Science Education International
Vol. 27, Issue 1, 2016, 88-116

Pre-service Teachers' Mental Models of Basic Astronomy Concepts

A. SAGLAM ARSLAN[*], U. DURIKAN[†]

ABSTRACT: The aim of the present study is to determine pre-service teachers' mental models related to basic astronomy concepts. The study was conducted using a survey method with 293 pre-service teachers from 4 different departments; physics education, science education, primary teacher education and early childhood education. An achievement test with open-ended questions was developed for the study, and the data obtained with this tool were analysed in two stages. In the first stage, pre-service teachers' level of understanding of basic astronomy concepts was determined and in the second stage, their mental models were defined based on these levels of understanding. It was determined that the pre-service teachers had 9 different mental models; ideal, basic, conceptual, memorizing, selective, definitional, concrete, relational and inappropriate. The analysis of data revealed that none of the pre-service teachers had an ideal model for the astronomy concepts in question, and the most common model was the inappropriate model. In addition, the results of this study put forward that pre-service teachers from different branches had similar mental models.

KEY WORDS: Mental model, Basic astronomy concepts, Pre-service teachers.

INTRODUCTION

Astronomy, which is closely associated with fundamental sciences such as mathematics, physics, chemistry and biology, has been a source of great interest and curiosity as a field of science for many years. Mankind first started astronomy studies by observing celestial bodies to fulfil their everyday needs. However today this field of science is so advanced that man can observe and gather information from far corners of the universe (Kırkbıyık et al., 2007).

When the part of astronomy in education is considered, it is effectively used to make students like and be interested in science (Tunca, 2005) and accordingly there are astronomy concepts and topics at different levels of the curricula. Percy (1998), who emphasized the importance of astronomy

[*] (Corresponding author) Karadeniz Technical University, Turkey. E-mail: asaglam-arslan@ktu.edu.tr
[†] Giresun University, Turkey

education, mentions that there are significant astronomy applications in our daily life and astronomy activities, which are particularly useful in the classroom since they have an observation dimension, unlike experimental methods. Moreover, astronomy is a science field that is effectively teaching individuals to think in a right and reasonable way (Tunca, 2005).

The role of teachers is vitally important in the process of conveying curriculum topics in the classroom environment (MEB, 2008). Besides instructional methods and techniques that teachers use, field knowledge possessed is also important (Erden, 2005). As Karal (2003) and Akpınar et al. (2004) highlighted in their studies, success in education and accordingly student performance, depend on teacher competences. Thus, determining the knowledge level of prospective teachers towards basic astronomy concepts faced in our lives from among the topics expected to be components of science studies, is important.

LITERATURE REVIEW

Astronomy related studies

There are many studies about astronomy concepts, which can be divided with respect to their sample groups.

Studies conducted with primary and secondary education level students

At the primary school level, studies were performed towards various aims:

- determining astronomy concepts perception state/levels of participants (Klein, 1982; Şahin, 2001; Baloğlu Uğurlu, 2005; Frede et al., 2009);
- determining related misconceptions (Sezen, 2002; Ekiz and Akbaş, 2005);
- analysing the effect of instruction in learners' learning (Kikas, 1998; 2005);
- to remediate the misconceptions on astronomy concepts (Sneider and Ohadi, 1998; Dunlop, 2000);
- increasing the efficiency of teaching astronomy concepts (Stahly, et al., 1999; Diakidoy and Kendeou, 2001; Barnett, et al., 2001; Lelliott, 2007; Barnett and Morran, 2002; Skopeliti and Vosniadou, 2007; Küçüközer et al., 2009; Plummer, 2009a, 2009b; Wilhelm, 2009)

There have been few studies at secondary school level and most existing studies have been mainly about the sun, Earth and moon system. At this level, there have been studies that aim to reveal existing knowledge/perception of students (Trumper, 2001a, 2001b), alternative

conceptions (Cin, 2007) and a focus on misconceptions (Sherrod and Wilhelm, 2009).

As generalizable results of these studies, it appears that students do not possess a sufficient level of conceptual knowledge about astronomy, but various instructional attempts have effectively contributed to the conceptual change of learners.

Studies conducted with pre-service and in-service teachers

Studies conducted with pre-service teachers have mainly aimed to determine the general understanding level of participants (Ünsal et al., 2001; Emrahoğlu and Öztürk, 2009), or perception states of basic astronomy topics (Bailey, 2006; Frede, 2006; Küçüközer, 2007) and to determine their opinions towards basic astronomy concepts (Kalkan and Kıroğlu, 2007). There have also been studies concerning the teaching of basic astronomy concepts/phenomena to pre-service teachers (Callison and Wright, 1993; Zeilik et al., 1997, 1999; Barnett, et al., 2001; Trundle, et al, 2002; Hudgins, 2005; Frede, 2008; Mullholland and Ginns, 2008) and focusing on misconceptions and alternative conceptions of pre-service teachers (Trumper, 2000; Fanetti, 2001; Trumper, 2006a, 2006b).

Only a limited number of studies have been conducted with teachers and most have focused on similar topics to the above mentioned studies. Thus, there have been studies about perceptions of teachers of astronomy concepts (Brunsell and Marcks, 2005); determining their alternative conceptions (Rutherford, 2004) and analysing the improvement in teachers' knowledge about basic astronomy topics (Henze, et al., 2008; Caballero, et al., 2008).

Some studies have been performed with both teachers and pre-service teachers. Barba and Rubba (1992) compared basic astronomy knowledge of pre-service and in-service teachers, Summer and Mant (1995) described the knowledge of pre-service and in-service teachers geared to basic astronomy concepts and Kanlı (2015) determined misconceptions of pre-service and in-service teachers in one stage of his study.

Analysing the studies indicated above, it can be said that they focus on determining an understanding level, misconceptions and alternative conceptions about astronomy concepts or designing educational environments seeking ways to improve the present situation. Based on these studies, determining mental models, which indicate the completeness of knowledge that an individual possess about a concept, is considered as a subject that can valuably add to findings for previous studies.

Mental Models

Mental models can be defined as individual, subjective, imperfect and improvable constructions, developed by a subject based on existing general

knowledge, they can only exist for a subject when dependent on a reason for their existence. The maintenance of their existence and the improvement of mental models are related to the living space provided by the subject (Sağlam-Arslan, 2010).

Not having an agreed and unique definition, mental models are defined as structural analogies of the real world, like perception and conceptualization (Johnson-Laird, 1983). Similarly, Vosniadou (1994) defined mental models as specific types of analogic, or cognitive representations, produced individually during cognitive processes. Rapp (2005) defined mental models as internalized and constructed structures of knowledge and experiences about real life. These definitions show that mental models bear similar attributes to models expressed as the result of the representation of an object, entity or idea (target) with a more familiar source (Örnek, 2008). In terms of instructional activities, mental models are as important as models used as principal teaching and learning tools (Harrison and Treagust, 2000). This is because mental models are internal representations of real situations existing in the thoughts of individuals, with the aim of understanding and perceiving events in the world (Franco and Colinvaux, 2000). In other words, mental models are cognitive representations used for reasoning, defining, explaining, guessing or sometimes testing operations about a phenomenon (Buckley and Boulter, 2000; Örnek, 2008). Norman (1983) noted that they guide mankind while using their thoughts. On the other hand, mental models can be interpreted as handy types of knowledge to reflect the degree of an individual's overall comprehension of events, situations and systems in the educational process (Vosniadou and Brewer, 1992). The most significant aspect of mental models is that the knowledge obtained from them presents important data to teachers and researchers regarding the knowledge construction of students (Vosniadou, 1994). Beyond being a kind of knowledge based on declaration and method, mental models are a learning outcome, including the acquiring of semantic relations and skills used for understanding a system (Bland and Tessmer, 1999). The general features of mental models and the development of a mental model is outlined in Figure 1.

When a subject encounters a system (this can be a piece of information, a concept, an issue, an event or a situation), mental model development does not occur spontaneously. It requires certain cognitive stages. The subject processes the system through a perception filter composed of a communication channel, experiences, language, pre-knowledge etc. to form perception.

In most cases, together with perception formation, another system is formed called the "*selected system*". Since the subject shapes his/her own system with his/her own features, the "*selected system*" is mentioned in the formation process of a mental model. The selected system is structured depending on the attributes of the subject, like understanding capacity,

existing context, cultural and social aspects *etc*. and thus the "*structured system*" is formed. Mental model formation about the initial real system is completed by likening or combining this structured system with pre-existing schemes in mind.

