiminde kullanılan modellerin sahip olması gereken bir özellik olarak görülmüştür. Bazı FBÖA, üç boyutlu modellerin öğrencilerin ilgisini artırdığını söylerken, bazıları da öğretimin etkinliğini artırdığını düşünmektedirler.

2.2. Fen Eğitiminde Model Kullanımının Gerekliliği ve Yararları

Görüşmelerden ve ders planlarından elde edilen veriler göstermiştir ki, FBÖA fen bilgisi öğretiminde, öğrencilerin öğrenmesini kolaylaştırmak, öğrendiklerini unutmamalarını sağlamak ve derse olan ilgilerini çekmek için modellerin kullanılmasının gerekli ve yararlı olduğuna inanmaktadırlar. FBÖA, modelleri, fen bilgisi öğretimi ve öğreniminin kaçınılmaz unsurları olarak kabul etmekte; ve modellerin, bilimsel kavramların öğretiminde mümkün olduğunca sık bir şekilde kullanılmaları gerektiğini savunmaktadırlar. FBÖA'nın fen eğitiminde model kullanımının yararlarına ilişkin düşüncelerinin kodlama planı ve frekans dağılımı Tablo 5'te verilmiştir.

Tablo 5. Model kullanımının yararlarına ilişkin kodlama planı ve frekans dağılımı

Model Kullanımının Yararları	Açıklama	Frekans dağılımı (N=14)
öğrenim ve öğretimi kolaylaştırmak	FBÖA, öğrenilecek ve öğretilecek kavramların soyut doğasından bahsederek, modellerin bu kavramların öğretilmesi ve öğrenilmesini (genellikle onları somutlaştırarak) kolaylaştırdığını ifade ederler.	12
bilginin kalıcılığını artırmak	FBÖA, modellerin görsel araçlar olduklarını düşünür, ve bu sebeple de akılda kalıcı olduklarına inanırlar.	10
öğrencilerin ilgilerini artırmak	FBÖA, modellerin görsel olma özelliğine değinip, bu özelliğin öğrencilerin kavramlara yönelik ilgisini artırdığını ifade ederler.	4
somut düşünmeyi kolaylaştırmak	FBÖA, modellerin, soyut kavramları somutlaştırması ve görselleştirmesi sebebiyle, henüz soyut düşünme yetenekleri gelişmemiş olan küçük yaştaki öğrencilere hitap ettiklerini düşünürler.	4
çoklu zekayı geliştirmek	FBÖA, modellerin görsel olma özelliğine atıfta bulunup, bu özelliklerinden dolayı görsel zekâya hitap ettiklerini düşünürler.	4

Çalışmaya katılan FBÖA modelleri görsel/fiziksel yapılar olarak algılamış, ve bu özelliğe bağlı olarak (yani, bilimsel kavramları görselleştirdikleri/somutlaştırdıkları için) modellerin, öğretim ve öğrenimi kolaylaştırdıklarını, kalıcı öğrenmeyi sağladıklarını, bilimsel konulara karşı ilgiyi artırdıklarını, ve somut düşünme seviyesinde olan küçük yaş öğrencilerine ve görsel zekaya hitap ettiklerini düşünmüşlerdir.

2.3. FBÖA'nın Derslerinde Model Kullanımları

Görüşmeler yoluyla elde edilen veriler, FBÖA'nın model kullanımına yönelik eğilimlerini ortaya koyarken; diğer yandan, ders planları ve sınıf içi ders gözlemleri ile elde edilen veriler, onların derslerinde kullandıkları modelleri ortaya çıkarmıştır. Daha önceki bölümlerde de belirtildiği gibi, bu çalışmaya katılan FBÖA, modellerin, fen bilgisi eğitiminde önemli bir yere sahip olduğunu düşünmüş, ve derslerinde modellerden sıklıkla faydalanacaklarını ileri sürmüşlerdir.