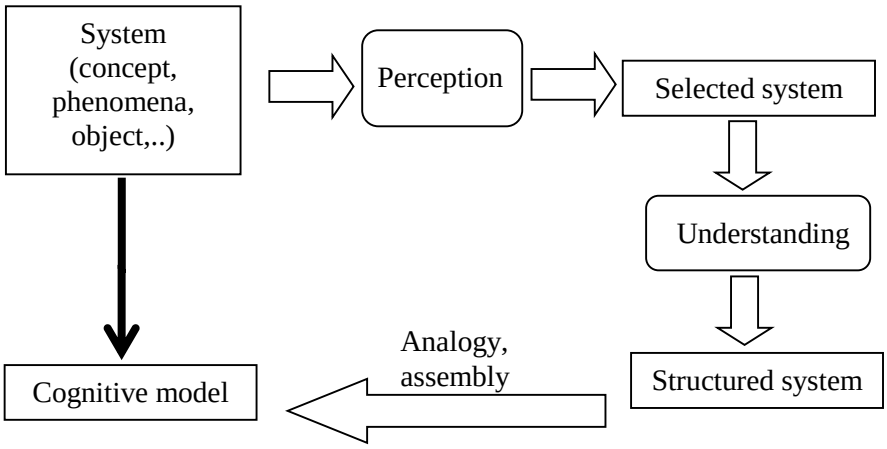


Figure 1 Development of a mental model

General mental models formed via this pathway are not similar one-to-one and therefore are not coincident to the real system. Actually, subjects define the existence of a system and how it is perceived. They explain the present situation of the system, how the system works and speculate on the future situation of the system, based on their own mental models (Norman, 1983; Rouse and Morris, 1986 cited by Bland and Tessmer, 1999; Barquoero, 1995; cited by Greca and Moreira, 2000; Jonassen and Cho, 2008).

Mental models, which cognitive science defines as centers where learning occurs, are not directly accessible. However, they can be identified by interpreting gestures, facial expressions, speech and writings of individuals used in communication (Justi and Gilbert, 2000). Therefore, the characteristics of mental models should be known, so that they can be identified and understood. Based on the literature, four fundamental characteristics of mental models can be mentioned:

- Mental models can be used in the process of producing new knowledge (Vosniadou and Brewer, 1992).
- Individuals can be unaware of the existence of their own mental models and that they use them (Örnek, 2008; Ünal-Çoban, 2009). Mental models include tacit knowledge (Franco and Colinvaux,

2000). Consequently, the existence and state of mental models can only be speculative, based on observable behaviors (Rapp, 2005).
- Mental models have a synthetic nature (Franco and Colinvaux, 2000). Eventually, learners form their mental models by synthesizing their pre-knowledge with knowledge they encounter during learning (Harrison and Treagust, 2000).
- Mental models are restricted to the vision of the owner, since they are affected by beliefs (Franco and Colinvaux, 2000; Örnek, 2008).

In addition to these four basic characteristics, some researchers see mental models as internal representations having different characteristics. Mental models can be incomplete, alterable, restructured, improvable and non-scientific, without strict borders but must be usable by their owners (Norman, 1983; Franco and Colinvaux, 2000; Buckley and Boulter, 2000; Harrison and Treagust, 2000; Barquoero, 1995 cited by Greca and Moreira, 2000; Ünal and Ergin, 2006). To summarize, mental models which are structured by experiences in our daily lives and learning processes, are assessed and reconstructed unconsciously when it is becomes necessary.

Mental model studies about astronomy topics

Mental model studies about astronomy topics in related literature were mainly at primary school level and clustered on the topics related to the concept of 'the Earth' and can be summarized as:

- Mental models of students from various levels of primary school about the shape of the Earth:
  a. initial model, synthetic model and scientific model (Vosniadou and Brewer, 1992);
  b. sphere in space model, sphere on water model, spheroid in space model, hollow sphere in space model, hollow sphere on water, disk in space model, disk on space model, rectangular earth on water model (Vosniadou and Brewer, 1994);
  c. scientific model, flat earth model, hollow sphere model and dual earth model (Panagiotaki, et al., 2008);
  d. sphere model, sphere without gravity model, hollow sphere model, disk model and rectangular model (Vosniadou, et al., 2004);
  e. flat, hollow, dual, flattened, no gravity, scientific model (Straatemeier, et al., 2008).
- Models of kindergarten students about the Earth: flat earth, hollow sphere, dual earth and flattened sphere, spherical earth (Hannust and Kikas, 2007).

- Mental models of university students about the Earth: scientific, circular, semi-circular, flat earth, dual earth, hollow earth, 2 pictures, three pictures (Nobes and Panagiotaki, 2007).

The studies above imply that students from different levels (kindergarten, primary school and university) have similar mental models about the Earth.

There have also been studies sampling mental models about astronomy topics: Samarapungavan et al., (1996) focused on mental models of primary school students about cosmology and determined students produce both sun centred and Earth centred models. In another primary school level study, Liu (2003) stated that students had four earth centred and three sun centred, mental models about the Earth. Vosniadou and Brewer (1994) investigated primary school students' mental models about night and day cycles and identified eight different models. They grouped these models under three titles and by associating them with the mental models formed a previous study (Vosniadou and Brewer, 1992). Three of the eight models were classified as initial models, four were put under a synthetic model title and the remaining one seen as a scientific model. By working with a different sample group, Spiliotopoulou and Ioannidis (1996) revealed mental models of teachers working at primary school level about the universe concept by using their explanations and sketches. The models were named as physical, meta-physical and symbolic models.

Apart from mental model determining studies, Taylor, et al. (2003) developed a novel Mental Model-building Strategy and investigated how this strategy affects learners' mental model about the sun–Earth–moon system.

Purpose and Problem

The literature review above suggests no studies have been carried out on mental models of pre-service teachers. As teachers shape the steps of education i.e. from kindergarten to the end of secondary school, it is obvious that identifying mental models of pre-service teachers is important. On the other hand, the literature study revealed that the majority of the studies conducted in this field focused on a particular astronomy concept/topic (the sun, the Earth, and the universe etc.). In this context, comparing and contrasting mental models about basic astronomy concepts (e.g. stars, planets) and mental models about concept examples (e.g. the sun, the Earth) is perceived as a valuable study added to the literature findings in this area.

This study determining the knowledge pre-service teachers have about basic astronomy concepts and concept examples examined from a holistic point of view. Thus, the purpose of the present study is to determine mental models of pre-service teachers from various departments about basic

astronomy concepts (planets, stars, satellites, the earth, the sun and the moon). Within this context, answers to the following research questions were pursued.

1. What are the pre-service teachers' mental models of basic astronomy concepts?
2. How do mental models differ with regard to the departments that pre-service teachers come from?
3. What kind of relation is there between mental models of concepts and concept examples?

METHODOLOGY

Sample

Since this study aims to describe an existing situation realistically, it was conducted using a survey method, as one of the descriptive methods, and aims to define and determine the related situation in the best way possible.

As basic astronomy concepts are taught exclusively by early childhood, classroom, science education and physics teachers, the sample of the study included 293 pre-service teachers, registered in the early childhood education (74), primary school (classroom) education (70), science education (87) and physics education (62) departments.

Instrument

At first, along with the aim of the study, basic astronomy concepts, which the participants are supposed to teach in their teaching life were determined by reviewing the related curricula. For example, the topics for early childhood education are day, night, earth, sun and moon. The primary school curricula add planet, star, moon and its phases, satellite, yesterday, today, afternoon etc. For high school teaching (science education and physics education), more complex topics include galaxies, the solar system, space, etc. Consolidating the results of this review, the topics to be included in the instrument were determined and an achievement test with open-ended questions was developed.

In order to test the appropriateness and comprehensibility of the instrument, research questions and the achievement test were discussed with a group including three physics lecturers and one physics teacher. Furthermore, in order to test the instrument, a pilot study was also conducted. In the pilot study, the achievement test was administered to 21 graduate students registered in Mathematics Education who were attending basic physics lessons and having the same background as the sample.

Based on the pilot study, the questions and expressions where participants had difficulty were reorganized. The achievement test was

finalized with repeated expert consultation. The questions in the survey included the following;

1. How can you explain the following concepts given below? You can support your explanations by giving examples when necessary. Earth, Sun, Moon, Planet, Star, Satellite
2. What kind of shapes can you draw related to these celestial bodies?
3. Describe the structure of these celestial bodies. What is/are contained in their structures?
4. How do you explain the differences and similarities between the following celestial body pairs? Earth-Planet, Sun-Star, Moon-Satellite

Data analysis

In this study, mental models about basic astronomy concepts were determined using a two-stage analysis method. In the first stage, the responses given to the achievement test questions were analysed with respect to their level of understanding (Table 1).