2.3.1. FBÖA'ların Model Kullanımı Konusundaki Eğilimleri

Görüşmeler sırasında FBÖA, derslerinde kullanmayı planladıkları modellerden bahsederken genellikle somut (maddesel/fiziksel) modeller (örn. insan vücudu modeli, göz modeli) ile, çizimler, imgeler ve simülasyonlara değinmişlerdir. Ayrıca, bazı FBÖA, okullarda istedikleri modelleri bulamamaları durumunda, kendilerinin model geliştireceklerini ya da öğrencilerini model geliştirmeye yönlendireceklerini ifade etmişlerdir. Ancak, model kullanımı konusunda bu kadar istekli olmalarına karşın, FBÖA'nın derslerinde yeterli ve etkili bir şekilde modellerden faydalanmadıkları gözlemlenmiştir.

2.3.2. FBÖA'nın Kullandıkları Modeller

Ders planları ve ders gözlemlerinden elde edilen veriler, çalışmaya katılan FBÖA'nın, derslerinde, çizimler, tablolar, grafikler, simülasyonlar ve kavram haritaları gibi öğretim modellerini kullanma eğiliminde olduklarını göstermiştir. FBÖA'nın kullandıkları modellerine ilişkin kodlama planı ve frekans dağılımı Tablo 6'da verilmiştir.

Table 6. FBÖA'nın kullandıkları modellere ilişkin kodlama planı ve frekans dağılımı

Öğretim Modeli	Açıklama	Frekans dağılımı (N=14)
çizimler, grafikler, tablolar	FBÖA, bazı bilimsel olguları göstermek, açıklamak veya özetlemek için çizimler, tablolar veya grafikler kullandılar.	10
simülasyonlar/ animasyonlar	FBÖA, bazı bilimsel kavramları görselleştirmek amacıyla simülasyonlar veya animasyonlar gösterdiler.	5
kavram haritaları	FBÖA, öğrettikleri anahtar kavramları kavram haritaları yoluyla özetlediler.	4

Daha önce bahsedildiği gibi, elde edebildikleri veya kendilerinin geliştirebildikleri mümkün olan tüm modellerden faydalanacaklarını söyleyerek FBÖA, fen eğitiminde modellerin kullanımı konusunda isteklilik göstermişlerdir. Çoğu, görüşmeler sırasında, derslerinde fiziksel/maddesel modellerden faydalanacaklarını ifade ederken; ilginçtir ki, hiçbir FBÖA, derslerinde hiçbir fiziksel modelden faydalanmamıştır. Ders gözlemlerinden elde edilen veriler açıkça göstermiştir ki, neredeyse tüm FBÖA, dersleri sırasında işlenilen konuları açıklamak, temsil etmek veya özetlemek için yazı tahtasını kullanmışlardır. Bu eğilim, çizim, grafik ve tabloların sıkça kullanımıyla sonuçlanmıştır. Bu tip kullanımlar, bilimsel olgulara dair açıklamalar ve temsiller sağladıklarında model olarak kabul edilebilirler. Bu modellerin yanı sıra, bazı FBÖA ise, birtakım bilimsel süreçleri göstermek amacıyla öğrencilerine simülasyonlar ve animasyonlar göstermişlerdir. Animasyonlar, ilgili olguların bazı özelliklerini göstermek ve anlamak amacıyla geliştirilen modelleme ürünleridir. Diğer yandan simülasyonlar, değişkenleri manipüle etme ve manipülasyonun gerçek olgu üzerindeki etkilerini gözlemleme şansı tanırlar. FBÖA, ders planlarında, simülasyonların ve animasyonların öğrencileri derse karşı motive ettiklerini ve öğretilen kavramların kalıcılığını artırdıklarını ifade etmişlerdir. Son olarak, bazı FBÖA, öğrettikleri konuları özetlemek amacıyla, derslerinin sonunda önceden hazırlanmış oldukları kavram haritalarını göstermişlerdir.

TARTIŞMA:

Bu tezin bulguları, modellerin daha iyi anlaşılması gerektiğini savunan literatür bulguları ile benzerlik göstermiş, ve sınıf ortamında modellerin kullanımı açısından öğretmen adaylarının birtakım pedagojik eğitimlere ihtiyaç duyduğu görüşünü desteklemiştir. Bulgular, sahip oldukları *alan bilgisi* açısından fen bilgisi öğretmen adaylarının modeller konusunda bazı açılardan yeterli bilgiye sahipken, diğer bazı açılardan yeterli olmadıklarını göstermiştir. Örneğin, bilim adamlarının bakış açısı veya yaratıcılığına bağlı olarak aynı olgu için birden fazla modelin oluşturulabileceğini kabul ederek "yapılandırmacı" bir bakış açısı sergilerken, FBÖA, aynı zamanda, modellerin açıkladıkları/temsil ettikleri olgulara yakın olmaları (benzemeleri) gerektiğini savunarak "mantıksal pozitivist" bir bakış açısı da sergilemişlerdir (Van Driel & Verloop, 1999, s.1147). Diğer taraftan, modellerin fen bilgisi öğretiminde etkili araçlar oldukları inancında olup, gelecekte yapacakları sınıf içi uygulamalarında modellerden faydalanacaklarına yönelik güçlü derecede bir isteklilik gösterirken, FBÖA'nın ders uygulamalarında modelleri yeterli ve etkili bir şekilde kullanmadıkları gözlemlenmiştir. Bu bulgu, niyet ve uygulama arasındaki boşluğu destekler niteliktedir. Bu nedenle, öğretmen adaylarının modeller konusunda *alan bilgisi* ve *pedagojik alan bilgisi (PAB)* açısından desteğe ihtiyaç duydukları aşikârdır (Justi & Van Driel, 2005).

Bilimsel modellerin oluşumunda etkin olan öznelliğin, toplumsal ve kültürel bağlamın ve yaratıcılığın önemini benimsemeleri; ve bilimsel olguları açıklayan metodolojilerdeki çeşitliliğin farkında olmaları ile FBÖA'nın bilimsel bilginin ve dolayısıyla bilimsel modellerin doğasının farkında oldukları açıktır. Örneğin, çalışmaya katılın tüm FBÖA modellerin değişken doğasına değinmiş, yeni bulgular ve gelişmeler ışığında modellerin değişebileceğini belirtmişlerdir. Ayrıca bulgular, çalışmaya katılan FBÖA'nın model ile gerçek olgu arasındaki ilişki konusunda da bilgili olduklarını göstermiştir. Örneğin, model ile gerçek olgu arasında birebir bir ilişki olamayacağı görüşünden yola çıkarak FBÖA, bir fotoğrafın model olarak değerlendirelemeyeceği görüşünü savunmuşlardır. Bu bulguyu destekler şekilde, Van Driel ve arkadaşları (2007) da bir fotoğrafın bilimsel bir model olarak kabul edilemeyeceğini çünkü fotoğrafın ilgili olgudan bağımsız olarak var olamayacağını belirtmişlerdir. Bu umut verici bulgular, FBÖA'nın, üniversitede kayıtlı oldukları programda almış oldukları ve genellikle içeriğine bilimsel bilginin doğası ile ilgili bilgilerin ve etkinliklerin entegre edildiği derslere atfedilebilir. Diğer yandan, çalışmanın bulguları literatürde yer alan çalışmalara kıyasla umut vericidir (Akerson, Khalick & Lederman, 2000; Berber & Güzel, 2009; Erdoğan, 2004; Van Driel & Verloop, 1999). Bir örnek vermek gerekirse, Berber ve Güzel'in (2009) çalışmasında, (fen bilgisi ve matematik) öğretmen adaylarının %34'ü modellerin değişmediğine inanmışlardır. Bu öğretmen adaylarının düşüncelerine göre modeller, gerçekler üzerine kuruludur ve gerçekler değişmez, veya modeller değişmemek üzere geliştirilmişlerdir.