Table 1 The levels of understanding and their characteristics

Theme	Level	Characteristics
Definition / Structure (for questions 1,3) (Abraham et al., 1994)	[0]	No response/ 'I do not know' / 'I have not understood' and similar responses/ Repeating question/ Irrelevant / ambiguous responses
	[1]	No understanding/ Wrong responses
	[2]	Partial understanding/ Responses having some aspects of the valid answer and misconceptions
	[3]	Restricted understanding/ Responses not having all requirements of the valid answer
	[4]	Sound understanding/ Responses having all requirements of the valid answer
Shape (for question 2) (Kara et al., 2008; Uzunkavak, 2009)	[0]	No drawing
	[1]	Wrong drawing
	[2]	Right drawing with wrong aspects
	[3]	Right but incomplete drawing
	[4]	Right and complete drawing
Relations between the concepts (for question 4) (Liu *et al*., 2008)	[0]	No response/ Non-scientific relations
	[1]	Unable to relate two concepts/ Making wrong relations or no relations
	[2]	Partial relation/ Drawing relations between two concepts but unable to explain
	[3]	Restricted relation/ Drawing relations between two concepts but explaining it in a restricted way
	[4]	Scientific relation/ Drawing relations between two concepts and explaining it

For any given concept, the participants' levels of understanding were analysed with regard to levels proposed by Abraham et al. (1994), and drawings made by the participants to exemplify any concept were analysed using the levels determined by Kara et al. (2008) and Uzunkavak (2009). The relationships established between any of the concepts and corresponding concept examples were analysed with the adaptation of the levels offered by Liu et al. (2008).

In the second stage of analysis, students' mental models were determined as a result of holistic analysis of all the questions related to the concept in question (or concept example). From the assembled mental models, explanations about these models and the relations among the levels of understanding about these models, were summarized and given in Table 2. This system of models was developed based on the system called Students' Model of Understanding in Typology of Perceived Knowledge by Sağlam (2004). Similarly, İyibil (2010), Sağlam-Arslan and Devecioğlu (2010) and Kurnaz (2012) used this model to determine mental models in their studies.

The participants' mental models for basic astronomy concepts were determined by analyzing the participants' levels of understanding from answers given in response to the items in the achievement test. For example, if a participant gave answers about a definition of a concept at the 3rd level, for shape at the 4th level, for structure at 2nd level and for relations with other concepts at the 1st level, the mental model of this participant could be determined as the *Memorizing model*, by considering the matrices presented in Table 2.

Reliability

To ensure the reliability of the results, classification of the students' responses according to the level was checked by another expert who studied in this area. In this process, the expert coded most of the student responses by referring to the characteristic features given in Table 1. Scorers' reliability coefficient between two coding was calculated to be 0.86.

A similar reliability procedure was followed in the second part of the analysis, the determining mental models phase. Each student answer sheet was considered individually and mental models were determined by seeking one to one correspondence between the levels of student answers and pre-determined levels for the mental models in Table 2. Therefore, all student answers, given for the questions in the data collecting tool who had a (NaM) model, were at 0, 1 or 2 levels. This classification was checked randomly by an expert and it was determined that all the requirements of the classification were met.

Table 2 Relationship between the level of understanding and pre-service teachers' mental models

Mental models	Characteristics of Model	Relations btw levels {D, S, St, R}
Ideal model (IM)	Defining the concept, drawing the figure of the concept, explaining the structure and making the relation between the concept and other concepts.	$\left\{\begin{matrix}3&3&3&3\\4&4&4&4\end{matrix}\right\}$
Basic model (BM)	Defining the concept, drawing the figure of the concept and making relation connections with other concepts but not being able to explain the structure of the concept.	$\left\{\begin{matrix}3&3&0&3\\4&4&1&4\\&&2&\end{matrix}\right\}$
Conceptual model (CM)	Defining the concept and making relation connections with other concepts but not being able to explain the structure of the concept and not being able to draw the figure of the concept.	$\left\{\begin{matrix}0&3&0\\1&3&1\\2&3&2\end{matrix}\right\}$
Memorizing model (MM)	Defining the concept and drawing the figure of the concept but not being able to make relation connections with other concepts and not being able to explain the structure of the concept.	$\left\{\begin{matrix}3&3&0&0\\4&4&1&1\\&&2&2\end{matrix}\right\}$
Selective model (SM)	Drawing the figure of the concept and making relation connections with other concepts but not being able to define the concept and they not being able to explain the structure of the concept.	$\left\{\begin{matrix}0&&0&\\1&3&1&3\\2&4&2&4\end{matrix}\right\}$
Defining model (DM)	Only defining the concept but not being able to make relation connections with other concepts; not being able to explain the structure of the concept and not being able to draw the figure of the concept.	$\left\{\begin{matrix}&0&0&0\\3&1&1&1\\4&2&2&2\end{matrix}\right\}$
Concrete model (CoM)	Only drawing the figure of the concept. / Not being able to define the concept; not being able to make relation connections with other concepts. Not being able to explain the structure of the concept.	$\left\{\begin{matrix}0&&0&0\\1&3&1&1\\2&4&2&2\end{matrix}\right\}$
Relational model (RM)	Only making relation connections with other concepts. Not being able to draw the figure of the concept. / Not being able to define the concept; not being able to explain the structure of the concept.	$\left\{\begin{matrix}0&0&0&\\1&1&1&3\\2&2&2&4\end{matrix}\right\}$
Non-adaptive model (NaM)	Not being able to define the concept; not being able to draw the figure of the concept. / Not being able to make relation connections with other concepts; not being able to explain the structure of the concept.	$\left\{\begin{matrix}0&0&0&0\\1&1&1&1\\2&2&2&2\end{matrix}\right\}$

* Abbreviations in this table: D stands for Definition of concept, S for shape, St for structure and R for relations with other concepts.

FINDINGS

The findings are reported as:

a. the responses given by each student for the questions about basic astronomy concepts (definition, shape, structure, relation), analyzed with respect to levels of understanding.
b. the mental model of each student for the given concept developed, based on these levels of understanding (by analyzing all the answers given by the student to the questions related to the concept in question).
c. comparisons of mental models of different pre-service teachers for concepts and concept examples.

a. Levels of understanding of basic astronomy concepts of pre-service teachers from different departments

Table 3 shows that the responses given by the participants for the questions inquiring about the definition and structural aspects of the planet concept were classified at the partial level of understanding and were almost at the same level for all departments. Furthermore, Table 3 shows that responses at the sound level of understanding were given to the question, which requires drawing a shape to explain planet concept.

The question

a. asking to define the Earth, as an example of planets, was mainly answered at the restricted level of understanding;
b. about structural characteristics of the earth was answered at the sound level of understanding by the majority of students (Table 3).
c. on identification of the relation between a planet and the earth was mainly answered by participants at the partial relation level.
d. question about defining the star concept and drawing its shape was mainly answered at the no understanding level.
e. about structural features of the sun were clustered at the no understanding and partial levels of understanding.
f. about the definition and structure of the sun were answered at the no understanding level and the answers about the shape of the sun were mainly at the partial level of understanding.
g. about the relations drawn by the participants between a star as a concept and the sun as a concept example were answered at the making no relation and making restricted relation level.
h. about definitions about satellites were answered at the no response level; the drawings about satellites were at the no response and sound levels of understanding;

Table 3 The distribution of the participants' levels of understanding about the characteristics of the astronomy concepts