Daha önce de bahsedildiği gibi, yapılandırmacı bakış açılarının yanında, bu çalışmaya katılan FBÖA'nın çoğu, modellerin gerçek olguya benzemeleri gerektiğini savunarak mantıksal pozitivist bakış açıları da sergilemişlerdir (Van Driel & Verloop, 1999). Modellerin gerçek olguların tam bir kopyası olması genelde öğrencilerde görülen naif bir bakış açısıdır (Chittleborough ve ark., 2005; Grosslight ve ark., 1991; Harrison & Treagust, 2000a; Treagust ve ark., 2002; Van Driel & Verloop, 1999). Ancak, artan yaş ve deneyim ile birlikte, bu tür realist anlayışların azaldığı ve daha anlamlı bakış açılarının geliştiği görülmüştür (Chittleborough ve ark., 2005; Crawford & Cullin, 2004; Grosslight ve ark., 1991). Bu bulguya paralel olarak, çalışmamıza katılan neredeyse tüm FBÖA, modellerin gerçek olguların tam bir kopyası olamayacağını kavramış; ancak, modellerin gerçek olgulara mümkün olduğunca benzemesi gerektiği görüşünde de ısrarcı olmuşlardır. Modelleri, doğaları gereği erişilemez/gözlemlenemez olan bilimsel olguların açıklamaları veya temsilleri olarak tanımlayarak gerçek olgunun erişilemez olma özelliğini farketmelerine ragmen, FBÖA'nın modellerin gerçek olgulara benzemesi gerektiğini düşünmeleri ilginç bir bulgudur. Bu bulgu, bizi FBÖA'nın model konusundaki anlayışlarında tutarsızlıklar görüldüğü sonucuna vardırabilir ki, bu tutarsızlığının altında yatan muhtemel neden de, modeller konusunda FBÖA'nın "net olmayan" görüşlere sahip olmalarıdır. Müfredat ve dolayısıyla da ders kitapları, model kavramı hakkında net bilgiler sunmadığı için, öğrenciler (ve öğretmenler), modeller konusunda net düşünceler oluşturma fırsatı bulamamaktadırlar. Türkiye'deki Fen Eğitimi müfredatı, 2005-2006 yılından itibaren yapılandırmacı yaklaşımlar benimsemeye başladığından, çalışmamıza katılan FBÖA, geleneksel yaklaşımı benimsemiş olan eski müfredata göre eğitim almışlardır. Bu eski müfredatta, öğretmenler, geleneksel öğretim yöntemlerini uygulamakta ve yeterince yüklü olan bu müfredattaki kavramların tümünü öğrencilere öğretmeye çalışmaktaydılar. Ayrıca, Türkiye'deki öğretmenler, normal müfredatı uygulamanın yanı sıra, öğrencileri lise veya üniversite giriş sınavlarına da hazırlama baskısı altındadırlar. Diğer bir deyişle, Türkiye'de sınav odaklı bir eğitim sistemi bulunmakta; ve büyük olasılıkla böylesi sınıf ortamlarında öğrenciler, model kullanma veya geliştirme olanağı bulamamaktadırlar. Bu olumsuzluklara karşın, modellerin gerçek olguların tam bir kopyası olmasıyla ilgili olarak, çalışmamızın bulguları, konuya ilişkin literatür ile karşılaştırıldığında daha umut vericidir. Örneğin, Berber ve Güzel'e (2009) ait çalışmada öğretmen adaylarının %15'i, modelleri gerçek olguların tam bir kopyası olarak tanımlamışlardır. Diğer yandan Dogan ve Khalick'in (2008) çalışmasındaki çoğu öğretmen (%66'dan fazlası), bilimsel modellerin gerçek olguların kopyaları olduklarına inandıklarını ifade etmişlerdir. Böyle düşünmelerinin nedeni olarak ise, bilim adamlarının modellerin doğru olduğunu söylemeleri veya birçok bilimsel gözlemin ve/veya araştırmanın onları doğru olarak göstermelerinden bahsetmişlerdir. Benzer bir şekilde, Erdoğan'ın (2006) çalışmasına katılan öğretmen adaylarının % 47,2'si de, modellerin gerçek olguların kopyaları olduğunu düşünmekte ve %21,8'i, modellerin gerçek olguya benzemeleri gerektiği inancındalardır. Güneş, Gülçiçek ve Bağcı (2004) da, üniversitedeki öğretim elemanlarının %36'sının bir modelin gerçek olguya benzemesi gerektiği düşüncesini desteklediklerini ifade etmişlerdir.

Bu çalışmanın bir diğer önemli bulgusu, FBÖA'nın, modellerin *maddesel* kullanımlarını vurgularken, teorik ve *kavramsal* kullanımlarının pek fazla farkında olmayışlarıdır. Modellerin bilimsel olayları açıklamadaki rollerini kavrayıp, kavramsal rollerine bir miktar değinseler de; FBÖA, çoğunlukla 'görselleştirmek' ya da 'somutlaştırmak' gibi rolleri vurgulayarak modelleri üç boyutlu nesneler olarak görmekten ileri gidememişlerdir. Örneğin, maddesel modelleri (moleküllerin top-ve-çubuk modelleri gibi) daha çok benimseyip, onları *gerçek* modeller olarak adlandırırken, kimyasal formüller ve çizimler gibi temsilleri model olarak görmemişlerdir. Aslında bu tür modeller (yani, top-ve-çubuk modelleri ve kimyasal formüller) atom ve molekül gibi gözlemlenemeyen olguları öğrencilere erişilebilir kılmak amacıyla (Shulman, 1986) öğretmenler için/tarafından geliştirilen açıklayıcı araçlardır (Harrison & Treagust, 2000b). FBÖA'nın modeller konusunda sahip oldukları bu tip 'maddesel' görüşlerin nedeni, muhtemelen, 'model' teriminin kullanımına ilişkin daha önceki deneyimleri, yani, daha önceki eğitimleri ve kişisel tecrübeleridir. Araştırmalar, öğretmenlerin, modeller konusunda çoğunlukla sınırlı bilgilere sahip olduklarını, ve derslerini planlarken de daha çok ders kitaplarına bağlı kaldıklarını göstermiştir; ancak ders kitapları da modelleri uygun şekilde açıklamakta yeterli olmamaktadır (Harrison, 2001). Fen bilgisi ders kitapları genellikle DNA veya atom modelleri gibi fiziksel temsilleri 'model' olarak adlandırmakta, ve model terimini başka model türleri için nadiren kullanmaktadırlar; böylece, bilimsel modellerin yalnızca atom modelleriyle sınırlı olması gibi yanlış bir izlenim ortaya çıkmaktadır (Halloun, 2007). Fen bilgisi ders kitaplarında, bilimsel yayınlarda genellikle tercih edilen, grafik, tablo ve denklemler gibi, modellerin daha soyut biçimleri nadiren kullanılıp (Roth, Bowen & McGinn, 1999, akt: Al-Balushi, 2011) 'model' olarak adlandırılmaktadır. Ders kitaplarının model konusundaki anlayışlar üzerinde etkili olduğu açıktır; çünkü öğrencilere atomların ne renk olduğu sorulduğunda, verdikleri cevaplar kullandıkları ders kitabı ile yakından ilintilidir (McComas, 1998). Yani, ders kitabları atomları mavi renkte gösteriyorsa, öğrencilerin atomlara atfettiği renk mavi olmuştur (McComas, 1998). Bizim çalışmamızın bulgularıyla paralel olarak, araştırmalar, modellerin maddesel nesneler olarak algılanmasının yaygın bir anlayış olduğunu göstermektedir (Aktan, 2005; Gilbert, 1991; Gülçiçek & Bağcı, 2004; Justi & Gilbert, 2003, Schwartz & Skjold, 2012). Örneğin, Aktan'ın (2005) çalışmasındaki öğretmen adayları, üç-boyutlu modelleri benimsemiş ve genellikle fiziksel/maddesel objeler ile şematik gösterimleri model olarak adlandırmışlardır. Benzer şekilde, Justi ve Gilbert (2003) da, öğretmenlerin yüzde 59'unun modelleri üç boyutlu nesneler olarak adlandırdıklarını belirtmişlerdir. Yine, Güneş, Gülçiçek ve Bağcı'ya (2004) ait bir çalışmada, üniversite öğretim elemanlarınca bahsedilen örnekler arasında daha çok ölçekli modellerin (örn. maketler) ve teorik modellerin (örn. atom modelleri) bulunduğu görülmüştür. Bu bulgulardan hareketle, fen bilgisi eğitiminde modellerin kullanımının teşvik edilmesinin; ve fiziksel (örn. üç boyutlu modeller), görsel (örn. resimler, şekiller veya haritalar), sembolik (örn. denklemler veya formüller) veya sözel (örn. sözlü açıklamalar) modeller gibi çeşitli model türlerinin (Gilbert, Boulter & Rutherford, 1998) fen eğitimine entegre edilmesinin önemi açıktır. Modellerin farklı türlerinin kullanımı öğrencinin öğrenme sürecini ve modellerin işlevleri ile özellikleri hakkındaki görüşlerini şüphesiz ki geliştirecektir.