		Planet[f (%)*]				The Earth [f (%)*]				Star [f (%)*]				The Sun [f (%)*]				Satellite [f (%)*]				The Moon [f (%)*]			
Theme	Levels	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE
Definition	[0]	26 (34)	25 (36)	12 (14)	12 (19)	12 (16)	18 (26)	2 (2)	6 (10)	19 (26)	23 (3)	11 (13)	17 (27)	10 (14)	14 (20)	3 (3)	4 (6)	38 (51)	39 (56)	26 (30)	25 (40)	12 (16)	19 (27)	4 (5)	5 (8)
	[1]	27 (36)	38 (54)	48 (55)	38 (61)	24 (32)	15 (21)	19 (22)	11 (18)	55 (74)	45 (64)	69 (79)	40 (65)	57 (77)	48 (69)	66 (76)	38 (61)	5 (8)	11 (16)	14 (16)	10 (16)	33 (45)	8 (11)	5 (6)	11 (18)
	[2]	22 (30)	7 (10)	27 (31)	10 (16)	31 (42)	20 (29)	39 (45)	24 (39)	-	2 (3)	6 (9)	5 (8)	7 (9)	7 (10)	13 (15)	15 (25)	27 (36)	13 (19)	20 (23)	10 (16)	3 (4)	1 (1)	6 (7)	4 (6)
	[3]	-	-	-	2 (3)	7 (10)	17 (24)	27 (31)	21 (33)	-	-	1 (1)	-	-	1 (1)	5 (6)	5 (8)	4 (5)	7 (10)	27 (31)	15 (24)	23 (31)	37 (53)	44 (50)	28 (45)
	[4]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2 (3)	3 (4)	5 (8)	28 (32)	14 (22)
Shape	[0]	17 (23)	5 (8)	10 (12)	13 (21)	4 (5)	3 (4)	1 (1)	4 (6)	8 (11)	2 (3)	10 (11)	13 (21)	4 (5)	2 (3)	-	5 (8)	27 (37)	28 (40)	21 (24)	20 (32)	5 (7)	2 (3)	1 (1)	5 (8)
	[1]	-	1 (1)	2 (2)	5 (8)	-	-	2 (2)	2 (3)	60 (82)	68 (97)	73 (84)	45 (73)	6 (8)	10 (14)	15 (17)	7 (11)	14 (19)	13 (19)	10 (12)	7 (11)	2 (3)	-	-	-
	[2]	2 (3)	1 (1)	-	-	21 (28)	33 (47)	34 (39)	28 (45)	6 (8)	-	4 (5)	4 (6)	64 (87)	58 (83)	71 (82)	50 (81)	7 (9)	1 (1)	-	2 (3)	44 (59)	29 (42)	18 (21)	16 (26)
	[3]	-	3 (4)	-	4 (6)	47 (64)	34 (49)	45 (52)	27 (44)	-	-	-	-	-	-	1 (1)	-	-	-	1 (1)	7 (11)	6 (8)	12 (17)	22 (25)	14 (22)
	[4]	55 (74)	60 (86)	75 (86)	40 (65)	2 (3)	-	5 (6)	1 (2)	-	-	-	-	-	-	-	-	26 (35)	28 (40)	55 (63)	26 (42)	17 (23)	27 (38)	46 (53)	27 (44)
Structure	[0]	25 (34)	17 (24)	9 (10)	7 (11)	2 (3)	1 (1)	-	-	24 (32)	11 (16)	20 (23)	19 (31)	12 (16)	8 (11)	12 (14)	10 (16)	37 (50)	20 (29)	18 (21)	17 (27)	15 (20)	6 (9)	7 (8)	6 (10)
	[1]	5 (7)	8 (11)	4 (5)	3 (5)	1 (1)	-	-	2 (3)	27 (37)	26 (37)	25 (29)	22 (35)	47 (64)	49 (70)	41 (47)	25 (40)	2 (3)	9 (13)	9 (10)	4 (6)	5 (7)	7 (10)	5 (6)	5 (8)
	[2]	30 (41)	29 (42)	32 (37)	28 (45)	11 (15)	11 (16)	12 (14)	12 (19)	21 (28)	32 (46)	35 (40)	19 (31)	9 (12)	8 (11)	18 (21)	10 (16)	25 (33)	27 (38)	28 (32)	23 (38)	26 (35)	24 (33)	20 (23)	12 (19)
	[3]	11 (15)	9 (13)	24 (28)	15 (25)	19 (26)	12 (17)	16 (18)	9 (15)	2 (3)	1 (1)	6 (7)	2 (3)	6 (8)	5 (8)	16 (18)	17 (28)	2 (3)	1 (1)	2 (2)	1 (2)	22 (30)	20 (29)	42 (48)	28 (45)
	[4]	3 (4)	7 (10)	18 (21)	9 (15)	41 (55)	46 (66)	59 (68)	39 (63)	-	-	1 (1)	-	-	-	-	-	8 (11)	13 (19)	30 (35)	17 (27)	6 (8)	13 (19)	13 (15)	11 (18)
Relation	[0]	9 (12)	7 (10)	5 (6)	6 (10)					8 (11)	6 (9)	3 (3)	6 (10)					17 (23)	19 (27)	10 (11)	12 (19)				
	[1]	6 (8)	5 (8)	7 (8)	6 (10)					24 (32)	26 (37)	36 (41)	18 (30)					1 (1)	6 (9)	4 (6)	4 (6)				
	[2]	39 (53)	31 (44)	46 (53)	28 (45)					10 (14)	10 (14)	15 (18)	8 (13)					45 (61)	31 (44)	44 (51)	28 (45)				
	[3]	20 (27)	27 (38)	29 (33)	22 (35)					32 (43)	28 (40)	33 (38)	30 (47)					11 (15)	14 (20)	29 (32)	18 (30)				
	[4]	-	-	-	-					-	-	-	-					-	-	-	-				

* The percentage values were calculated for pre-service teachers from different departments considering the number of participants from that department.

i. about structural characteristics of satellites were answered at the no response and partial levels of understanding.
j. about the definition of the moon were answered at the restricted level of understanding; the drawings about it were at the partial and sound levels of understanding; the explanations about the structure of the moon were at the partial and restricted levels of understanding.
k. about responses to match the conceptual relation between the satellite concept and the moon were mainly answered at the partial relation level.

b. Mental models of pre-service teachers from different departments about basic astronomy concepts

The participants' mental models about basic astronomy concepts, investigated by considering the distribution of the levels of understanding of the responses they had given to the questions in the achievement test, are summarized in Table 4. The table shows that none of the participants had an ideal model about basic astronomy concepts.

Table 4 Pre-service teachers' mental models about basic astronomy concepts

	Planet [f (%)]	The Earth [f (%)]	Star [f (%)]	The Sun [f (%)]	Satellite [f (%)]	The Moon [f (%)]
Ideal model (IM)	-	-	-	-	-	-
Basic model (BM)	5 (2)	20 (7)	-	-	19 (7)	38 (13)
Conceptual model (CM)	-	14 (5)	1 (1)	5 (2)	1 (1)	11 (4)
Memorizing model (MM)	-	22 (7)	-	-	27 (9)	**83 (28)**
Selective model (SM)	**83 (28)**	34 (12)	-	-	26 (9)	11 (4)
Definitional model (DM)	-	16 (6)	-	-	8 (3)	**50 (17)**
Concrete model (CoM)	**113 (39)**	**84 (29)**	-	-	**71 (24)**	37 (13)
Relational model (RM)	10 (3)	30 (10)	**122 (41)**	**118 (40)**	25 (8)	12 (4)
Inappropriate model (InM)	**82 (28)**	**73 (24)**	**170 (58)**	**170 (58)**	**116 (39)**	51 (17)

Table 5 shows that the early childhood pre-service teachers had mostly concrete (49%) mental models. The pre-service teachers from primary school classroom teachers' education, on the other hand, had inappropriate (58%) mental models and selective (31%) mental models for the same concept. The mental models possessed by the pre-service teachers from primary school science education and physics education departments had similar patterns.

Table 5 The distribution of mental models of basic astronomy concepts according to their departments

	Planet[f (%)*]				The Earth [f (%)*]				Star [f (%)*]				The Sun [f (%)*]				Satellite [f (%)*]				The Moon [f (%)*]			
Mental models' types	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE	ECTE	CTE	STE	PTE
Basic model (BM)	-	-	-		2 (3)	3 (4)	10 (12)	5 (8)	-	-	-	-	-	-	-	-	1 (1)	3 (4)	8 (9)	7 (11)	3 (4)	4 (6)	19 (22)	12 (19)
Conceptual model (CM)	-	-	-	-	1 (1)	4 (6)	-	9 (15)	-	-	1 (1)	-	-	1 (1)	-	4 (6)	-	-	-	1 (2)	2 (3)	3 (4)	4 (5)	2 (3)
Memorizing model (MM)	-	-	-	-	4 (5)	4 (6)	11 (13)	3 (5)	-	-	-	-	-	-	-	-	2 (3)	3 (4)	16 (18)	6 (10)	7 (10)	19 (27)	38 (43)	19 (31)
Selective model (SM)	19 (26)	22 (31)	26 (30)	16 (26)	11 (15)	10 (14)	10 (12)	3 (5)	-	-	-	-	-	-	1 (1)	-	5 (7)	4 (6)	11 (13)	6 (10)	2 (3)	3 (4)	4 (5)	2 (3)
Definitional model (DM)	-	-	-	-	-	6 (9)	6 (7)	4 (6)	-	-	-	-	-	-	-	-	1 (1)	1 (1)	3 (3)	3 (5)	14 (18)	16 (23)	11 (13)	9 (15)
Concrete model (CoM)	36 (49)	41 (58)	49 (56)	26 (42)	32 (44)	16 (23)	19 (22)	17 (27)	-	-	-	-	-	-	-	-	18 (24)	18 (26)	21 (24)	14 (22)	11 (15)	11 (16)	7 (8)	8 (13)
Relational model (RM)	1 (1)	5 (8)	3 (4)	4 (6)	6 (8)	10 (14)	9 (10)	5 (8)	32 (43)	28 (40)	32 (37)	30 (48)	32 (43)	27 (39)	32 (37)	26 (42)	5 (7)	7 (10)	9 (10)	4 (6)	4 (5)	4 (6)	2 (2)	2 (3)
Inappropriate model (InM)	18 (24)	2 (3)	9 (10)	14 (23)	18 (24)	17 (24)	22 (25)	16 (26)	42 (57)	42 (60)	54 (62)	32 (52)	42 (57)	42 (60)	54 (62)	32 (52)	42 (57)	34 (49)	19 (22)	21 (34)	31 (42)	10 (14)	2 (2)	8 (13)

ECTE: **E**arly **C**hildhood **T**eacher **E**ducation, CTE: **C**lassroom **T**eacher **E**ducation, STE: **S**cience **T**eacher **E**ducation, PTE: **P**hysics **T**eacher **E**ducation

* The percentage values in the table were calculated for pre-service teachers from different departments by considering the number of participants sampled from that department

The participants had different mental models for the earth, three of which were dominant ones: concrete, selective and inappropriate models. The participants had more or less parallel mental models for the star concept and the sun. It was determined that

a. participants from the early childhood education and classroom teachers' departments had concrete (24%, 26%) and inappropriate (57%, 49%) models;
b. participants from the science education and physics departments had concrete (24%, 22%), basic (9%, 11%), memorizing (18%, 10%), selective (13%, 10%) and inappropriate (22%, 34%) models for the satellite concept;
c. early childhood pre-service teachers mostly had inappropriate (42%), then definitional (18%), concrete (15%) and memorizing (10%) models respectively for the moon concept example;
d. pre-service classroom teachers had memorizing (27%), definitional (23%), concrete (16%) and inappropriate (14%) models;
e. pre-service science teachers had memorizing (43%), basic (22%) and definitional (13%) models;
f. pre-service physics teachers had memorizing (31%), basic (19%), definitional (15%), concrete (13%) and inappropriate (13%) models.