Son olarak, bu çalışmanın bulguları, modeller hakkında sınırlı anlayışlara sahip olsalar da, FBÖA'nın, modelleri fen eğitiminin önemli bir parçası olarak değerlendirdiklerini ve onları kullanma konusunda oldukça istekli olduklarını göstermiştir. Ancak, ilginç bir şekilde, derslerinde genel olarak fiziksel modelleri (güneş sistemi modeli gibi) kullanmayı planladıklarını söylemelerine rağman, hiçbir FBÖA, ders anlatırken bu tür modellerden faydalanmamıştır. Ayrıca, görüşmeler sırasında, mümkün olduğunca sık bir şekilde modelleri kullanacaklarını ve modellere ulaşamadıkları durumlarda da kendi modellerini geliştireceklerini söylemelerine rağmen, FBÖA'nın model kullanımları çizimler, grafikler, tablolar, animasyonlar ve kavram haritaları ile sınırlı kalmıştır. FBÖA genellikle yazı tahtasına çizim, tablo veya grafik yapmayı tercih etmiş; birtakım olguları göstermek için ise, simülasyon ya da animasyonlardan faydalanmıştır. Ayrıca, öğrettikleri konuları özetlemek için kavram haritaları da oluşturmuşlardır. FBÖA'nın fiziksel modelleri kullanmamalarının olası bir nedeni, bu tür modelleri oluşturmanın zorluğu olabilir. Yani, model geliştirme üzerine herhangi bir eğitim almadıklarından, bu tip bir etkinlik onlara zor gelmiş olabilir. Bu sebeple de, yapması daha kolay olan çizim, tablo ve grafikleri tercih etmiş olabilirler. FBÖA'nın model kullanımları ile ilgili diğer bir ilginç nokta ise, derslerinde animasyon, kavram haritaları veya grafik, çizim, tablo gibi *öğretim* modellerini kullanmalarına rağmen, ders planlarında veya derslerinde bu modelleri 'model' olarak nitelendirmemeleridir. Bu bulgular, FBÖA'nın modelleri başarılı bir şekilde kullanmak ve öğrencilerinin bilimsel modelleme etkinliklerine katılımlarını sağlamak için bilimsel modeller konusunda *pedagojik alan bilgisi (PAB)* açısından daha fazla eğitime ihtiyaç duyduklarına (Davis, Nelson, & Beyer, 2008) dair daha önce bahsedilen saptamayı teyit etmektedir. Schwarz ve White (2005), bilimsel modeller ve modelleme uygulamalarının amaçları ve doğası hakkındaki bilgileri "metamodelleme bilgisi" olarak adlandırmakta; ve bilimsel modeller hakkındaki PAB, öğretmenlerin anlamlı metamodelleme bilgisine sahip olmalarını, öğrencilerine modelleme uygulamaları yaptırabilecek öğretim stratejilerini bilmelerini, ve bilimsel modelleme konusunda öğrencilerin sahip olduğu düşünceleri ve zorlukları anlamalarını gerektirir (Davis, Nelson, & Beyer, 2008). Modellerin işlevleri olarak 'somutlaştırma' ve 'görselleştirmeyi' vurgulayak, çalışmamıza katılan FBÖA'nın yeterli metamodelleme bilgisine sahip olmadıkları açıkça görülmektedir. Diğer yandan derslerinde modelleri kısıtlı bir şekilde kullanmaları ve öğretim modelleri kullandıklarını farketmemeleri sebebiyle de, pedagojik araçlar olarak modellerin farkında olmadıkları görülmektedir. Öğretmenliğe yeni başlayacak olan bu öğretmen adaylarının, modeller hakkında bilgi sahibi olmaları ve pedagojik amaca hizmet edecek şekilde bu bilgilerini nasıl uygulamaya geçireceklerini öğrenmeleri önemlidir (Justi & Van Driel, 2005; Kenyon, Davis, & Hug, 2011; Windschitl, 2003; Windschitl & Thompson, 2006). Diğer bir deyişle, öğretmen adaylarının, modelleri kendilerinin anlamalarının yanı sıra, onları sınıf ortamlarında etkin bir şekilde kullanmayı öğrenmeleri ve öğrencilere modeller hakkındasağlıklı bilgiler edinmelerine yardımcı olmaları gerekmektedir.