In order to make the manner of the classification of the participants' mental models clearer and more objective, the responses given by the participants were exemplified for each separate mental model in Appendix 1.

c. Relationship Between the pre-service teachers' mental models in concept and examples of the concept

The relationship between mental models that participants have for the Planet-Earth pair is presented in Table 6.

Table 6 shows that pre-service teachers had five different models for the planet concept and concrete and selective models were the most dominant. In addition, Table 6 also indicates that the majority of the participant had similar mental models for the planet- the earth couple. One of the two participants having a basic model for the planet concept also had a basic model for the earth. Moreover, 63 of 113 participants with a concrete model for the planet concept also had a concrete model for the Earth. Similarly, 19 of 43 participants with an inappropriate model; 6 of 13 participants with a selective model; and 31 of 83 participants with a selective model, also had the same model for the Earth. Concerning this data, it was concluded that the mental model related to the planet concept affects the mental model for the Earth.

Table 6 Relationship between the mental models about planets and the Earth

Planet / f	The Earth / f	ECTE	CTE	STE	PTE
Basic Model / 2	Basic Model / 1	-	-	-	1
	Conceptual Model / 1	-	-	-	1
Selective Model / 83	Basic Model / 19	2	3	10	4
	Selective Model / 31	11	9	8	3
	Relational Model / 24	5	7	8	4
	Conceptual Model / 9	1	3	-	5
Concrete Model / 113	Concrete Model / 63	22	15	15	11
	Inappropriate Model / 55	11	16	19	9
	Memorizing Model / 19	3	4	10	2
	Definitional Model /15	-	6	5	4
Relational Model / 13	Relational Model / 6	1	3	1	1
	Conceptual Model / 4	-	1	-	3
	Selective Model / 3	-	1	2	-
Inappropriate Model / 43	Inappropriate Model / 19	7	1	4	7
	Concrete Model / 20	10	1	3	6
	Memorizing Model / 3	1	-	1	1
	Definitional Model / 1	-	-	1	-

ECTE: **E**arly **C**hildhood **T**eacher **E**ducation, CTE: **C**lassroom **T**eacher **E**ducation, STE: **S**cience **T**eacher **E**ducation, PTE: **P**hysics **T**eacher **E**ducation

The relationship between the mental models for the star concept and the sun is summarized in Table 7.

Table 7 Relationship between the mental models for the star concept and the Sun

Star / f	The Sun / f	ECTE	CTE	STE	PTE
Conceptual Model / 1	Relational Model / 1	-	-	1	-
Relational Model / 122	Relational Model / 116	32	27	31	26
	Conceptual Model / 5	-	1	-	4
	Selective Model / 1	-	-	1	-
Inappropriate Model / 170	Inappropriate Model / 170	42	42	54	32

Table 7 shows that the majority of the pre-service teachers had similar mental models for the star-sun pair. Accordingly, all of the pre-service teachers having the most common mental model; the inappropriate model for the star concept, also had the same model for the sun. Similarly, 116 of 122 pre-service teachers with a relational model for the star concept also had a relational model for the sun. However, this situation was different for a pre-service teacher with the conceptual model for the star concept.

The relationship between the mental models about the satellite concept and the moon is summarized in Table 8.

Table 8 Relationship between the mental models for the satellite concept and the moon

Satellite/ f	The Moon / f	ECTE	CTE	STE	PTE
Basic Model / 19	Basic Model / 15	1	3	6	5
	Conceptual Model / 2	-	-	1	1
	Relational Model / 1	-	-	1	-
	Selective Model / 1	-	-	-	1
Conceptual Model / 1	Basic Model / 1	-	-	-	1
Selective Model / 26	Basic Model / 12	1	-	7	4
	Selective Model / 7	2	2	2	1
	Relational Model / 4	1	1	1	1
	Conceptual Model / 3	1	1	1	-
Concrete Model / 71	Concrete Model / 23	4	5	5	9
	Inappropriate Model / 9	5	2	1	1
	Memorizing Model / 13	3	8	2	-
	Definitional Model / 13	6	3	1	3
	Selective Model / 17	-	-	12	5
Relational Model / 25	Relational Model / 7	3	3	-	1
	Conceptual Model / 6	1	2	2	1
	Selective Model / 3	-	1	2	-
	Basic Model / 9	1	1	5	2
Definitional Model / 8	Definitional Model / 4	-	1	1	2
	Inappropriate Model / 2	1	-	-	1
	Memorizing Model / 2	-	-	2	-
Memorizing Model / 28	Memorizing Model / 20	-	2	12	6
	Definitional Model / 7	1	1	5	-
	Concrete Model / 1	1	-	-	-
Inappropriate Model / 116	Inappropriate Model / 40	25	8	1	6
	Concrete Model / 17	6	6	2	3
	Memorizing Model / 33	4	9	12	8
	Definitional Model / 25	7	11	3	4
	Basic Model / 1	-	-	1	-

ECTE: **E**arly **C**hildhood **T**eacher **E**ducation, CTE: **C**lassroom **T**eacher **E**ducation, STE: **S**cience **T**eacher **E**ducation, PTE: **P**hysics **T**eacher **E**ducation

Table 9 indicates that the pre-service teachers mainly had inappropriate and concrete models for the satellite concept. Those who had an inappropriate model for the satellite concept (116 teacher candidates) generally had an inappropriate model for the moon as well. In the same way, the pre-service teachers with concrete, basic, memorizing, definitional and selective models for the satellite concept also had the same models with dominant frequencies for the moon. Although this pattern was not valid for the relational and conceptual models, it can be said that the majority of the pre-service teachers had similar mental models for the satellite concept and the moon pairing, as they had for the planet-earth and star-sun pairs.

DISCUSSION AND RESULTS

The obtained data has shown that candidates, in general, answered most of the questions in the achievement tests at a low level i.e. they could not give responses of scientific quality. Accordingly, it can be said that the candidate teachers don't have a sufficient level of knowledge about basic astronomy concepts. This result is supported by numerous previous studies conducted by various researchers: (e.g. Barba and Rubba, 1992; Summers and Mant, 1995; Atwood and Atwood, 1996, 1997; Zeilik et al., 1997, Zeilik, et al., 1999; Trumper, 2001c, 2003, 2006a, 2006b; Ünsal et al., 2001; Rutherford, 2004; Hudgins, 2005; Frede, 2006; Kalkan and Kıroğlu, 2007; Küçüközer, 2007; Caballero et al., 2008; Emrahoğlu and Öztürk, 2009). Additionally, since in this study the present state of the sample was not manipulated, the mentioned result can be accepted as the indicator that the candidate teachers could not appropriately construct the knowledge related to these concepts and reach a persistent learning stage during the education they have had so far.

Nine mental models related to astronomy concepts were determined There were: ideal, basic, conceptual, memorizing, selective, definitional, concrete, relational and inappropriate models. The analysis of the data showed that none of the pre-service teachers had the ideal model, which is supposed to be fully coherent with scientific data. Moreover, it was determined that the inappropriate model, which is related to non-scientific knowledge, was quite common among the participants from different departments.

The model referred to as the ideal model in this study has similar features to the scientific model, and also the inappropriate model in this study has similarities to the initial model, which represents the non-scientific knowledge or peculiar opinions of bearers, proposed by Vosniadou and Brewer (1992). Another frequent model type in this study is the concrete model. The concrete model tests the scientific appropriateness of the shapes drawn to explain or visualize basic astronomy concepts in particular. It can be said that this model resembles the spherical model used to explain the shape of the earth by various researchers such as Vosniadou and Brewer, 1992; Samarapungavan et al., 1996; Vosniadou et al., 2004; Hannust and Kikas, 2007; Panagiotaki et al., 2008; Straateemeier et al., 2008.

In both models, the shape of the concept in question needs to be explained at a scientific level. Another highlight from the data of the present study was that most of the pre-service teachers drew the moon as a crescent shape. We think that the reason for this situation was due to daily life referrals of the participants. Representations like a 'flag with star and crescent' might have negatively affected the participants' knowledge.

Other mental model types described in this study (basic, conceptual, memorizing, selective, definitional and relational) had similar aspects to the synthesis model put forward by various researchers (Vosniadou and Brewer, 1992; Samarapungavan et al., 1996; Sezen, 2002; Acar, 2003; Vosniadou et al.,

2004). As a matter of fact, basic, conceptual, memorizing, selective, definitional and relational models in this study are formed by individuals generating knowledge constructions by blending their pre-existing knowledge with life experiences, just as in synthesis models (Vosniadou and Brewer, 1992). Still, the models offered by this study are qualitative models, developed with the aim of differentiating the differences between mental models and synthesis models more precisely.

The aim of this study was determining the relationships between mental models regarding basic astronomy concepts and concept examples. As a result of the collective analysis of the mental models regarding concepts and concept examples, along with the research inquiry above, it was determined that the participants' mental models about a concept were also largely valid for the related concept example. Accordingly, it was determined that the dominant mental models for the planet-earth pair were the "concrete model" and the "inappropriate model" and for the star-sun pair, they were the "relational model" and the "inappropriate model". Unlike the planet-earth and star-sun pairs, this coherence was not valid for the satellite-moon pair. This result could be explained by the attained daily life meaning of the satellite concept, which had developed based on technological advancements. Consequently, it could be said that the analysis of the bulk of the data allowed us to determine that similar mental models were developed by individuals about any concept and related concept example. This result could be related with the absence of the astronomy courses in university level for different department. This is to say that, taking into account the common courses of high school, the participant from different departments have similar background concerning basic astronomy concepts.

This study also examined how the participants' mental models, regarding basic astronomy concepts, differ with respect to the departments which they were registered. The analysis of data showed that there was no significant difference between the mental models of the participants from different departments. This situation implied that the pre-service teachers, independent of the department in which they were registered, could not develop mental models compatible with scientific knowledge regarding basic astronomy concepts. Considering mainstream teacher training curricula, it could be said that this result was closely related to the lack of courses covering astronomy topics. Although prior to its implementation, there had been an expectation that science and physics pre-service teachers had more scientific knowledge about astronomy topics than the rest, because of the relatedness of their departments. This, in fact, was not the case. This result could be explained by the rupture between the university curricula and the high school curricula these teacher candidates needed to teach after graduation.

Based on an understanding level and mental models of pre-service teachers within the present study, it can be said that learning environments they have had from pre-school level to bachelor's degree about basic astronomy concepts are insufficient. Accordingly, it can be suggested that candidate teachers, who are

responsible for teaching these concepts in the future, need to be provided with high quality learning environments which enables them to construct their own knowledge effectively. This necessity is backed up with the studies by Trumper (2006a; 2006b). Trumper stated that the activities performed in the Introduction to Astronomy course that he delivered with a constructivist-based approach affects learning of pre-service teachers positively and helps them to remove their misconceptions.

Concerning the problems stated by the findings of the study and the explanations by Duval (1993, 1995) about the importance of different types of representation in concept teaching and learning, it can also be suggested that different representation types need to be used in the instruction of basic astronomy concepts. In addition, it can be suggested that pre-service teachers need to participate in related excursion and observation activities like planetarium visits, as Plummer (2006) tested in his study. On the other hand, by using software and applications such as 'stellarium,' pre-service teachers can be better acquainted with space. We believe that the better they consolidate basic concepts, the better they are able to convey them to their students.

REFERENCES

Abraham, M.R., Williamson, V.M. & Westbrook, S.L. (1994). A Cross Age Study of the Understanding of Five Chemistry Concepts. *Journal of Research in Science Teaching*, 31(2),147-165.

Akpınar, B., Turan, M. & Tekataş H. (2004). Öğretmen Adaylarının Gözüyle Sınıf Öğretmenlerinin Yeterlilikleri, *XIII. Ulusal Eğitim Bilimleri Kurultayı*, Malatya, 260-261.

Atwood, R.,K. & Atwood, V., A. (1996). Preservice Elementary Teachers' Conceptions of the Causes of Seasons, *Journal of Research in Science Teaching*, 33(5), 553-567.

Atwood, R., K. & Atwood, V., A. (1997). Effects of Instruction on Preservice Elementary Teachers' Conceptions of the Causes of Night and Day the Seasons, *Journal of Science Teacher Education*, 8(1), 1-13.

Bailey, J., M. (2006). *Development of a Concept Inventory to Assess Students' Understanding and Reasoning Difficulties about the Properties and Formation of Stars*, Unpublished PhD dissertation, University of Arizona, ABD.

Baloğlu Uğurlu, N. (2005). İlköğretim 6.sınıf Öğrencilerinin Dünya ve Evren Konusu ile ilgili Kavram Yanılgıları, *Gazi Eğitim Fakültesi Dergisi*, 25(1), 229-249.

Barba, R., H., Rubba, P., A. (1992). A Comparison of Preservice and in Service Earth And Space Science Teachers' General Mental Abilities, Content Knowledge, and Problem – Solving Skills, *Journal of Research in Science Teaching*, 29(10),1021-1035.

Barnett, M., MaKinster, J., G. & Hansen, J.,A. (2001). Exploring Elementary Students' Learning of Astronomy Through Model Building, *The Annual Meeting of the American Educational Research Association*, 1-21, Seattle, ABD.

Barnett, M., Barab, S. A.,& Hay, K. E., (2001). The virtual Solar System Project: Student Modeling of the Solar System, *The Journal of College Science Teaching*, 30(5), 300–304.

Barnett, M., Morran, J. (2002). Addressing Children's Alternative Frameworks of the Moon's Phases and Eclipses, *International Journal of Science Education*, 24(8), 859-879.

Bland, R. & Tessmer, M.(1999). Student Model Construction: An Interactive Strategy for Mental Models Learning, *Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology*, Houston, ABD.

Brunsell, E. & Marcks, J., (2005). Identifying A Baseline For Teachers' Astronomy Content Knowledge, *Astronomy Education Review*, 3(2), 38- 46.

Buckley, B.C. & Boulter, C.J. (2000). Investigating the Role of Representations and Expressed Models in Building Mental Models. J.K.Gilbert & C.J. Boulter (Eds.), *Developing Models in Science Education*, Kluwer Academic Publıshers, England.

Caballero, C., Moreira, M., A. & Rodriguez, B.L., (2008). Concept Mapping as a Strategy to Explore Teachers' Mental Representations about The Universe, Concept Mapping: Connecting Educators, *Proceedings of the Third International Conference on Concept Mapping*, 108-116, Tallinn, Estonya and Helsinki, Finlandiya.

Callison, P., L. & Wright, E., L., (1993). The Effect of Teaching Strategies Using Models on Preservice Elementary Teachers' Conceptions about Earth- Sun- Moon Relationships, *Annual Meeting of the National Association for Research in Science Teaching*,1-17, Atlanta, ABD.

Cin, M., (2007). Alternative Views of the Solar System Among Turkish Students, *Review of Education*, 53, 39-53.

Diakidoy, I., N. & Kendeou, P. (2001). Facilitating Conceptual Change in Astronomy: A Comparison of the Effectiveness of Two Instructional Approaches, *Learning and Instruction*, 11, 1-20.

Dunlop, J., (2000). How Children Observe the Universe, *Publications Astronomical Society of Australia*, 17, 194-206.

Duval R. (1993) Registres de représentation sémiotique et fonctionnement cognitif de la pensée. *Annales de Didactique et de Sciences Cognitives*- IREM de Strasbourg 5,37–65

Duval R. (1995) *Semiosis et pensée humaine. Registres sémiotiques et apprentissages intellectuels*. Peter Lang, Berne.

Ekiz, D. & Akbaş, Y. (2005). İlköğretim 6.sınıf Öğrencilerinin Astronomi ile İlgili Kavramları Anlama Düzeyi ve Kavram Yanılgıları, *Milli Eğitim Dergisi*, 165.

Emrahoğlu, N. & Öztürk, A. (2009). Fen Bilgisi Öğretmen Adaylarının Astronomi Kavramlarını Anlama Seviyelerinin ve Kavram Yanılgılarının İncelenmesi Üzerine Boylamsal Bir Araştırma, *Çukurova Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 18(1),165-180.

Erden, M. (2005). *Öğretmenlik Mesleğine Giriş*, Epsilon Press, İstanbul.

Etkina, E., Warren, A. & Gentile, M. (2006). The Role of Models in Physics Instruction.*The Physics Teacher*, 44, 34-39.

Franco, C. & Colinvaux, D. (2000). Grasping Mental Models. J.K.Gilbert & C.J. Boulter (Eds.), *Developing Models in Science Education*, Kluwer Academic Publishers, England.

Frede, V. (2006). Pre-Service Elementary Teacher's Conceptions about Astronomy, *Advances in Space Research*, 38, 2237–2246.

Frede, V., (2008). Teaching Astronomy for Pre-Service Elementary Teachers: A Comparison of Methods, *Advances in Space Research*, 42, 1819–1830.

Frede, V., Troadec, B. & Zarhbouch, B. (2009). Cultural Artifact and Children's Understanding of the Shape of the Earth: The Case of Moroccan Children, *European Journal of Psychology of Education*, 24 (4), 485-498.

Greca, M.I. & Moreira, M.A. (2000). Mental Models, Conceptual Models and Modeling. *International Journal of Science Education*, 22(1) 1-11.

Hannust, T. & Kikas, E. (2007). Children's Knowledge of Astronomy and Change in the Course of Learning. *Early Childhood Research Quarterly*, 22, 89-104

Harrison, A.G. & Treagust, D.F. (2000). A Typology of School Science Models. *International Journal of Science Education*, 22(9), 1011-1026.

Henze, I., Driel, J. H.V. & Verloop, N. (2008). Development of Experienced Science Teachers' Pedagogical Content Knowledge of Models of the Solar System and the Universe, International *Journal of Science Education*, 30(10), 1321-1342.

Hudgins, D., W. (2005). *Investigation of the Effect of Ranking Tasks on student Understanding of Key Astronomy Topics*, Unpublished PhD dissertation, The University of South Africa, South Africa.

Johnson-Laird, P.N. (1983). *Mental Models*. Cambridge University Press, England.

Jonassen, D. & Cho, Y.H. (2008). Externalizing Mental Models with Mindtools. D., Ifenthaler, P., Pirnay-Dummer & J.,M.,Spector(Eds.), *Understanding Models for Learning and Instruction*, Springer, USA.

Justi, R. & Gilbert, J. (2000). History and Philosophy of Science through Models: Some Challenges in the Case of 'the Atom'. *International Journal of Science Education*, 22(9), 933-1009.

Kalkan, H. & Kıroğlu, K., (2007). Science and Nonscience Students' Ideas about Basic Astronomy Concepts in Preservice Training for Elementary School Teachers, *Astronomy Education Review*, 6(1), 15-24.

Kanlı, U. (2015). Using a Two-tier Test to Analyse Students' and Teachers' Alternative Concepts in Astronomy, *Science Education International*, 26(2),148-165.

Kara, İ., Erduran-Avcı, D. & Çekbaş, Y. (2008). Fen Bilgisi Öğretmen Adaylarının Işık Kavramı İle İlgili Bilgi Düzeylerinin Araştırılması. *Mehmet Akif Ersoy Üniversitesi Eğitim Fakültesi Dergisi,* 8(16), 46-57.

Karal, I., S. (2003). *Fizik Öğretmeni Adaylarının Konu Alanı Bilgi Düzeylerinin Belirlenmesi*, Unpublished Master's Thesis, Karadeniz Technical University, Trabzon, Turkey.

Kırbıyık, H., Kızıloğlu, Ü., Kızıloğlu, N., Civelek, F., R. & Beklen, E. (2007). *Evren Nasıl Oluştu?*, METU Press, Ankara, Turkey.

Kikas, E. (1998). The Impact of Teaching on Students' Definitions and Explanations of Astronomical Phenomena, *Learning and Instruction*, 8(5), 439-454.

Kikas, E. (2005). Development of Children's Knowledge: the Sky, the Earth and the Sun in Children's Explanations, *Electronic Journal of Folklore*, 31, 31- 56.

Klein, C.,A. (1982). Children's Concepts of the Earth and the Sun: A Cross Cultural Study, *Science Education*, 65(1), 95-107.

Küçüközer, H. (2007). Prospective Science Teachers' Conceptions about Astronomical Subjects, *Science Educational International*, 18(2), 113-130.

Küçüközer, H., Korkusuz, M., E., Küçüközer, H., A. & Yüzümezoğlu, K. (2009). The Effect of 3D Computer Modelling and Observation Based Instruction on the Conceptual Change Regarding Basic Concepts of Astronomy in Elementary School Students, *Astronomy Education Review*, 43(6), 40-58.

Lelliott, A., D. (2007). *Learning about Astronomy: A Case Study Exploring How Grade 7 and 8 Students Experience Sites of Informal Learning in South Africa*,

Unpublished PhD dissertation, University of the Witwatersrand, Johannesburg, South Africa.

Liu, S.H. (2003). Models of "The Heavens and the Earth": an Investigation of German and Taiwanese Students' Alternative Conceptions of the Universe. *International Journal of Science and Mathematics Education*, 3, 295-325.

Liu, O.L., Lee, H.S, Hofstetter, C. & Linn, M.C. (2008). Assessing Knowledge Integration in Science: Construct, Measures and Evidence. *Educational Assessment*, 13, 33-55.

Nobes, G. & Panagiotaki, G. (2007). Adults' Representations of the Earth: Implications for Children's Acquisition of Scientific Concepts. *British Journal of Psychology*, 98, 645-665.

Norman, D. (1983). Some Observations on Mental Models. D. Gentner &A.L. Stevens (Eds.), *Mental Models*, Lawrence Erlbaum Associates, Hillsdale, England.

Örnek, F. (2008). Models in Science Education: Applications of Models in Learning and Teaching Science. *International Journal of Environmental and Science Education*, 3(2), 35- 45.

Panagiotaki, G., Nobes, G. & Potton, A. (2008). Mental Models and Other Misconceptions in Children's Understanding of the Earth. *Journal of Experimental Child Psychology*, 104(1), 52- 67.

Percy, J. R., (1998). Variable Stars in Astronomical Research, Education, and Development, *Astrophysics and Space Science*, 258, 357-365.

Plummer, J. D., (2006). *Students' Development of Astronomy Concepts across Time*, Unpublished PhD dissertation, The University of Michigan, ABD.

Plummer, J. D., (2009a). A Cross-age Study of Children's Knowledge of Apparent Celestial Motion, *International Journal of Science Education*, 31(12), 1571 -1605.

Plummer, J. D., (2009b). Early Elementary Students' Development of Astronomy Concepts in the Planetarium, *Journal of Research in Science Teaching*, 46(2), 192-209.

Rapp, D. (2005). Mental Models: Theoretical Issues for Visualizations in Science Education. J.K. Gilbert (Ed.), *Visualization in Science Education*, 43-60, Netherlands.

Rutherford, I., B. (2004). *Exploring Alternative Conceptions of Teachers and Informal Educators about Selected Astronomy Concepts*, Unpublished PhD dissertation, The University of Cincinnati, ABD.

Sağlam, A. (2004). *Les Équations Différentielles en Mathématiques et en Physique: Étude des Conditions de Leur Enseignement et Caractérisation des Rapports Personnels des Etudiants de Première Année D'université a cet Objet de Savoir*, Unpublished PhD Thesis, Universite Joseph Fourier, Grenoble, France.

Sağlam-Arslan, A. & Devecioğlu, Y. (2010). Student Teachers' Levels of Understanding and Model of Understanding about Newton's Laws of Motion. *Asia-Pacific Forum on Science Learning and Teaching*, 11 (1), 1-20.

Samarapungavan, A., Vosniadou, S. & Brewer, W.F. (1996). Mental Models of the Earth, Sun, and Moon: Indian Children's Cosmologies. *Cognitive Development*, 11, 491-521.

Skopeliti, I. & Vosniadou, S., (2007). Reasoning with external representations in elementary astronomy. In S. Vosniadou, D. Kayser, and A. Protopapas (eds.),*Proceedings of EuroCogSci07, the European Cognitive Science Conference*, 244-249, Delphi, Greece.

Sezen, F., 2002. İlköğretim 7. Sınıf Öğrencilerinin Astronomi Kavramlarını Anlama Düzeyleri ve Kavram Yanılgıları, Unpublished Master's Thesis, Karadeniz Technical University, Trabzon, Turkey.

Sherrod, S., E. & Wilhelm, J., (2009). A Study of How Classroom Dialogue Facilitates the Development of Geometric Spatial Concepts Related to Understanding the Cause of Moon Phases, *International Journal of Science Education*, 31(7), 873-894.

Skopeliti, I. & Vosniadou, S. (2007). Reasoning with External Representations in Elementary Astronomy. In S. Vosniadou, D. Kayser, & A. Protopapas (Eds.), *Proceedings of EuroCogSci07, the European Cognitive Science Conference*, 244-249, Delphi, Greece.

Sneider, C., I. & Ohadi, M., M., (1998). Unraveling Students' Misconceptions about the Earth's Shape and Gravity, *Science Education*, 82, 265- 284.

Spiliotopoulou, V. & Ioannidis, G. (1996). Primary Teachers' Cosmologies: The Case of the 'Universe'. G. Welford, J. Osborne & P. Scott (Eds.), *Research in Science Education in Europe Current Issues and Themes*, The Falmer Press, England.

Stahly, L., L., Krockover, G., H. & Shepardson, D., P. (1999). Third Grade Students' Ideas about the Lunar Phases, *Journal of Research in Science Teaching*, 36(2), 159-177.

Straatemeier, M., Van der Mass, H.L.J. &Jansen, B.R.J. (2008). Children's Knowledge of the Earth: A New Methodological and Statistical Approach. *Journal of Experimental Child Psychology*, 100, 276-296.

Summers, M. & Mant, J., (1995). A Survey of British Primary School Teachers' Understanding of the Earth's Place in the Universe, *Educational Research*, 37(1), 3-19.

Şahin, F., 2001. İlköğretim 2. Sınıf Öğrencilerinin Uzay Hakkındaki Bilgilerinin Değerlendirilmesi, *Burdur Eğitim Fakültesi Dergisi*, 2, 156–169.

Taylor, I., Baker, M. & Jones, A. (2003). Promoting Mental Model Building in Astronomy Education. *International Journal of Science Education*, 25(10), 1205-1225.

Trumper, R., (2000). University Students' Conceptions of Basic Astronomy Concepts, *Physics Education*, 35(1), 9- 15.

Trumper, R., (2001a). A Cross-age Study of Junior High School Students' Conceptions of Basic Astronomy Concepts, *International Journal of Science Education*, 23(10), 1111-1124.

Trumper, R., (2001b). A Cross-age Study of Senior High School Students' Conceptions of Basic Astronomy Concepts, *Research in Science and Technological Education*, 19(1), 97-109.

Trumper, R., (2001c). A Cross- College Age Study of Science and Nonscience Students' Conceptions of Basic Astronomy Concepts in Preservice Training for High-School Teachers, *Journal of Science Education and Technology*, 10(2), 189-195.

Trumper, R., (2003). The Need for Change in Elementary School Teacher Training –a Cross- College Age Study of Future Teachers' Conceptions of Basic Astronomy Concepts, *Teaching and Teacher Education*, 19, 309-323

Trumper, R., (2006a). Teaching Future Teachers Basic Astronomy Concepts- Sun- Earth-Moon Relative Movements-at a Time of Reform in Science Education, *Research in Science and Technological Education*, 24(1), 85-109.

Trumper, R., (2006b). Teaching Future Teachers Basic Astronomy Concepts-Seasonal Changes- at a Time Reform in Science Teaching, *Journal of Research in Science Teaching*, 43(9), 879-906.

Trundle, K., C., Atwood, R., K. & Christopher, J., E. (2002). Preservice Elementary Teachers' Conceptions of Moon Phases before and After Instruction, *Journal of Research in Science Teaching*, 39(7), 633-658.

Tunca, Z., (2005). Türkiye'de İlk ve Ortaöğretimde Astronomi Eğitim ve Öğretiminin Dünü, Bugünü, www.fedu.metu.edu.tr/UFBMEK-5/b_kitabi/PDF/Astronomi/Panel/_t1-3d.pdf, 20 Mayıs 2009.

Uzunkavak, M. (2009). Öğrencilerin Newton Kanunları Bilgilerinin Yazı ve Çizim Metoduyla Karşılaştırılması. *SDU International Journal of Technologic Sciences*, 1(1), 29-40.

Vosniadou, S. & Brewer, W. (1992). Mental Models of the Earth: A Study of Conceptual Change in Childhood. *Cognitive Psychology*, 24, 535-585.

Vosniadou, S. & Brewer, W. (1994). Mental Models of the Day/Night Circle. *Cognitive Science*, 18, 123-183.

Vosniadou, S.(1994). Capturing and Modelling the Process of Conceptual Change. *Learning and Instruction*, 4, 45-69.

Vosniadou, S., Skopeliti, I. & Ikospentaki, K. (2004). Modes of Knowing and Ways of Reasoning in Elementary Astronomy. *Cognitive Development*, 19, 203-222.

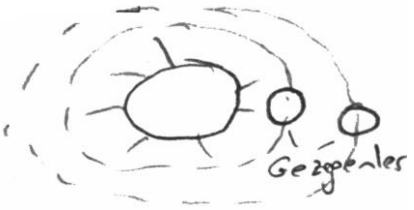
Zeilik, M., Mattern, N., Schau, C., Hall, S., Teague, K., W. & Bisard,W., (1997). Conceptual Astronomy: A Novel Model for Teaching Post Secondory Science Courses, *American Journal of Physics*, 65(10), 987-996.

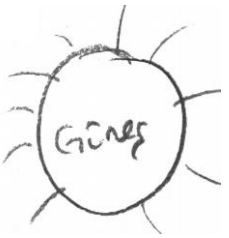
Zeilik, M., Mattern, N. & Schau, C., (1999). Conceptual Astronomy II. Replicating Conceptual Gains, Probing Attitude Changes Across Three Semesters, *American Journal of Physics*, 67(10), 923-927.

Wilhelm, J., (2009). Gender Differences in Lunar Related Scientific and Mathematical Understandings, *International Journal of Science Education*, 31(15), 2105-2122.

APPENDICES

Appendix 1 Examples of mental models of basic astronomy concepts

Planet	**Selective model (F40)** "*Planet, celestial bodies revolving around the sun and affected by its gravitational force*" (Level 2). Celestial bodies running in a certain orbit around the sun were described as planet (Level 4). Planets are composed of elements (Level 1). "*Celestial bodies revolving around the sun are called planet. The earth is also a planet revolving around the sun.*" (Level 1)  **Concrete model (S37)** "*Planets are celestial bodies existing in the outer space generally with no living creatures on*" (Level 1). The participant drew the planet in spherical shape (Level 4). The participant explained the structure of planet with 'the inner core and layers' (Level 2). The participant explained the relation between planet and the earth as "*Planet is a general term. The earth is in the class of planets*" (Level 2)  **Inappropriate model (OÖ64)** *"There are other planets other than the earth"* (Level 1). The participant did not draw any figure for the structure of the planet (Level 0); did not give any explanation for the structure of the planet (Level 0). The participant found out the relation between two celestial bodies by saying "*The earth is a planet*" (Level 2)
The Earth	**Concrete model (OÖ19)** *"The earth is a place composed of earth and water where we live"* (Level 2) The participant drew shapes on a circle to represent continents to explain the shape of the earth (Level 3). The participant explained the structure of the earth with "*earth, water and fire*" words (Level 1). Explained the relation between the earth and the planet as "*The earth is a planet*." (Level 2).  **Inappropriate model (OÖ27)** *"The earth is the place where we live on"* (Level 1). The participant drew a house, flowers, trees and human figures on a disc (Level 1). As structure; the earth, which is composed of different layers, is a planet (Level 2). 

Star	**Relational model (F28)** "*Star is a celestial body that has no energy and reflecting the light coming from the sun*" (Level 1). It was described with the points belonging to a star (Level 1). No explanation was made about the star concept (Level 0). "The sun is one of the biggest stars having own light resource" (Level 3)  **Inappropriate model (FT40)** "*Star is a celestial body that emits light but it seems bright on the earth because of the light coming from the sun*" (Level 1). The structural characteristics were not explained (Level 0). The relationship between star and the sun: "*The sun is natural; stars are artificial light resources.*" (Level 1)
The Sun	**Relational model (FT5)** "*The sun is the biggest star in the solar system. It emits heat and light*" (Level 2). The drawing describing the sun was a circle emitting light. (Level 2). There was no explanation about the structure of the sun (Level 0). "*The sun is a star since it produces own light.*" (Level 3).  **Inappropriate model (F12)** "The sun is the biggest planet in the universe which provides energy needs of the other planets in the form of heat and light" (Level 1). The drawing describing the sun was a sphere emitting light. (Level 2). The participant explained the structure of the sun with "methane explosions and radioactive explosions" (Level 1). The relationship between the sun and star explained as "T*he sun is a source of energy but star uses this energy*" (Level 1).
Satellite	**Concrete model (OÖ9)** "*Satellite is the moon*" (Level 2). "*The shape of it is spherical*" (Level 4). The structure was not explained (Level 0). The relation between satellite and the moon; "*The moon is the satellite of the earth*" (Level 2).  **Inappropriate model (OÖ69)** *"They are smaller celestial bodies revolving with planets."* (Level 2). The moon was drawn only as a crescent (Level 2). "*The moon is composed of earth and other solid matters*." (Level 1). The relation between the moon and satellite was indicated as; "*The moon is the satellite of the earth*" (Level 2). 

The Moon	**Memorizing model (S69)** *"The moon is the celestial body running around the earth and reflecting the light coming from the sun." (Level 3).* The participant drew the shape of the moon with craters on it (Level 3) The participant could not explain the structure (Level 0). The relation between two celestial bodies was explained as "*Both of them have reflective nature.*" (Level 2). **Definitional model (OÖ20)** *"The moon is our satellite appearing at night."* (Level 3). The participant drew the shape only as a crescent (Level 2). There was no explanation about the structure of the moon and the relation between the moon and satellite.