APPENDIX D

CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Yenilmez Türkoğlu, Ayşe
Nationality: Turkish (TC)
Date and Place of Birth: 1980, İskenderun
Marital Status: Married
Phone: +90 312 210 75 05
Fax: +90 312 210 79 84
e-mail: ayseyenilmez@gmail.com

EDUCATION

Degree	**Institution**	**Year of Graduation**
MS	METU - Elementary Science and Mathematics Education	2006
BS	METU - Elementary Science Education	2003

WORK EXPERIENCE

Year	**Place**	**Enrollment**
2004-Present	METU - Department of Elementary Education	Research Assistant

FOREIGN LANGUAGES

Advanced English, Fluent German

PUBLICATIONS

1. Yenilmez Türkoğlu, A. & Tekkaya, C. (2012, September). *What understandings do pre-service science teachers possess about scientific models?* Paper presented at Applied Education Congress, Middle East Technical University, Ankara, Turkey.

2. Yenilmez Türkoğlu, A. & Boğar, Y. (2012, Haziran). *Eğitim fakültelerindeki araştırma görevlilerinin bilimsel modeller hakkındaki anlayışlarının incelenmesi.* 10. Ulusal Fen Bilgisi ve Matematik Eğitimi Kongresi, Niğde Üniversitesi, Niğde.

3. Yenilmez Türkoğlu, A**.** (2009, September). *What do teachers think about environmental education? A case study.* Paper presented at European Conference on Educational Research (ECER), Vienna, Austria.

4. Yenilmez Türkoğlu, A. & Tekkaya, C. (2008, September). *Elementary students' knowledge about models.* Paper presented at European Conference on Educational Research (ECER), Gothenburg, Sweden.

5. Tekkaya, C. & Yenilmez, A. (2006). Relation among measures of learning orientation, reasoning ability, and conceptual understanding of photosynthesis and respiration in plants for grade 8 males and females. *Journal of Elementary Science Education, 18*(1), 1-14.

6. Yenilmez, A. & Tekkaya, C. (2006). Enhancing students' understanding of photosynthesis and respiration in plant through conceptual change approach. *Journal of Science Education and Technology, 15*(1), 81-87.

7. Yenilmez, A., Sungur, S. & Tekkaya C. (2006). Students' achievement in relation to reasoning ability, prior knowledge and gender. *Research in Science and Technological Education*, *24*(1), 129-138.

8. Yenilmez, A. & Tekkaya, C. (2006, Eylül). *Öğrencilerin önbilgisi, öğrenme yaklaşımları, mantıksal düşünme yetenekleri, farklı öğretim yöntemleri ve fotosentez ve bitkilerde solunum konularını anlamaları arasındaki ilişkilerin araştırılması*. 7. Ulusal Fen Bilgisi ve Matematik Eğitimi Kongresi, Gazi Üniversitesi, Ankara.

9. Yenilmez, A., Sungur, S., & Tekkaya, C. (2005). Investigating students' logical thinking abilities: the effects of gender and grade level. *Hacettepe University Journal of Education*, *28*, 219-225.

HOBBIES

Balcony Gardening, Hand Made Crafts, Drawing and Painting, Cooking

APPENDIX E

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

Fen Bilimleri Enstitüsü ☐

Sosyal Bilimler Enstitüsü ■

Uygulamalı Matematik Enstitüsü ☐

Enformatik Enstitüsü ☐

Deniz Bilimleri Enstitüsü ☐

YAZARIN

Soyadı : Yenilmez Türkoğlu
Adı : Ayşe
Bölümü : İlköğretim Fen Bilgisi Öğretmenliği

TEZİN ADI : "INVESTIGATING PRE-SERVICE SCIENCE TEACHERS' UNDERSTANDINGS AND USE OF MODELS"

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ■

1. Tezimin tamamından kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
2. Tezimin içindekiler sayfası, özet, indeks sayfalarından ve/veya bir bölümünden kaynak gösterilmek şartıyla fotokopi alınabilir. ☐
3. Tezimden bir (1) yıl süreyle fotokopi alınamaz. ■

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: