A CASE STUDY ON PRE-SERVICE SCIENCE TEACHERS' DYNAMIC MENTAL CONSTRUCTS ON THE CONCEPTS REGARDING THE PHASES OF THE EARTH'S MOON

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

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ABSTRACT

A CASE STUDY ON PRE-SERVICE SCIENCE TEACHERS' DYNAMIC MENTAL CONSTRUCTS ON THE CONCEPTS REGARDING THE PHASES OF THE EARTH'S MOON

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The purpose of the current study is to examine pre-service science teachers' knowledge pieces regarding concepts of phases of the moon. The data were collected from fourteen pre-service science teachers via clinical interview. Pre-service science teachers responded interview question with oral explanation, drawing and model demonstration. The finding of the study showed that pre-service science teachers activated knowledge elements and constructed mental structure in order to explain phases of the moon. It was revealed that their mental construct were dynamic characteristics, which may change in different contexts. More importantly, it was showed that pre-service science teachers' explanations are shaped by their spatial abilities. The finding of the study suggested that pre-service science teachers should re-organize their knowledge elements in order to have sophisticated understanding

regarding phases of the moon. Therefore, pre-service science teachers should be provided training which may improve their awareness on their own mental structure.

Keywords: Pre-service Science Teachers, Phases of the Moon, Knowledge in Pieces, Clinical Interview

ÖZ

FEN BİLGİSİ ÖĞRETMEN ADAYLARININ AYIN EVRELERİNE İLİŞKİN KAVRAMLAR AÇISINDAN HAREKETLİ ZİHİNSEL YAPILARI ÜZERİNE DURUM ÇALIŞMASI

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Bu çalışmanın amacı fen bilgisi öğretmen adaylarının ayın evreleri kavramları üzerine sahip oldukları bilgi parçacıklarının incelenmesidir. Çalışmanın verileri klinik mülakat ile on dört öğretmen adayından toplanmıştır. Öğretmen adayları kendilerine yöneltilen mülakat sorularını sözlü olarak, çizerek ve model üzerinde göstererek cevaplamışlardır. Bu çalışmada, öğretmen adaylarının ayın evreleri ile ilgili olarak sahip oldukları bilgi parçacıklarını aktifleştirerek zihinsel yapılar oluşturdukları gösterilmiştir. Öğretmen adaylarının sahip oldukları zihinsel yapılarının farklı bağlamlarda değişebilen dinamik bir yapıda olduğu görülmüştür. Ayrıca öğretmen adaylarının cevaplarının sahip oldukları uzamsal yetenekleri tarafından şekillendirildiği ortaya konulmuştur. Bu çalışmada öğretmen adaylarının ayın evreleri ile uygun bir anlayışa sahip olmaları için sahip oldukları bilgi

parçacıklarını tekrardan organize etmeleri gerektiği anlaşılmıştır. Bundan dolayı öğretmen adaylarının kendi zihinsel yapılarına yönelik farkındalıklarını artıracak eğitim faaliyetleri ile desteklenmeleri gerekmektedir.

Anahtar Kelimeler: Ayın Evreleri, Fen Bilgisi Öğretmen Adayları, Bilgi Parçacıkları, Klinik Mülakat

To my wife and daughter
For their love, patience, encouragement

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Mone	Ministry of National Education

CHAPTER 1

INTRODUCTION

Astronomy is a way to understand celestial phenomenon surrounding us. It has been stated that astronomy is as old as human history even who is the first astronomer is not known. Bone engravings concerning lunar phases which belong to 30,000 years ago may indicate us how old this discipline is (Karttunen, Kroger, Oja, Poutanen, & Donner, 2007). Some scientific evidences have shown that our ancestors noticed some interesting phenomenon pertinent to astronomy such as solar/lunar eclipses, comets and meteors. They systematically observed and recorded these events, which contributed to the development of modern astronomy (Aslan, Aydın, Demircan, Derman, & Kırbıyık, 1993).

Earliest humans' interest in astronomy contributed to improving their life standards. People observed variety of different events such as change of seasons, position of stars and movement of celestial bodies. As a consequence of these observations, they found new systems or ways to improve their welfare. To illustrate, they systematically observed the sky in order to predict seasonal change, which made significant contribution to agricultural development (Karttunen et al., 2007). Astronomy has been regarded as unique and requires timeless endeavor for human beings. In the same vein, modern people also focus on sky in order to enhance their knowledge regarding universe. How the universe begin, how and when it will end, and black holes are among the issues that modern astronomers focus on (De Pree & Axelrod, 2001). The focus points of modern astronomers are not limited to such popular questions, even the most distant galaxies' elementary particles may have value to examined (Karttunen et al., 2007).

People frequently come across with news in social or visual media regarding some astronomy topics such as eclipses, explorations of new stars, forecasting end of universe, comets and potential extraterrestrial life. In addition, there are numerous numbers of popular movies which have scenario related to astronomy. For instance,

movies such as Mars Attacks! (1996), G.O.R.A (2004), Man in Black (1997) have plots containing aliens and space travel. Gravity (2013) and Apollo 13 (1995) are among movies described space mission and challenge of space. There are also movies such as the Martian (2015), the Last Days on Mars (2013) which have plots focus on survivor on space or other planets. It has been depicted that all these impressions have potential to motivate or increase an individual's' awareness towards astronomy.

Considering significance and vague of astronomy for human beings, it is inevitable to integrate astronomy into educational programs at all levels (Bailey & Slater, 2004). There are reasonable benefits of integration of astronomy to educational program. Astronomy content can be adapted to many other topics which are taught for students in primary and secondary education. For instance, astronomy has been viewed as a vehicle to teach some concepts in physics such as gravitation and light. Plotnick, Varelas, and Fan (2009) designed integrated science courses for elementary teacher candidates and benefitted from astronomy content while instructing in physic concepts. Accordingly, Kepler's laws and tides were content for their instruction in gravity concept, and the Earth's magnetic field was utilized for explaining electricity and magnetism. In addition, heat and energy concepts were introduced in the context of climate and earth's interior heat. On the other hand, mathematical concepts emerging from trigonometry, logarithms and calculus can be operated with respect to astronomy. Instructors may utilize astronomy as a content while teaching these mathematical concepts. As a result, astronomy connects mathematics with the real world and improve motivation of students towards mathematics (Ros, 2009).

Astronomy appears to be found at the center of scientific revolutions, which makes astronomy a useful way to teach history of science. Thus, it can enable teachers teach nature of science (NOS) within the context of astronomy (Percy, 2009). For instance, Abell, Martini, and George (2001) designed a undergraduate course in order to enhance future elementary teachers understanding of the NOS via phases of the moon issue. They focused on three features of the NOS as empirically based, invention of explanation and socially embedded. Accordingly, participants observed

the moon and recorded data in order to understand that science is empirically based. Then, they examined data and proposed an explanation regarding different appearance of the moon. This step designed so that students acquire the idea that scientific knowledge involves the invention of explanation. Finally, future teachers shared their explanations and theories regarding phases of the moon with their classmates, which reflects socially embedded aspect of scientific knowledge. In another study, Abell, George, and Martini (2002) presented historical science stories to future elementary teachers regarding astronomy. These stories included depicting of antic models of the sun/moon/earth system, development of these models over the years and contribution of different civilizations to these models. Researcher stressed that science stories regarding the astronomy have potential to represent tentative nature of scientific knowledge for future elementary teachers.

Considering benefits of astronomy, curriculum developers locates astronomy issues to curriculum in a different manner depending on its perceived importance for countries (Pasachoff & Percy, 2009). Accordingly, astronomy topics may emerge as a part of geology or physics courses considering on its connections with these disciplines. On the other hands, some countries present astronomy as an independent course, which reflect its uniqueness. There are many countries integrated astronomy issues in their national curriculum either as an independent course or as a part of other disciplines. Fitzgerald (2018) examined fifty-three national curriculums of thirty-seven OECD counties and underlined that almost all the national curriculums includes astronomy related issues. Some countries as Denmark, Sweden, Spain, Netherlands, Australia and Estonia integrated astronomy issues all grade level from primary school to high school. There are some other counties integrated astronomy courses to primary and middle school as Turkey and Italy, to primary and high school as Greece and Poland, or to only high school as Belgium (Fitzgerald, 2018).

Despite of benefits stressed above, it faces with many challenges that obstruct effective teaching and learning. Some challenges are peculiar to nature of astronomy, while some others may be attributed to teachers' knowledge and students' spatial abilities. As stressed by some researchers in the field of astronomy education (e.g.,

Kasturirangan, 1997; Pasachoff & Percy, 2009) teaching astronomy may have some barriers stemming from its own nature. For instance, many hands-on teaching activities on astronomy topics could be carried out at night. It requires students to be outside in order to observe stars, planets, moon and some other celestial bodies. However, ensuring safety and appropriate conditions for students to make some observations outside is a challenge. Consequently, students are unable to combine their classroom learning with their experience on the sky. Moreover, astronomy teaching needs expensive equipment such as telescope, optical devices and simulation software. Many schools and families do not have economic welfare to effort such requirements.

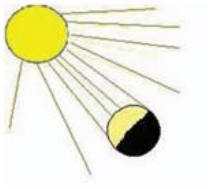
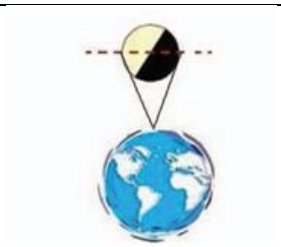
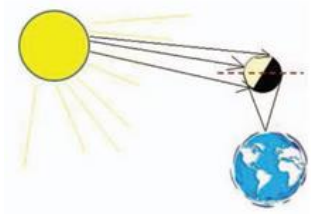
Obstacle for an affective astronomy teaching pertinent to teachers' characteristics cover nonscientific understandings and limited pedagogical content knowledge of teachers regarding astronomy topics. Comparing the findings of varies studies (e.g., Cinzia & Perucchini, 2013; Schoon, 1995) focusing on conceptual understandings of in-service teachers and primary or middle school students revealed that misconceptions on astronomy topics were similar for these groups. Correspondingly, there are empirical research indicate that teachers' lack of conceptual understanding limits their students' learning (Ahn & Choi, 2004; Monk, 1994). On the other hand, teachers should be equipped with necessary pedagogical content knowledge. Pedagogical content knowledge is described as teacher knowledge that transform of subject matter knowledge to meaningful forms for their students (Marks, 1990; Shulman, 1987). Therefore, it is indispensable for effective teaching (Shulman, 1987). Teachers should aware of students' problems while teaching astronomy topics and should know techniques and approaches to solve these problems (Broadfoot & Ginns, 2009), which is an indicator of rich pedagogical content knowledge.

Students' spatial ability is among the important factors which shape student understandings of astronomy issues. Taking into account different definitions, spatial ability can be regarded as a mental process including rotation, transformation and generation, which ensure creation of an object in mind (Linn & Petersen, 1985;

Lohman, 1988; Michael, Guilford, Fruchter, & Zimmerman, 1957). Previous researchers indicated that mental process underlined in definition of spatial ability contributes to acquisition of the many phenomena and lack of this ability triggers students' learning on astronomy. Therefore, individuals should have sufficient level of spatial abilities regardless of their education level. Previous research studies showed that individuals equipped with limited spatial skills face difficulties while explaining seasons (Rudmann, 2002), celestial motions (Plummer, Wasko, & Slagle, 2011) and phases of the moon (Cole, Wilhelm, & Yang, 2015).

The phases of the moon is one of the basic astronomy concept cover all these difficulties in learning process. Therefore, it has been perceived as a one of the challenging issues among astronomy topics. Explanation of phases of the moon should cover some mechanism of the sun-moon-earth system in order to be classified as scientific understanding. As presented in Table 1.1, individuals should be able to see that half of the moon was illuminated by sun, while the moon revolves around the earth. In addition, they should be aware of that relative position of the moon, sun and earth determine part of the moon we see; and illuminated part of the moon we see correspond to different phases of the moon (e.g., Parnafes, 2012; Trundle, Atwood, & Christopher, 2002, 2007b).

Table 1.1 Phases of the Moon

Figures	Explanation
	Half of the moon was illuminated by the sun.
	The moon revolves around the earth.
	Only half of the moon is visible from the earth.
	The extend of illuminated part of the moon that is seen from the earth corresponded to lunar phases.

Figures were adapted from (Parnafes, 2012)

Treagust and Duit (2008) defined conception as "learners' internal representations constructed from the external representations of entities constructed by other people such as teachers, textbook authors or software designer. There are variety of concepts. For instance, category like concept is one of them, which classify entities whether or not they have certain feature of characteristics (diSessa, 2002; Howard, 1992). For instance, planet concepts require determining whether or not an observed entity possess characteristics of a planet. However, some concepts require more information; therefore, they are different from category like concept. diSessa and Sherin (1998) articulated that there are concepts which includes a knowledge

system and entitled them as coordination classes. According to their perspective, individuals cannot easily obtain direct information regarding this type of concepts; therefore, they should perform some strategies in order to acquire them. Velocity and force are common exemplar of coordinator classes.

It is important to specify what conceptions students have since learning as conceptual change is a results of interaction between students' existing concept and instruction (Posner, Strike, Hewson, & Gertzog, 1982). In other words, determining students' current conceptions before instruction is the first step of conceptual change studies. In the literature, students' conceptions which are not consistent with the scientific explanation is called as misconception or alternative conception. According to (Hawkins, 1979), misconceptions that students possess are among the factors which inhibits their science learning. Due to the difficulties to conceptualizing complex mechanism of the sun/earth/moon system, individuals may have misconceptions regarding phases of the moon. Many researches were conducted in order to reveal conceptual understanding of participants from elementary students to adults with respect to phases of the moon. Results of these studies revealed that understanding on phases of the moon were not consistent with scientific view as shown in Table 1.1, therefore categorized as misconception. It was detected that the earth's, other planets' or sun's shadow on moon (Baxter, 1989; Dunlop, 2000; Sharp, 1996); clouds' prevention appearance of the moon (Baxter, 1989; Dunlop, 2000; Sharp, 1996; Subramaniam & Padalkar, 2009); blocking of the moon by sky (Wilhelm, 2009a); different location of observer on the earth (Dunlop, 2000; Stahly, Krockover, & Shepardson, 1999; Trundle et al., 2007b); the earth's rotation (Baxter, 1989); distance between the moon and the sun (Trundle et al., 2002; Trundle, Atwood, & Christopher, 2007a) were some of the common misconceptions that perceived as reasons of phases of the moon by individuals.

Phases of the moon topic, like many other astronomy phenomena, require individuals to perform their spatial abilities. Studies of Reynold (1990) and Wellner (1995) indicated that individual equipped with high spatial ability explained phases of the moon with more accurately (as cited in Wilhelm, 2009b). The rationale behind

this association is more explicit considering nature of astronomy issues such as phases of the moon, eclipses, tides, seasons and day/night cycle. More specifically, Plummer (2014) argued that many astronomy issues including phases of the moon requires individual to comprehend two different frames of reference as earth based perspective and space based perspective. Earth based perspective refers to appearance of celestial bodies from the earth. In addition, actual movement of celestial bodies in space refers to space-based perspective. Individual should have both perspective and shift between them considering different time scales and astronomical dimensions. For instance, in the Table 1.1., figures in the first and second rows are examples of the space-based perspective related to phases of the moon. Furthermore, figure in the third row show us how the moon appears from the earth which correspond to earth based perspective. However, individuals should combine both perspectives in order to explain phases of the moon as seen in the fourth row. While performing these mental activities, individuals are required to perform their spatial abilities.

Wilhelm, Jackson, Sullivan, and Wilhelm (2013) specified specific four spatial and mathematical concept which are necessary for understanding phases of the moon concept. Accordingly, these concepts are entitled as geometric spatial visualization, spatial projection, cardinal directions and periodic patterns. Geometric spatial visualization corresponds to visualizing geometric characteristic of the sun/moon/earth system from different views points in space. The second skill spatial projection refers to visualizing an object depending on observer point. One should visualize appearance of the moon considering not only its own location but also different location in the earth such as equator, north hemisphere, south hemisphere. Other requirements in order to understand phrases of the moon are cardinal directions which refers to vector directions such as north, west, east, south and intercardinal. Individuals should acquire meaning of this direction to describe position of an objects in space (Wilhelm, 2009b). Finally, understanding mechanism behind phenomenon such as periodicity of orbits, phases, illumination correspond to periodic patterns. Researcher stressed that it is not possible to have complete understand regarding phases of the moon without these four spatial ability (Wilhelm et al., 2013).

Besides problems originating from spatial ability, students' lack of knowledge on some fundamental physics is also among the barriers for sound of understanding regarding phases of the moon. According to Parker and Heywood (1998) viewpoint, nature of the light including its propagation and reflection from spherical surfaces are critical issues in order to acquire how lunar phases occur. Similar to this idea, Suzuki (2002) declared that the source of many misconceptions is associated with not being aware of the fact that the sun is a light source and the surface of the moon is illuminated by the light derived from the sun.

Terminology is another challenge for students. Dove, (2002) exemplified how terminology may be misleading. Accordingly, although it is called "new moon", there is no moon that can be observed from the earth. In addition, although it is called as "first quarter", half of the moon is visible from the earth, not its quarter. These terminologies stem from space base perspective; therefore, they are not consistent what we observe from the earth. In addition, interchangeable use of the same words is another challenge for individuals' sophisticated understanding regarding phases of the moon. It is stressed that teachers uses some words like "spin" and "orbit" interchangeably, which cause difficulties for appropriate understanding of the moon concepts (Parker & Heywood, 1998).

Phases of the moon issue is in conjunction with some other lunar concepts, since it has causal networks with other lunar issues. Lindell and Olsen (2002) determined concept domain regarding phases of the moon. Accordingly, lunar phases concept domain covers not only cause of lunar phases but also some related issues as role of observer's location on lunar phases, association between phases of the moon and eclipses, apparent movement of the moon and orbital movement of the moon. In addition, many research studies focused on a couple of moon concepts instead of examining only reason of its phases. The common concepts examined with lunar phases could be exemplified as eclipses (Barnett & Morran, 2002), appearance of the same face of the moon (Dove, 2002; Parker & Heywood, 1998), appearance of the moon from different location on the earth (Suzuki, 2002). For this reason, phases of the moon concept is not limited to reason behind phases of the moon, some other

issues as observer location, eclipses and appearance of the moon are parts of phases of the moon concept.

One of the most spectacular event in the sky is eclipse which refers to movement of a celestial objects through shadow of the other (Karttunen et al., 2007). Solar and lunar eclipses are more well-known events for many people since they are spectacular events. Lunar eclipse occurs when the moon enters the earth's shadow cone while the solar eclipse takes places occultation of the sun by the moon (Moore, 2000). The moon located between the sun and the earth in solar eclipse, which corresponds to new moon phase. On the other hand, lunar eclipse occurs when the earth located between the moon and the sun, which also corresponds to full moon phase. Although both new moon and full moon were observed once a month, eclipses do not reveal every month since orbit of the moon is tilted 5.2 degree of earth orbit. Shadow of the earth and the moon usually below or above because of tilted orbit, which is seen in the Figure 1.1.

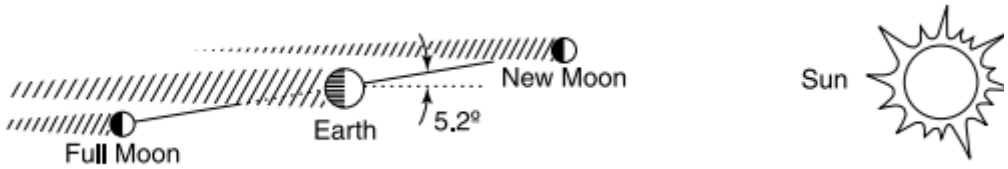


Figure 1.1 Condition for Eclipses (Moché, 2004)

As explained in the previous paragraph, eclipses and phases of the moon are overlapping issues. Both eclipses and lunar phases occur owing to movement of the sun/earth/moon. Therefore, it is difficulties to differentiate these two phenomena for individuals. Previous studies were revealed that some misconceptions regarding phases of the moon were related to eclipses. For instance, individuals consider that phases of the moon occurs due to shadow of the earth on the moon (Baxter, 1989; Schoon, 1995; Trundle et al., 2002) and the moon should be full during solar eclipse (Kanli, 2014; Trumper, 2003). In addition, it was stressed that students cannot explain differences between full moon and lunar eclipses even after instruction, because the earth locates between the earth and the moon during these two natural phenomena (Barnett & Morran, 2002).

Appearance of the moon also depends on our location in the earth. The study of the Schoon (1995) indicated that pre-service teacher face with difficulties on visualize appearance of the moon from different location. More than half of the pre-service teachers participated that study declared while full moon was observed in the USA, Australians observes different phase. This situation reflects that pre-service teachers lacks role of longitude on lunar phases. Similar to this finding, Suzuki (2002) reported that role of observers location on appearance of the moon is one the challenging topics regarding phases of the moon and pre-service teachers face difficulties understanding this phenomenon even after instruction.

One of the interesting points regarding the moon is that half part of it never seen from the earth. To put it in another, we can only see the same half surface of the moon. In brief, the moon spends 27.3 day for its rotation. This figure also equal to its revolution around the earth; therefore, we observe the same face of the moon. According to finding of Dove (2002), more than half of the participants faced with difficulties explaining why they observe only one face of the moon. Considering this finding, researcher argued that relative movement of three objects as the sun/earth/moon make this concept difficult. In addition, understanding of slow rotation of the moon comparing with its revolution around the earth (Parker & Heywood, 1998) and lack of the personal experience regarding rotation of the moon (Dove, 2002) limit students understanding why we observe only one face of the moon.

As noted previously, research studies on conceptual change (e.g., Hawkins, 1979; Posner et al., 1982) have put an emphasis on the potential role of pre-instructional knowledge on students' learning. Students have commonsense or pre-instructional knowledge which is obtained from their environment by means of their daily experiences. However, these conceptual acquisitions often do not fit with scientifically normative explanations. It is pointed out that pre-instructional conceptions may be among the barriers for formal education process across various scientific issues (Clement, 1982; Hawkins, 1979; Viennot, 1979). Barnett and Morran (2002) underlined that enhancing individuals' understanding is a complex process

since their existing pre-instructional concepts and contextual factors may interact each other. On the other hand, studies showed that misconceptions are resistant to change; therefore, apparent change in conceptual understanding may be limited with a short time period (Kikas, 1998; Libarkin & Kurdziel, 2001). Therefore, students' misconceptions may reappear after specific time period.

There is a consensus among the researchers studying on conceptual change that students have pre-instructional conceptions before instruction and these conceptions influence their learning. However, there is no consensus among researchers with respect to structure of pre-instructional knowledge. There are three fundamental perspective that describe nature of pre-instructional knowledge as knowledge of theory, knowledge in pieces and ontological view. On the one hand, some researcher argue that pre-instructional knowledge has coherent structure, which resembles theory like structure (Vosniadou & Brewer, 1992). On the other hand, some of the researchers stressed that pre-instructional knowledge of individuals fragmented and nearly independent from each other (diSessa, 1993). In addition to these two perspectives, ontological view of conceptual change stressed that entities were placed to ontological categories (Chi & Slotta, 1993). Debates regarding nature of pre-instructional concepts are crucial since its initial step of conceptual change. diSessa underlined importance of structure of knowledge as seen in following paragraph.

> I believe that the fragmented vs. coherent issue is manifestly epistemologically and empirically fundamental. Our very sense of the nature of knowledge and how it changes is at stake. If we cannot settle on a broad characterization of naïve knowledge, how can we expect to settle other more subtle issues, such as tracking conceptual change in detail? (diSessa, 2008, p.36).

Studies on conceptual change were generally dominated by knowledge of theory perspective. Especially, early studies were highly influenced by the notions of paradigm shift proposed by Thomas Kuhn, which emphasize holistic and radical shift among scientific theories (diSessa, 2014a). In parallel to this idea, some researchers (e.g., Carey, 1985) assert that students' pre-instructional knowledge as a coherent and theory like structure, which resembles a scientific theory. However, Vosniadou,

(2008) stressed that although they are coherent, students' initial concepts are not similar to scientific theories since students are not aware of their theories and they cannot falsify them as scientists do. Therefore, it is suggested to "framework theory", which describes coherent, narrow and explanatory characteristic of naïve knowledge (Vosniadou, 2012). Unlike classical approach, framework theory does not advocate unitary conception, conceptions have a complex structure and include different type of elements such as mental models, beliefs, presuppositions. Students naïve knowledge is perceived as theory since students can provide consistent explanation regarding complex issues they encounters (Vosniadou, 2012).

According to ontological view, all entities belongs to a specific ontological category. There were three main categories as matter, process and mental states (Chi & Slotta, 1993; Chi, Slotta, & de Leeuw, 1994). All the concepts belong to a specific category and have common characteristic of their category. Although science concepts like heat, light and force actually belong to process category, it was generally placed to matter category by students (Chi, 2005). Therefore, conceptual change referred to replacement of concepts to their right ontological categories via formal science education (Chi & Slotta, 1993).

On the other hand, some researchers (e.g., diSessa, 1993; Minstrell, 1982) assert that pre-instructed knowledge of individuals were fragmented rather than coherent, as opposed to knowledge of theory perspective. Knowledge system was constructed by knowledge elements called by different terminologies by researcher such as p-prims, facets, nodes. They are primitive elements of conceptual system and they explains natural world surrounding individuals (diSessa, Gillespie, & Esterly, 2004). For instance, diSessa, (1993) stressed that knowledge was constructed by phenomenological primitives (p-prims). On the one hand, it was underlined that p-prims is context depended and quasi-independent knowledge elements, but there is not enough linkage to labelled them as theory like structure. However, students' responses include a set of activated knowledge elements which fit together and meaningful for students. This characteristic of knowledge pieces is entitled as "local coherence" (Hammer, Scherr, & Redish, 2005). In contrast to knowledge of theory

perspective, local coherence highly depends on context. Therefore, students' activated knowledge elements can easily change after they encounter different contextual factors. On the other hand, all activated knowledge elements may not equally contribute to mental structure. Some of them may have higher status comparing the others. Individuals' may prioritize specific knowledge elements depending on their life experience (Parnafes, 2012; Sherin, Krakowski, & Lee, 2012).

It is asserted that grain size and contextuality aspects of knowledge should be consider before deciding students' initial knowledge fit with theory or pieces structures (diSessa, 2008; diSessa et al., 2004). Accordingly, grain size refers to extent and type of information that is enough for categorizing naïve ideas. On the other hand, contextuality correspond to differentiation among students' responses in different situations. diSessa criticized adherents of knowledge of theory perspective and stressed that they do not share adequate information, which is indicator of coherent structure of students' knowledge. It is stressed:

> Early descriptions of "intuitive theories" of mechanics were often in terms of a single phrase or sentence, and seldom more than a paragraph. In recent work, for example, Vosniadou (2002) describes sufficient number of meanings of force to cover about 90% of subjects, across a wide developmental span (from kindergarten to ninth grade) in a one-page chart, using a sentence or two to describe each meaning. In contrast, in one paper (diSessa, 1993), I describe more than three dozen "elements of intuitive knowledge" in mechanics, using about a paragraph each, while making clear that the descriptions are partial, and that the listing is representative, not by any means complete (diSessa, 2008, p.37).

In addition to grain size issue, it is asserted that knowledge of theory perspective also ignores contextual factors and does not describe them in-detail. Therefore, findings of researchers on fragmented and coherence side can be different each other. diSessa explained contextuality issues as follow;

> Do children always say things that are aligned with descriptions of their intuitive ideas, or, in contrast, is it easy to ask questions about slightly different situations that elicit different responses? A fair amount of my empirical work demonstrates circumstances and questions that elicit answers that cannot be covered by the kind of sparse descriptions of naïve ideas offered by coherence advocates (diSessa, 2008, p.38).

Sherin, Krakowski, and Lee, (2012) elaborated to opinion of diSessa regarding contextuality and they stressed that issues regarding coherence depending

on two issues as characteristics of population and the subject matter, and manner utilized in order to reveal students' knowledge. To put other word, in addition to characteristics of participants and content, data collection way is another factor influence researchers' finding on students' knowledge structure. For instance, it is explained that although some studies have the same purpose (e.g., Nobes et al., 2003; Siegal, Butterworth, & Newcombe, 2004; Vosniadou & Brewer, 1992) their findings did not verify each other because of different ways utilized in order to reveal students' knowledge (Sherin et al., 2012).

Clinical interviews are perceived as among the fundamental ways in order to reveal participants' conceptual understandings. Many pioneer studies that focused on conceptual change (e.g., diSessa, 1993; Posner et al., 1982; Vosniadou & Brewer, 1994) utilized clinical interview as a data collection way. However, clinical interviews are dynamic process, in which interviewees may explain a phenomena different ways and change rapidly their responses without any manipulation (diSessa et al., 2004; Sherin et al., 2012; Welzel & Roth, 1998). Questions, setting, environment or interviewer have potential to influence response of the participants since knowledge pieces have context sensitive structure. Considering this important function of clinical interview, it is stressed that clinical interviews should be critically examined, since some changes may occur during the interview process (Blown & Bryce, 2006; Sherin et al., 2012).

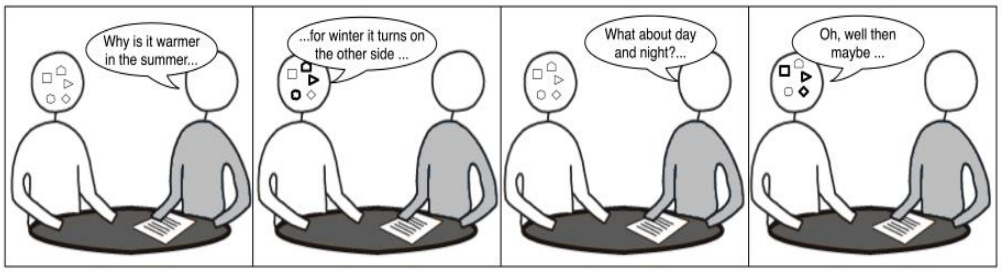


Figure 1.2 Interaction in Clinical Interview

Sherin et al., (2012) caricatured possible interaction between interviewer and participants as seen Figure 1.2. Accordingly, after directing the question that "why is it warmer in the summer", students activated some of knowledge elements as seen

second pane and responded the question. However, participants activated knowledge pieces and response changed in fourth pane. Although interviewer does not intend for change on participant's conceptual understanding, further question directed to participants to provoke shift.

Changes on participants conceptual understanding during clinical interview was admitted as a type of conceptual change that reveal at a short time period (Lee, Krakowski, Sherin, Bang, & Dam, 2006). This sort of conceptual change was entitled as "conceptual dynamics" by Sherin et al., (2012) or "crystallization" by Blown and Bryce (2006). Sherin, Lee, and Krakowski, (2007) stressed that since clinical interview is dynamic and complex process, researcher need relatively simple framework in order to examine this process. Therefore, they suggested node-mode framework for examining clinical interviews. Accordingly, this framework includes three units as node, mode and dynamic mental construct (DMC). Nodes referred to any kind of knowledge elements and a set of activated nodes are called as mode. The last unit DMC is produced by nodes and modes as a consequence of mental reasoning. While nodes and modes are perennial units of long time memory of human, DMC is temporary construct which have potential to change in seconds (Sherin et al., 2012).

1.1 Research Questions

The present study was conducted to reveal how middle school pre-services teacher constitute scientific explanation in the domain of the phases moon. That is to say, this study targeted to obtain rich and detailed information regarding pre-service teachers' conceptual understandings in the light of knowledge in pieces perspective. The current research was designed with respect to qualitative research paradigm and followed case study approach in order to disclose elementary science teachers' candidates' structure of knowledge on the moon concepts. Pre-service science teacher was referred to a case of the current study. However, examination of each cases was limited to specific conceptual structure which was underlined by research question of the current study.

Pre-service science teachers participated in the present study had different experience, which shape their conceptions. In addition, there were variety of nodes that pre-service science teachers may perform in order to develop their conceptions on phases of the moon. Therefore, it is plausible to consider that pre-service teachers' understanding of moon concepts is correspond to a unique system for each teacher candidate. Pre-service teachers' responses were examined in the light of the knowledge of pieces perspective with node-mode frameworks suggested by (Sherin et al., 2012). The knowledge elements activated during the interview process was examined and how these elements constituted pre-service science teachers' dynamic mental constructs which could be regarded as a temporal mental state.

In this aspect, this research study was guided by the following research questions;

- What is the mental construct behind pre-service science teachers' responses on phases of the moon?
    - Which knowledge elements activated while explaining phases of the moon?
    - Which factors shaped pre-service science teachers' response on phases of the moon?
- How do pre-service science teachers alter their dynamic mental construct during clinical interview designed with multimedia approach?

The moon concept refers to a series of concept associated to the moon. Understanding of the moon refers to phases of the moon, lunar and solar eclipses, daily appearance of the moon from the earth and function of different longitudes and latitudes to appearance of the moon. Interview question separated to four parts considering these moon concepts, these questions directed considering order. In addition, participants asked to respond these questions via verbal answer, drawing and model demonstration. Pre-service science teachers' responses on interview questions analyzed considering different moon concepts and response types.

1.2 Significance of the Study

This study elaborated our recent understanding of pre-service elementary science teachers' knowledge structures on phases of the moon concept. Previous studies indicated that students from elementary level to higher education have alternative conceptions regarding the moon concepts. However, majority of these studies (e.g., Bell & Trundle, 2008; Stahly et al., 1999; Trundle et al., 2007a; Trundle & Bell, 2010) were designed considering the knowledge of theory perspective which asserts student's knowledge possess coherent structure. Therefore, research on astronomy issues with respect to knowledge in pieces perspective was relatively limited. To put it differently, there is limited information about nature of the knowledge pieces concerning moon concepts. Therefore, this study aims to fill this gap and contribute to understanding of knowledge pieces regarding phases of the moon activated during the clinical interview.

Studies conducted to reveal students conceptual understanding generally ignore nature of clinical interview process. Accordingly, these studies focused on participants final model and they ignore other models suggested during the interview. In addition, steps that was followed by the participants in order to construct model is not important issue for perspective of these studies. However, the current study focused on complete interview process. Therefore, all the dynamic mental construct and final model were examined in the content of the current study. Furthermore, it was presented how they construct an explanation and factors which influence this construction process.

Studies regarding phases of the moon generally utilized drawing and three-dimensional model in order to elicit participants conception on phases of the moon during interview process. These studies generally designed to promote conceptual understanding via an instructional period. Before and after instruction, students' conceptual understanding was measured by clinical interview enriched by three dimensional models and drawing. Changes on conceptual understanding was attributed to instruction. Majority of these studies ignored potential contribution of

dimensional models and drawing on students' understandings. Furthermore, Trundle et al., (2002) empirically found that three-dimensional models and drawings do not have instructional value during the interview process. However, it was revealed that three dimensional modals and drawings influence students' responses in the context of the current studies. Accordingly, many pre-service science teachers activated different nodes while utilizing three dimensional models and drawing than nodes activated during verbal explanation. In addition, some of the pre-service science teachers altered their dynamic mental construct after they exposed to three-dimensional models.

On the one hand, many researchers focusing on astronomy education with respect to knowledge on element perspective sampled young children (Wilhelm, 2009a), elementary (Parnafes, 2012) and middle school students (Sherin et al., 2012). Beyond this tendency, the current study conducted with pre-service elementary teachers. It is plausible to consider that these teacher candidates have more experience on moon concepts comparing with pupils. Therefore, findings of the current study ensure comparison of knowledge elements regarding moon concepts with respect to different age groups. In addition, it is revealed that to what extend pre-service science teachers conceptual dynamics resemble to middle school or elementary school students.

Although both knowledge in pieces and knowledge of theory have different ideas regarding conceptual system, both of them aim to reach more effective learning in classroom environment. However, reflection of these two perspectives to instruction process is completely different each other. With respect to knowledge of theory perspective, it is difficult to link new knowledge with previous alternative concepts. Therefore, instructions are designed in order to alter misconceptions. This process generally contains presenting conflicting examples which aims dissatisfaction with existing conceptions (Posner et al., 1982). On the other hand, activation of the knowledge elements are important aspect of an instruction based on knowledge of pieces perspective (Özdemir & Clark, 2007). While teaching, instructor focus on suitable knowledge elements and ensure opportunity for students to use them

in different context. As a result, individuals can appropriately reorganize knowledge pieces and constitute mental state. Therefore, it is important to understand conceptual structure of pre-service science teachers in order to improve their understanding. Astronomy courses that is located in-service education program can be designed considering pre-service teachers' conceptual structure so that they can activate appropriate knowledge elements and neutralized others.

1.3 Definition of Important Terms

Pre-service science teachers: Teacher candidates who are junior and senior level and enrolled in the elementary science education program in education faculty.

Dynamic Mental Construct: *"Constructed explanation that is produced by the reasoning that occurs within a mode"* (Sherin et al., 2007).

Node: *"Mental elements of many different types and multiple level of abstraction"* (Sherin et al., 2012).

Mode: *"It is an interconnected subset of nodes within a conceptual ecology that tends to be triggered in response to a particular class of cognitive tasks"* (Sherin et al., 2007).

Clinical Interview: "*A type of interview which aims to ascertain the nature and extent of an individual's knowledge about a particular domain by identifying the relevant conceptions he or she holds and the perceived relationships among those conceptions"* (Posner & Gertzog, 1982).

Concept :"*Learners' internal representations constructed from the external representations of entities constructed by other people such as teachers, textbook authors or software designer*" (Treagust & Duit, 2008).

Conceptual structure: " *Conceptual structure is a set of interrelated concepts, sometimes called as schema*" (Howard, 1992).

Phase: "*The ratio between the illuminated area of the disk of a celestial body as it presents to an observer on Earth and the area of its entire disk, taken as a circle"* (Mitton, 2007).

Concepts on Phases of the moon: In the current research study, concepts on the phases of the moon referred to different appearance of the moon from the earth. Therefore, this terminology covers variety of sub-concepts including phases of the

moon, eclipses, appearance movement of the moon and appearance of the moon from different location in the earth.

Terminator: *"The boundary between the illuminated and unilluminated parts of the surface of a planet or moon"* (Mitton, 2007).

CHAPTER 2

LITERATURE REVIEW

2.1 Conceptual Change Theory

During the 1960s, science education mainly concentrated on science content that students do not have. Students' limited understanding regarding a specific science topic was attributed to their limited mental abilities (Carey, 2000). However, this idea rapidly changed as a consequence of result of studies on cognitive and conceptual structure of human. Accordingly, the idea emerged that science learning mainly depended on what students already know rather than their lacks. Therefore, science education was regarded as changing existing conception with scientifically accepted ideas.

Conceptual change theory mainly originated ideas of Thomas Kuhn regarding nature of theories and history of science, and studies of Jean Piaget's experiments on children's understandings. On one hand, the notion of assimilation and accommodation asserted by Piaget were regarded as a mechanism of conceptual change in early stages (diSessa, 2014a). According to Piaget, schemas are knowledge blocks which represent world surrounding an individual. In case of consistency among existing scheme and new experience obtaining from environment, individuals easily adapt this new experience to the existent schema. However, if there is inconsistency between existent schema and new experience, mental conflict occurs. As a result, individuals may change this schema or constitute a new one, which correspond to conceptual change. In addition to this mechanism, studies on conceptual change utilized Piaget's clinical interviews, also known as Piagetian interview, in order to reveal students understanding. On the other hand, notion of Kuhn's paradigm shift explained that change of theories occurs radically. Posner et al., (1982) integrated ideas of Piaget and Kuhn to science learning and stressed that conceptual change occurs as a result of accommodation, which refers to radical change on students' conceptions. In addition, they suggested a conceptual change

mechanism so as to show how students learn science. Accordingly, there were four steps as dissatisfaction with existing concept, a new intelligible theory, plausibility of new concept for learner and new concept's fruitfulness. Considering this classical approach, creating cognitive conflict in students' conceptions was regarded an appropriate way for science teaching (Vosniadou, 2012).

The framework suggested by Posner et al., (1982) were criticized since students' progress was less than expected because of difficulties of ensuring dissatisfaction and providing better explanations (Treagust & Duit, 2012). In addition, some of the studies also showed that there was a peripheral change rather than complete change of conceptions (Chinn & Brewer, 1993) and new ideas was combined with pre-instructional concepts (Vosniadou & Brewer, 1992).

More recently, Vosniadou, (2012) reframed the classical approach of conceptual change and asserted the framework theory approach. According to this perspective, conceptual change occurs as a consequence of slow and gradual change rather sudden change. It was explained that there are many elements, which constructs a coherent knowledge structure. New ideas were inserted to existing conceptual framework; therefore, replacement between new and existing idea does not occur. According to framework theory perspective, conceptual change occurred as a result of ontological, epistemological and representational change of students' intuitive knowledge. In addition to this mechanism, misconceptions were separated as preconceptions and synthetic models/fragmented conceptions. On the one hand, students' conceptions obtaining as a consequence of their daily life experience was entitled as preconceptions. Children preconceptions have coherent structure, which means their responses to interview questions are consistent each other. On the other hand, as a result of formal education, coherence generally disappeared, and synthetic models/fragmented conceptions occurred (Vosniadou & Skopeliti, 2014). In other words, students integrated scientific idea to their pre-instructional concepts; therefore, they can explain a phenomenon via incompatible fragments. It is stressed that synthetic models/ fragmented conceptions are completely different from pre-

instructional conceptions since they are dynamic and easily change as a result of development of knowledge structure.

Classical approach of conceptual change portrayed conceptual change's epistemological perspective. Conceptual change theory were enriched by some other researchers by examining its ontological and social aspects. Chi, Slotta, & de Leeuw, (1994) asserted that concepts can be assigned three ontological categories such as matter, process and mental state. Although many science concepts represent characteristics of process category, students generally assigned them into matter category. Therefore, conceptual change corresponds to change of category of a concept from its initial category to category that it actually belongs.

Conceptual change was perceived as an internal cognitive mechanism from the point of views of classical approach (Vosniadou, 2008). However, recent studies indicated that social and emotional factors also influence conceptual change. For instance, Pintrich, Marx, and Boyle (2008) stressed that four motivational construct such as goals, values, self-efficacy and control beliefs may influence conceptual change mechanism. Accordingly, it was pointed out motivational factors may obstruct or contribute to conceptual change.

As showed in previous paragraphs, there were different viewpoints regarding mechanism of conceptual change, nature of concept and type of conceptual change among the researchers. In addition to this issue, there were no agreement with respect to structure of concept. There is a discussion whether students' knowledge coherent or fragmented. In the following part, different views regarding characteristic of students' knowledge was examined.

2.2 Structure of Knowledge

One of the issues in conceptual change theory is characteristic of intuitive knowledge. There are two competing viewpoints explaining structure of knowledge entitled as "knowledge as theory" and "knowledge in pieces". On one hand, some researchers argue that students' knowledge shares similar characteristics with

theories. Broadly speaking, theory refers to coherent structure of knowledge of individuals and consistency among variety of context (Vosniadou, 2008). On the other hand, adherence of knowledge in pieces perspective advocate that these semi-dependent and irregular knowledge pieces constituted knowledge structure of individuals. According to this perspective, conceptual change refers to organization of these knowledge pieces in a specific context. Coherence is temporal and local with respect to knowledge in pieces perspective (Parnafes, 2012). In other words, it refers to activation of specific knowledge elements in a specific context. There were some studies conducted in order to examine whether student's knowledge structure fit in knowledge in pieces or knowledge of theory perspective. In the following paragraphs, some of the studies, which examines soundness of these competing theories were presented.

Blown and Bryce (2006) conducted a longitudinal study with 686 students. Researchers examined students' conceptual understandings on apparent motion of the sun/moon/earth and characteristic of the earth. Results showed that changes on students' conceptual understanding may occurs after years as a consequence of weak reconstruction. Furthermore, it is revealed that some changes may happen in seconds which called as conceptual crystallization. Considering these results researchers argue that students' conceptual structures are coherent system rather than fragmented pieces.

According to admitted view related to conceptual change is that students have commonsense knowledge before formal instruction. Considering the fact that culture is a factor shape individual commonsense knowledge, some of the studies were examined conceptual change theories with respect to cultural origins. Nobes et al. (2003) conducted interviews with 167 students whose age vary between 4-8 with respect to earth concept. Research conducted in Britain where Asian and British students were available. Quantitative analysis of the data indicated that there were no differences between Asian and British students with respect to their understanding on earth. In addition, it supported that both groups of students have fragmented knowledge rather than coherent mental model. Researchers criticized Vosniadou and

Brewer's (1992, 1994) findings that support children have coherent mental models by pointing methodological problems of these studies.

There are some other studies asserting that students' knowledge may reflects attribution of both Knowledge in Pieces and Knowledge of Teory perspectives. For instance, Venville, Louisell, and Wilhelm, (2012) conducted semi-structured interview regarding the moon between ten children whose ages vary from three to eight. Results showed that children had four dynamic and complex knowledge nodes about the moon such as ontological ideas, animism, creatures and artefacts; and permanence. Accordingly, children's ideas regarding shape, color, size of the moon categorized as ontology aspect while the moons' emotions, movement, life reflects animism characteristic. Furthermore, students expressed some of the issues regarding rockets, aliens and astronauts, which shows students' knowledge nodes of artefacts and creatures with respect to moon. Finally, there were some ideas whether the moon always exists in sky, always have the same shape, which categorized as permanence aspects. In addition to these findings, researchers asserted that children knowledge structure was not completely consistent with knowledge of theory nor knowledge of pieces perspective. It is stressed that students have four knowledge nodes and these nodes may be different elements such as mental models, p-prims or presuppositions. The main characteristics is that knowledge system of children complex, dynamics and influenced by social and cultural factors.

Some studies asserted that portraying students' knowledge structure is associated with the utilizing data collection ways. Sherin et al., (2012) conducted clinical interview with 54 seven and eight grade students in the context of seasons. Researchers aims to ascertain how students' dynamic mental contracts changes during the interview process. As a consequence of their analysis, it is stressed that they encounter dynamic mental constructs regarding seasons as tilted based, earth moving closer and farther from the sun, side-based, and some other vague constructs during the interview. In addition, they examined conceptual dynamics of the individuals which is effective during the interview. Accordingly, mode skimming, mode has the explanation, stable reasoning with existing DMC, updating the apple

card, drawing related dynamics, shifting modes were the types of conceptual dynamics which researchers encountered during clinical interview on the seasons. Considering these results, researchers argued possible change on students' conceptual understandings as a consequence on classroom interaction. They implied that teacher should also design their courses regarding considering this aspect.

2.3 Conceptual Understandings on Astronomy Issues

Researcher differentiated the "intended curriculum" and the "the implementation curriculum" and stressed that although the intended curriculums may be included with astronomy topics, teachers generally overlook and ignore astronomy in their implementations. Considering this situation, Hemenway (2005) stressed lack of insufficient astronomy knowledge of teachers because of insufficient pre-service teacher education programs. Actually, great number of studies was conducted to ascertain in teachers' and pre-service science teachers' understandings in astronomy topics support that they do not have sufficient content knowledge. Diagnostic test, conceptual understanding tests, drawing and open-ended questions were directed to both in service and pre-service teachers for this manner. According to Lelliott and Rollnick (2010) gravity, the solar system, stars, and the concept of size and distance are fundamental and common themes which are focused by researchers. Moreover, it is stressed Earth's shape; the day/night cycle, the seasons, and the Earth/Sun/Moon system are commonly included in curriculum and examined by researchers. Majority of studies regarding astronomy issues followed closely footsteps of knowledge of theory perspective both phases of the moon and some other astronomy issues. Important results related these concepts are summarized in the following paragraphs.

Atwood and Atwood (1996), conducted a study in order to reveal conceptualization of prospective elementary science teachers' regarding causes of seasons. More specific, the study aims to find out whether or not participants held misconceptions about causes of seasons. The data were collected from forty-nine teacher candidate via open ended questions and interviews enriched by sun-earth model. Researchers followed the idea that knowledge may be declarative or

procedural. Accordingly, teachers' candidate responses to open ended question reflects their declarative knowledge, their explanation of seasons with models refers to their procedural knowledge. Considering these perspectives, results indicated that teachers' candidate frequently have alternative conceptions regarding causes of seasons. Researchers underlined two problem which were revealed as a consequence of the study as limited scientific literacy and unfulfilled teaching responsibility.

Day and night is another astronomy issue which is located many national curriculums and examined by many researchers. In one of these studies, Atwood and Atwood (1995), examined pre-service elementary teachers' conceptual understanding on causes of day and night. Fifty pre-service elementary teachers were responded a written question concerning causes of night and day. A few days later, participants were interviewed individually and asked to responses questions with both verbal explanations and using models. By this way researchers examined teacher candidates' both procedural and declarative knowledge concerning causes of day and night. Both written and verbal explanation of the teacher's candidate were classified as scientific conception, alternative conception or incomplete explanation. Results showed that responses of the teacher candidates with using three dimensional models were more conistent with scientific explanations. On the one hand, many teacher candidates believe that earth's orbit around the sun, earth tilts, the moon and the sun's movement around the earth causes day and night cycle.

In addition to studies with prospective teachers, Barba and Rubba (1992) concentration on the difference between prospective and in-service teachers knowledge with respect to earth-science and astronomy issues. The research categorized teachers' knowledge domain as declarative (content) and procedural knowledge; and each of the domain examined with respect to specific earth-science and astronomy issues. Comparison of the sixty participants conceptual understanding indicated that in-service teachers conceptual understanding was better all the issues such earth history, oceans/lakes, solid earth, atmosphere and space. Furthermore, in-service teachers also have better performance with respect to their procedural knowledge comparing with in-service teachers.

According to Vosniadou and Skopeliti (2014), conceptual change refers to ontological, epistemological and representational change on students' initiative ideas. In addition, they stated that students should develop perspective taking abilities and explained a phenomenon taking into account different perspectives in order to ensure conceptual change. Therefore, some studies focused on students' spatial abilities and influence of spatial abilities on students' conceptual understanding. For instance, Plummer et al. (2016) examine how students explained seasonal change, apparent motion of sun and stars by the help of perspective shift enriched participants' gestures. Data gathered from fifteen 7 to 9 years old students during a five days summer camp. Students were directed the questions concerning appearance from the earth and change of this appearance depending on position of observer. Each clinical interview lasted approximately 15 minutes and participants were ensured a model in order to obtain clear data. Students' responses were converted to qualitative value and analyzed by logistic and liner regression analyses. Results indicated that there were both students utilizing non-perspective or perspective-shift ways in order to explain astronomy phenomena. Therefore, it was stressed importance of the additional support for lower perspective skill students in order to improve competencies on astronomy issues.

Heyer et al., (2013) conducted a study in order to examine relationship between undergraduate students' spatial ability and their conceptual understanding on astronomy. Researchers conducted to a single group constituted by 154 undergraduate students in order to measure their astronomy concept and spatial abilities. Result of the Pearson correlation analysis indicated that undergraduate students' spatial ability is moderately associated with their understanding on astronomy. Accordingly, spatial ability explains 25% of the variation of student's success in astronomy. This study provides empirical support that spatial ability is related to understanding of astronomical concepts.

Nicolaou and Constantinou (2002) studied on how undergraduate students in the primary education department explain movement of the sun and earth. Researchers stressed that there are two valid model based on their frame of reference,

which can be preferred so as to explain motion of sun. Considering this situation, students exposed to challenging question about movements of sun and earth; and their spatial ability were examined via phenomenological analysis about this question. Results indicate that pre-service teachers encountered four type of difficulties while explaining their models. The first, many teacher candidates transform their geographical direction to space. They considered that geographical direction referred to absolute point in space. The second; the clockwise and anti-clockwise concepts cannot be differentiated by teacher candidates. The third; they cannot locate four direction considering difference situation. They generally influenced traditional symbol which north located top, south located bottom. The last difficulties are related to reversibility. It is explained that students cannot utilized both earth and space centered model in order to explain phenomena. Nicolaou and Constantinou (2002) argue that both students and teachers may have learning difficulties emerged from spatial ability and these problems are generally ignored.

2.4 Conceptual Understanding on the Phases of the Moon

In order to understand perspective on the phases of the moon studies, previous studies can be categorized as descriptive and conceptual change studies. Considering both types, studies towards phases of the moon have been conducted for more than fifty years. These studies covered different age groups from early childhood to adults. In addition, different research paradigms as qualitative and quantitative were preferred in these studies. Focus points of these studies may be only lunar phases or a couple of lunar concepts as lunar phases, eclipses, movement of the moon. The following paragraphs will cover these studies.

There is a wide consensus that children have their own ideas and explanation regarding astronomy issues that is constituted before formal education (Baxter, 1989). Therefore, the studies focus on the understanding of phases of the moon were conducted with different age groups from young children to adults. Wilhelm, (2009a) conducted a research in order to ascertain understanding of three children at ages under nine regarding some of the moon concepts. The researcher conducted Piagetian type interviews and analyzed children's stories about the moon. Results indicated that

children responses were shaped with two perspectives as animism, objects are alive, and artificialism objects are created by God. For instance, wishes and feelings of the moon determines lunar phases, which is a sample animistic thinking. In addition, the other two children stressed that they observe different appearance of the moon because of the fact that the sky blocks the moon. Although the idea that shadow of the moon causes lunar eclipses is more popular misconception, these young children did not mention it. These situations indicate that young children's misconceptions ideas may be different from the older ages.

Baxter, (1989) conducted a study in order to reveal understanding of pupils between 9 to 16 with respect to some of the astronomy issues including phases of the moon. Specifically, it is examined how children understanding resemble to middle ages opinions. As a consequence of interviews with twenty children and administration of astronomy concept survey to a hundred students, it was revealed that students have some of the misconception which resemble to middle age opinions. Considering similarity between children understanding and middle age opinions, researcher suggested utilizing history of science as a way to teach astronomy concepts.

Barnett and Morran (2002) focused on enhancing five grade students' conceptual understanding on phases of the moon and eclipses concepts and eliminating their alternative conceptions on these issues. For this purpose, seventeen students instructed with a series of student-centered activities. Results showed that majority of students improved their understanding on phases of the moon and eclipses concepts. However, it was revealed that some of the students still have difficulties in order to differentiate full moon and lunar eclipses.

The study of Parker and Heywood (1998) included both in-service teachers and post-graduate students. A total of 58 participants were asked to draw diagrams including explanation of the concepts in order to revealed some of the astronomy issues including phases of the moon. It is revealed that participant do not face difficulties while drawing orbit of the moon and writing name of the several phases.

However, with respect to reason of the phases, just 10 % of the participant have scientifically accepted viewpoint. Many of the participants believe that shadow of the earth or other planets cause lunar phases. In addition, researchers stressed that participants could not visualize how we observe only one side of the moon. Depending on their findings, researchers expressed some of the factors which require proper understanding of astronomical issues. These factors listed as "spatial awareness", "two and three-dimensional reasoning", "spin and orbit", "the earth's tilt", "light shining on sphere", "language and communication" and "applying knowledge".

In a similar vein, Schoon, (1995) administered to 122 pre-service elementary teachers an instrument 18 multiple choice including common astronomy topics. The instrument was also included one extra section in order to find sources of misconceptions. Comparing the acceptance frequencies of the misconceptions with scientifically accepted concepts were categorized as primary and secondary alternative conceptions. Primary alternative conceptions were more common than their scientific concepts, while secondary alternative conceptions are less common. The results showed that pre-service teachers have many primary and secondary misconceptions. With respect to phases of the moon, teachers were of the opinion that of the earth cause phases of the moon and while observing full moon in north hemisphere, different phase is seen in south hemisphere. In addition to these primary alternative misconceptions, some of the teacher candidates think that the moon revolves around the earth in one day and is a light source, which refers their secondary alternative conceptions. In the context of the study, results were compared with the previous studies of the same researcher (Schoon, 1995) on 5^{th} grade students' understanding. It is revealed that primary misconception regarding phases of the moon were more popular among prospective teachers while secondary is more popular for 5^{th} grade students.

Mant & Summers, (1993) conducted a research in order to ascertain twenty primary school teachers understanding on the concepts of seasonal change, phases of the moon, occurrence of day and night, sky observation and solar system. Data were

collected by interview lasting about one hour. With respect to phases of the moon, just two teachers explained the phenomenon consisted with scientific view. Sixteen teachers considered that something like earth, earth shadow, sun etc. block the appearance of the moon, which is reason for lunar phases. In addition to this finding, researcher directed to participants question regarding daily movement of the moon. Only two of them appropriately explained movement of the moon. The rest of the primary school teachers did not explain what exactly happened in the sky including movements and appearance of the celestial bodies. In other word, were not equipped with knowledge stemming from their observation and experience on sky.

The concept of the phases of the moon was also examined regarding elementary students' acquisition. Stahly et al., (1999) were conducted to a qualitative inquiry in order to assessed third grade elementary students' conceptual understandings and change of their understanding after inquiry. Four elementary students, reflected the characteristic of the school population, were directed the interview question enriched by drawings and three-dimensional model usage before and after the lessons on phases of the moon. Students' answers on a written survey and classroom observations were also utilized as a data source. Examination of participants pre-instructional conceptions indicated that none of the students have scientific perspective towards phases of the moon. Two of the participants asserted that location of the observer is reason behind different appearance of moon phases. In addition, one of the participants come up with the role of clouds for phases of the moon. On the one hand, the last participants do not have any model for reason of the lunar phases. As a consequence of the six lessons which contains instruction on three-dimensional nature and position of the sun, moon and earth, occurrence of the lunar phases; it was revealed that students acquired some of the critical points in order to explained reasons of the lunar phases such as revolution of the moon around the earth, role of the sun. However, it was showed that students still utilized their unscientific ideas while explaining lunar phases.

Trundle et al., (2002) examined conceptual change on pre-service teachers on the concept of the phases of the moon. A total of seventy-eight pre-service teachers

were divided two groups. While one of them did not received any instruction, other group was instructed by inquiry. Analyzing of the research data constituted by classroom observations, structured interview and documents revealed that inquiry-based training contributes acquisition of scientific understanding of pre-service science teachers on phases of the moon concept. Besides the results, the researcher considers that due to three-dimensional nature of the phases of the moon, data collection should include model and drawings, which represent more comprehensible information. Therefore, researchers were utilized three-dimensional model and drawing in their data collection process. In addition, models utilized in pre and post-interviews were examined with respect to their instructional value. As a consequence of comparison of potential effect of modeling and drawing with three different group of pre-service teachers, it was revealed that using three-dimensional model by data collection process does not have instructional value.

Pre-service teachers understandings on phases of the moon and way of the improvements this understanding were also researched across different nations. Suzuki (2002) conducted a case study with Japanese pre-service teachers in order to both examine and enhance pre-service teachers' understanding on phases of the moon. The number of eight pre-service teachers were engaged with research-oriented instruction seminars which is enriched with discussions. As a consequence of twelve weeks of periods, improvement on teacher candidates understanding were reported. In addition, it is argued that determining appropriate time to observe the moon and role of the observers' location in the earth were the most difficult concepts rather than differentiate eclipses and lunar phases for Japanese pre-service teachers.

Ucar (2008) conducted a research with 72 pre-service teachers in order to understand differences between traditional modeling and technology enriched course including 45 minutes instruction. Pre-service science teachers' understanding was measured with conceptual understanding test and phases of the earth transfer test. Results indicate that both groups equally improve their understanding on phases of the moon. That is to say, simulation is not more effective way than modeling phases

of the moon. However, students instructed with simulation performed better in order to explain phases of the earth.

As stressed previously, studies on conceptual change regarding astronomy and phases of the moon issues followed knowledge of theory perspective. There are limited number of studies conducted knowledge of pieces perspective. One of the study, Parnafes, (2012) conducted a research in order to ascertain students' conceptual progression on phases of the moon concept with respect to Knowledge in Pieces theory. Research focuses on drawings and explanations of a pair of eleven years old pupils in order to understand their progression. Depending on the theoretical background, researcher examined students' knowledge resources via their mental images, mental models, propositions and general scheme. Researcher analyzed students' progression considering their explanations range and resolution. Accordingly, range of their explanation corresponded to whether or not their explanation fit to other similar phenomena. On the other hands, resolution was explanatory power of an explanation regarding a specific issue. As a consequence, students' progression was expressed by utilizing the terms "resolution", refers to level of details, and "range" refers to feasibility of explanation for difference cases. Although, initially, it is stressed that students' explanations had low level of range and resolution, it was higher at the end of the study. Furthermore, researcher stressed analyzing students' misconception by taking into account their fragmented knowledge pieces ensured more sophisticated information towards their conceptual understanding.

2.5 Summary of Literature Review

According to conceptual change theory, learning science is associated with what students know rather than their lack. Therefore, enhancing students' existing idea is focus point of conceptual change studies. However, there are different perspective regarding mechanism of conceptual change. Theory theory, framework theory, ontological perspective and affective viewpoint are some of the different perspective regarding conceptual change. In addition, there are different viewpoints in terms of structure of initial knowledge. On the one hand, some of researchers

stressed that pre-instructional knowledge has coherent structure, which resemble a scientific theory. On the other hand, opponents of this perspective say initial knowledge is consisted of context depended knowledge pieces.

There are different researches conducted in order to determine individuals' knowledge characteristics. For instance, some studies of (e.g., Blown & Bryce, 2006; Vosniadou & Brewer, 1992, 1994) showed that students have coherent knowledge system rather than fragmented. On the other hands, some other studies (e.g., Nobes et al., 2003; Parnafes, 2012) showed that students' have fragmented knowledge pieces. Considering these different findings, it was argued that characteristics of initial knowledge may dependent on subject domain and data collection way (Sherin et al., 2012).

Like many other science content, pre-service and in-service teachers' conceptual understanding regarding astronomy issues including phases of the moon generally followed knowledge of theory perspective. These studies reported that individuals do not have sufficient level of content knowledge (Atwood & Atwood, 1995, 1997; Mant & Summers, 1993; Trundle et al., 2002). In addition, it was revealed that spatial ability of individuals were highly associated with their understanding on astronomy issues (Heyer et al., 2013; Nicolaou & Constantinou, 2002; Plummer et al., 2016).

CHAPTER 3

METHODOLOGY

In this chapter, the methodology of the current study was explained. Research design, participants, instrument and analysis of data was described respectively.

3.1 Research Design

Qualitative research is described as an effective way to explore the details of an issue (Creswell, 2007). Researchers can examine and interpret complex issues or phenomenon by this method with its own context without any manipulation (Patton, 2002).

In the field of educational research, early studies on the phases of the moon concepts and astronomy issues (e.g., Bissard, Aron, Francek, & Nelson, 1994; Schoon, 1995; Zelik, Schau, & Mattern, 1998) followed quantitative research paradigm and used multi-choice and open ended surveys for data collection. However, research utilizing these data collection methods could not present deep and detailed information regarding conceptual understanding of their participants. For instance, information gathered from multi-choice items is limited due to fact that choices could reflect only a couple of alternative concepts. Moreover, Atwood and Atwood (1996) underlined that students' written responses correspond to declarative knowledge which is a low status knowledge when compared with verbal responses. Taking into account these arguments, qualitative methods were suggested as a more suitable perspective for studies on conceptual understanding regarding phases of the moon concept since it presents data collection ways which reveal participants' in-depth ideas and explanation (Stahly et al., 1999). Therefore, the present study was shaped by qualitative research paradigm in order to reach deep and detailed information regarding participants' conceptual structures regarding phases of the moon.

The current qualitative study followed the case study design. Case studies were defined as examination of an issue depending on one or more cases which are within a bounded system (Creswell, 2007). According to Merriam (2009), the important aspect of case studies is determining what the case is, which also correspond to unit of analysis. This unit within boundaries may be a particular event, issue, process or person have unique characteristics. Yin (2003) underlined that case studies are more appropriate research methodology for researchers directing "why" and "how" questions toward a phenomenon within real life context (Yin, 2003). In addition, case studies are unique methods of examination of a phenomenon which depends on contextual conditions. Although there are some confusions with respect to nature of case study, many studies from variety of disciplines such as economy, psychology, sociology, politics were conducted with case study design since all these disciplines need to analysis complicated phenomenon they have (Yin, 2003).

Prospective science teachers participated in the current research referred to cases were cases. The current research focused on only their conceptual understanding on phases of the moon issues including subtopics of appearance of lunar phases, reason of phases, lunar/solar eclipses, apparent movement of the moon and appearance of the moon from different longitude and longitude. Therefore, unit of analysis is pre-service science teachers' understanding on phases of the moon issues. Their conceptual understanding regarding concept on the phases of the moon is a complex system includes variety of knowledge elements. These knowledge pieces constituted different conceptual structure, and these are unique for each participant, which reflects boundaries of the cases in the current study. In addition, knowledge pieces are interacted to each other and they are highly context depended with respect to Knowledge in Pieces perspective. Therefore, case study research method was preferred in the current research design. In Figure 3.1, design of the current research was portrayed.

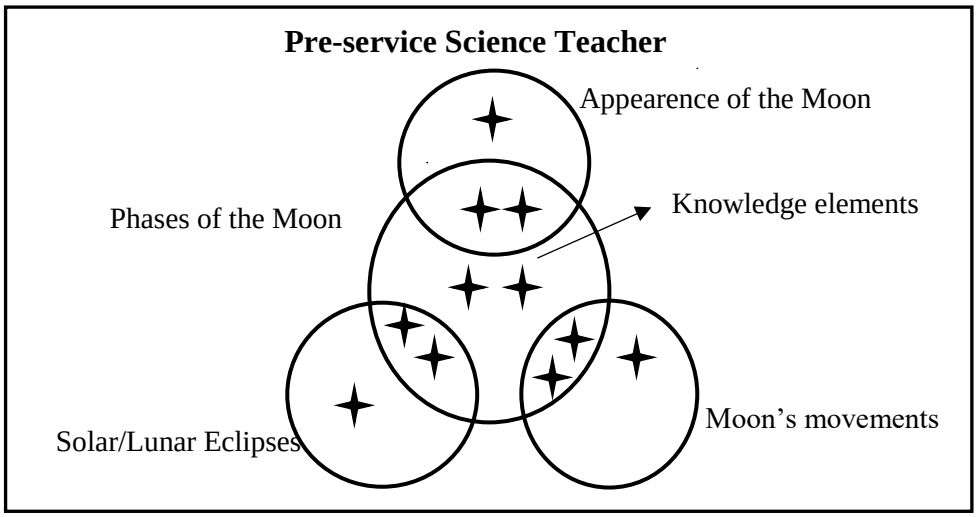


Figure 3.1 Research Design

As seen in Figure 3.1, unit of analysis of the present study referred to pre-service science teachers' understanding on phases of the moon, solar/lunar eclipses, moon's movement and appearance of the moon from different longitude and latitude. Phases of the moon issue is overlapping concept with other three concepts regarding the moon. Therefore, some studies (e.g., Barnett & Morran, 2002; Lindell & Olsen, 2002; Trumper, 2006b) focused on phases of the moon as a broad concept which may cover eclipses, moon's movement and appearance of the moon from different location. In addition, there are common knowledge elements that pre-service science teachers should activate while explaining phases of the moon and other moon related concepts. Therefore, unit of analysis of the current research covered not only phases of the moon but also solar and lunar eclipses, moon's movements and appearance of the moon from different longitude and latitude.

According to perspective of Yin (2003), determining types of a case study design makes the research more powerful and facilitates to conduct it. There are many types of case studies considering their function, design, orientation and purpose of the research. They traditionally are categorized as single case or multisite/multiple/cross case studies with respect to number of cases. Multisite case studies differentiate from single cases in that possessing subunits or more than one case (Merriam, 1998; Yin, 2003). Researcher collect and analyze data obtained from

each case which have common characteristics (Stake, 2006). To put it differently, each case is an instance of the same phenomenon, but they differentiate each other. On the one hand, single case study represents more intensive examination regarding case. Since focus point of the multiple case study is a collection of cases, intensive examination of each case is limited (Gerring, 2006). In addition to this difference, the perspective on data analysis procedure is also different. While single case studies chiefly examine within case variation, multiple case studies examine variation among cases (Gerring, 2006). However, according to perspective of Gerring (2006) single and multiple case studies are complements rather than opponents. A research possibly has characteristics of both single and multiple case design at the same time.

In addition to this traditional categorization, Stake (2006) suggested a typology considering focus point of the case studies. According to this viewpoint, there are two categories for case studies as intrinsic case studies and instrumental case studies. Accordingly, intrinsic case studies pay attention to case itself. These studies are interested in particular situations. On the other hand, cases are figurant with respect to instrumental case studies. The major purpose of this type of studies might be developing a theory, examining an abstract concept or generalizing to other cases.

Taking into account of the purpose of the study which is to examine pre-service science teachers' conceptual structure during a clinical interview, it is revealed that case study design is more appropriate. As stressed previously, pre-service science teachers participated to the current study refers to cases. Since there are more than one teacher candidate and primary focus is cross case variation rather than within case variation, this study is a multiple case study. On the other hands, target of the current research is to portray pre-service science teachers' conceptual structure during the clinical interview. Namely, this study aims to understand abstract issue rather than cases themselves. Therefore, this research can be also categorized as instrumental case study.

3.2 Participant Selection

Qualitative research aims to obtain rich information from specific cases with an in-depth examination. Purposive sampling is a popular data collection way of qualitative studies for this objective. It refers to selecting cases for a qualitative study which have potential to present deep and detailed information about the phenomenon (Patton, 2002). First step of the purposive sample procedure is determining criteria list in order to select participants. Merriam (2009) argued that criteria list has critically important for identification of cases which have great information with respect to research objectives.

This research aims to find out pre-service science teachers' conceptual understanding in the content of phrases of the moon. The main aim of the study is to obtain richer and deeper understanding. Therefore, the participant of the study will be chosen via purposive sampling method. Three criteria were shaped participant selection process;

- Participants of the research were selected from junior and senior teacher candidates. These students enrolled in major courses in the teacher education program which also includes astronomy and physic courses. Chief course in teacher education program regarding astronomy concepts is astronomy course. Pre-service science teachers are enrolled in this course at fourth semester. Content of the course covers some concepts such historical development, contribution of different civilization to astronomy, devices utilized in astronomy, solar system, movement of the earth, the moon and the sun, Kepler law, time-seasons-calendars; stars, constellations, galaxies, milky way, structure and origin of the universe, and space technologies (YÖK, 2018). In addition to, some of the physics courses present some basic concepts which support their understanding on astronomy. These courses are physics 1 and 3, which are offered first and third semester respectively. Physics 1 course includes newton laws and universal gravitational force and physics 3 course includes structure

of light, reflection, refraction and optical devices (YÖK, 2018), which may prerequisite for clear understanding of astronomy concepts.

- Participants were acquaintance with the researcher of the current study. Researcher has assisted undergraduate courses entitled as laboratory application in science education, evaluation and measurement, school experience and practice teaching in which the participants enrolled. Therefore, they were willing to participant the study as a consequence of a rapport to be established between course assistant and students. As a consequence of this relationship, pre-service science teachers frankly responded interview questions without any concern regarding their academic achievement or social perception toward them. It was an important to obtain rich and reliable data from pre-service science teachers.

- As stressed previously, research of the current study was a research assistant and assisted to instructors of some of the undergraduate courses that pre-service science teachers pursue. Therefore, researcher was familiar with teacher candidates and had prior knowledge regarding them, which generally constituted by unsystematic observations. Pre-service science teachers who are outspoken and more sociable pre-service science teachers were preferred in order that they have potential to present more rich data regarding their conceptual understanding regarding phases of the moon. In addition, researcher's observation regarding pre-service science teachers' interest in astronomy was a criterion for participant selection process.

There are different types of purposive sampling methods. In the current study, typical sampling method was adopted. Accordingly, participants reflects typical characteristics of phenomenon that research focus on (Merriam, 2009). Therefore, researchers who possess typical characteristics regarding research objectives preferred as participants. Participants of the current study were selected from senior

and junior pre-service science teachers in a public university. There were total number of seventy-six pre-service science teachers. Considering researcher's prior observation and sampling criteria, sixteen pre-service teachers were asked to participate in the current research. Fourteen of them accepted this request and enrolled in the study. Participants were directed pre- questions at the beginning of the interview in order to determine their characteristics. Pre-service science teachers' responses were categorized as astronomy engagement and their teaching engagement which is shown in Table 3.1.

Table 3.1 Characteristics of Pre-service Science Teachers

	Engagement		**Teaching Engagement**
1	Observing the sky	1	Preparing educational materials
2	Reading books or articles	2	Designing a teaching plan
3	Following social, press and visual media news	3	Assisting a lecture
4	Watching documentaries and tv programs	4	Instructing
5	Visiting space camps or observatories		
6	Participating astronomy clubs		

As seen Table 3.1, astronomy engagements refer to participation to activities in order to improve their astronomy knowledge. Six activities were determined considering ways of informal science learning explained in the report of National Research Council (National Research Council [NRC], 2009) and astronomy context. On the other hand, teaching engagement corresponds to teacher candidates' participation to teaching activities regarding astronomy. Four items of teaching engagement were determined by researcher of the current study. In the following table shows number of pre-service teachers engaging these activities.

Table 3.2 Frequency of Activities

Activities	**Frequency**
Observing the sky	6
Reading books or articles	3
Following social, press and visual media news	5
Watching documentaries and tv programs	7
Visiting observatories or space camps	4
Participating astronomy clubs	2
Preparing educational materials	7
Observing an instruction at middle school	3
Assisting a lecture	2
Instructing	1

Watching documentaries and tv programs were the most common activity for pre-service science teachers. Three pre-service science teachers declared that they watched episodes of Cosmos documentary. In addition, one of the participants explained he/she followed national geographic and discovery channels for watching documentary. The subject of solar system, planet and formation of the universe were more attractive while watching documentary for another participant. On the other hand, the number of the participants stressed that they observe the sky is six. Two of them grew up in a rural area; therefore, observing the sky was more enjoyable activity for them. They also stressed that they had more clear view for sky observation comparing with urban areas. In addition to, one of the pre-service science teachers utilized application in her smart phone in order to find location and name of celestial bodies. Stars and constellations were common objects for pre-service science teachers for their observations.

Although none of the participants were member of an astronomy club, two of them participated a number of activities organized by university astronomy club. They visited an observatory and joined a training regarding telescopes. Similar to participation to astronomy club, pre-service science teachers rarely read books or articles regarding astronomy. A total of two teacher candidates declared that they read "A brief history of time" written by Stephan Hawking. Other participant explained that s/he read many scientific articles regarding space pollution.

Five pre-service science teachers declared that they follow some of the accounts sharing new regarding astronomy in social media. three of them explained that they follow official account of NASA in Twitter. The other two participants read new regarding astronomy via their Facebook account. Finally, number of the pre-service science teachers visited an observatory, space camp or planetarium were five. Three pre-service science teachers explained that they visited the space camp located in Izmir. They stressed that they participated some of the activities and simulations regarding space life of astronomer, gravity and space explorations. Other place they visited is Ankara University Kreiken Observatory. Three pre-service science teachers stressed that they went to this observatory and observe the Moon, Saturn and Mars. In addition, one of the pre-service science teachers explained that they participated to planetarium activity in Middle East Technical University Science and Technology Museum.

Some of the pre-service science teachers were involved in activities regarding astronomy teaching. Three of them prepared a measuring tool considering middle school science curriculum pertaining solar system in the context of an undergraduate course. In addition, preparing a quiz pertaining phases of the moon in their internship, power point presentation about space pollution and scientific magazine regarding phases of the moon were other activities pre-service science teachers performed. Three of pre-service science teachers observed in-service science teachers while instructing phases of the moon to middle school students. Two of them were also assisted science teachers via preparing quizzes and evaluating exams. Only one of the pre-service science teachers instructed with respect to phases of the moon to middle school students. The following table shows astronomy engagements of each participants considering number of the activities they engage regarding astronomy.

Table 3.3 Rating of Pre-service Science Teachers' Engagement

No	Pseudonym	Grade	Engagement	Teaching Engagement
			1 2 3 4 5 6 7	1 2 3 4
1	Ayşıl	Junior	□ □ □ □ □ □	■ □ □ □
2	Aybüke	Junior	■ □ ■ □ □ □	□ □ □ □
3	Aytolun	Junior	□ □ □ ■ □ □	■ □ □ □
4	Ayten	Junior	□ □ □ □ □ □	□ □ □ □
5	Ayça	Junior	□ □ ■ ■ □ □	□ □ □ □
6	Aykut	Junior	□ □ □ ■ □ □	■ □ □ □
7	Aygün	Junior	□ ■ □ ■ ■ □	□ □ □ □
8	Aynur	Junior	■ □ □ □ □ □	■ □ □ □
9	Aydan	Junior	■ ■ □ ■ □ □	□ □ □ □
10	Aybilge	Senior	■ ■ ■ ■ ■ ■	■ □ □ □
11	Ayşin	Senior	□ □ ■ ■ ■ □	■ ■ ■ □
12	Ayfer	Senior	■ □ □ □ ■ ■	□ □ □ □
13	Aytaç	Junior	■ □ □ ■ □ □	□ □ □ □
14	Aysu	Senior	■ □ □ ■ □ □	■ ■ ■ ■

Considering the Table 3.3, it was revealed that the current study covered participants have different interest towards astronomy. For instance, some of the participants such as Ayten, Ayşıl have low engagement while some participants such as Aybilge, Aygün, Ayşin and Aysu have high level of engagement.

3.3 Data Collection

The current study aimed to explore pre-service science teachers' conceptual structure regarding phases of the moon issue. To put it in another, this study examined conceptual mechanism of the participant during short time period and multiple stages like many other studies designed in the context of knowledge in pieces framework (e.g., Parnafes, 2012; Sherin et al., 2012; Wagner, 2006). In order to accomplish this aim, a set of open-ended interview questions were directed to voluntary teacher candidates in places where they felt comfortable. This interaction between participants and researcher was video-recorded and transcribed.

Interviews are used among the data collection ways for qualitative studies. Researchers aim to ascertain participants' mind with respect to their research

questions (Patton, 2002). Many studies traditionally preferred interviews in order to examine the changes in students' understanding before and after different implementations. However, recent research revealed that interviews are dynamic process, which means there may be changes during the interview because of its nature (diSessa et al., 2004; Sherin et al., 2012; Welzel & Roth, 1998). These changes may occur in a short time period which may be in seconds or a few minutes; or a long-time period in which individuals are exposed new contextual situations.

3.4 Clinical Interview

One of the types of interview utilized by researchers are clinical interviews. According to Posner and Gertzog (1982), essential aim of clinical interview is *"to ascertain the nature and extent of an individual's knowledge about a particular domain by identifying the relevant conceptions he or she holds and the perceived relationships among those conceptions."* It is a process that subjects attempted to find a way in order to solve problems situation directed by practitioners (diSessa, 2007). This process is highly flexible; therefore, it lets interviewees to talk freely and to rethink about their responses (Posner & Gertzog, 1982). Each participants have unique cognitive structure with respect to research purpose and interviewers should keep their eyes open for capturing these essential parts of cognition (Posner & Gertzog, 1982).

In the present study, clinical interviews designed in line with multimedia approach (Blown & Bryce, 2006, 2010), in which participants have opportunity explain their opinions in different ways. Media refers to instruments that participants utilize for their explanations. Phases of the moon concept, like many other astronomy issues, cover three-dimensional nature, which make it a thorny issue for students. Therefore, as proposed by (Atwood & Atwood, 1995, 1996; Stahly et al., 1999; Trundle et al., 2002), different media were preferred in order to examine pre-service science teachers conceptual understandings. These instruments were verbal explanation, drawing and model demonstration. Initially, pre-service science teachers responded interview question verbally. Then, they try to explain phenomenon by drawing some figures or diagrams. Finally, modelling by the phenomenon using three

different ball is the last media for pre-service teachers' explanations. This technique was preferred by (Atwood & Atwood, 1995, 1996; Barnett & Morran, 2002; Plummer et al., 2016; Stahly et al., 1999; Trundle et al., 2002), and researchers stressed that using three dimensional models elicit participant conceptual understanding more clearly.

All the clinical interviews conducted in the current study followed the same patterns. Firstly, interviewer introduce research aim and interview procedure then asked to introduce themselves with respect to their experience on astronomy. In order to decrease potential stress of the participants, researchers explained that the data obtaining them would not share anyone and would not evaluate in the context of any undergraduate course they pursue. Then the question related to the parts were directed to interviewee respectively. In each part, participant responded the question by verbally, drawing and using three-dimensional model. At the end of the interview, researcher asked to participants not to share interview question with their classmates.

Participants' responses during clinical interview may be vague or ambiguous. Therefore, many follow up questions were also directed to participants in order to capture participants understanding on phases of the moon. An example of follow up questions with respect to lunar eclipses were presented in the following excerpt.

Interviewer: What is the lunar eclipse and what would you observe while looking from the earth?
Aykut: I am not sure. I said it was dark in solar eclipse. How can I explain… The moon shade the sun depending on in its orbital position.
Interviewer: So, what is the difference between solar and lunar eclipse?
Aykut: Difference between solar and lunar eclipse is that there is no sudden darkness in lunar eclipse. We observe the sun as orange rather then red. I could not describe that color.
Interviewer: Why does we observe the sun as orange colored?

As shown the excerpt above, since participants' initial explanation was similar to his solar eclipse explanation, interviewer directed a follow up question. Participant explained difference between solar and lunar eclipses in his response. However, interviewer also asked another further question in order to understand mechanism behind different color of the sun during the lunar eclipse.

Utilizing interviews enriched by model and drawing is quite important in order to clearly understand individual understanding on phases of the moon. Data collecting via open ended questions or just verbal responses may be misleading while analyzing. For instance, Bayraktar (2009) conducted a research in order to understand pre-service primary teachers understanding on phases of the moon via open-ended questions. As a consequence of the analyses, Bayraktar (2006) found that more than half of the pre-service teachers have scientific conceptual understandings. Some of the responses of the pre-service science teachers were labeled as scientific presented below.

> The moon revolves around the Earth. At the same period, it rotates on its axis. That is why we always see its same face. However, sun lights fall on different parts of the moon. Depending on what parts getting light from the sun we can see different shapes of the moon (Bayraktar, 2009, pp. 17-18).

> It depends on the sun light becomes effective in some areas or not due to the revolution of the moon around the earth. The area lit by the sun is seen bright and the area that is not lit by the sun is seen dark (Bayraktar, 2009, pp. 17-18).

It is reasonable to consider pre-service teachers' these explanations as scientific since they had four conditions as the moon's moving around the earth, illumination of the moon by the sun, and our observation to the illuminated part. However, these responses still could not guarantee that these pre-service teachers have scientific understandings because of limitation of the open-ended questions. Teachers candidate may activate knowledge elements those are not obviously clear in their responses. Following responses of the Aynur, a participant of the current study, resembles to two responses of the preservice teachers participated in Bayraktar's (2009) study.

> *The moon and the earth revolve together. Sometimes the moon…Because of receiving sunlight, I mean the moon located in the middle and the moon revolves. The moon receiving sunlight… Since both the moon and the earth revolve the moon cannot receive sunlight directly.*

At first glance, this explanation can be categorized as scientific. However, understanding of the Aynur was far away from scientific understanding. Her explanation of each phases and demonstrations using three-dimensional model

showed that Aynur has a blocking concepts that shape her responses. Accordingly, she believes that the sunlight received to the moon was determined by blockage of the earth. Depending on degree of the earth blockage, the moon is appeared with different phases. This situation showed that examining response of the participants may be misleading. Multi-method approach is more appropriate in order to determine pre-service teacher knowledge elements and portray their conceptual structures. Therefore, pre-service science teachers verbal explanations, drawing and model demonstrations were utilized in order to detect their conceptual understanding on phases of the moon.

Some researchers have investigated changes on conceptual understanding after a specific implementation or teaching techniques discusses whether or not using three-dimensional model appropriate. The basic rationale behind this discussion is that models may influence participants conceptual structure, which prevent measuring obvious contribution of the implementation. For instance, Atwood & Atwood (1995, 1996) underlined potential contribution of models for participants during interviews. However, Trundle et al., (2002) empirically support that using three dimensional model do not have instructional value in their studies on pre-service teachers.

Beyond this discussion, the current study followed knowledge of pieces framework. Therefore, any material that was provided to participants have potential to change their conceptual dynamics. In the current study, initially participants were asked to responded interview question by verbally. Then, they drew figures in order to clarify their opinions. Finally, three dimensional materials were utilized in order to respond to the question. Therefore, three set of data were obtained from participants. In this way, it is examined how participants explanations change while explaining the phenomenon by verbal explanation, drawing and using three-dimensional model.

3.5 Interview Questions

Interview questions of the current study included fourteen questions. These questions adopted from previous studies regarding phases of the moon. Considering the research aim of the present study, questions were modified and divided into four sub-categories as seen below.

Part 1: What cause the phases of the moon?

Part 2: Solar and lunar eclipse

Part 3: Appearance of the moon depending different longitude and latitude

Part 4: Apparent movement of the sun and the moon

Part 1 is essential part of interview questions. It includes four question regarding phases of the moon. More specifically, participants were asked to demonstrate different appearance of the moon and explained why we observe those appearances.

Second part of the interview protocol involves in questions concerning lunar and solar eclipses. As stressed previously, result of the previous studies regarding conceptual understand on phases of the moon indicated that many individuals from different age groups believe reason of different appearance is shadow of the earth. This shows phases of the moon issues and eclipses concepts are overlapping issues. Furthermore, there are many study (e.g., Barnett & Morran, 2002; Trumper, 2006b) examined conceptual understanding while combining these two issues. Considering rationale behind this tendency, questions regarding eclipses and their association with lunar phases inserted to the interview protocol.

Moreover, the study of Lindell and Olsen (2002) inspired the current study while constituting part 3 and part 4. In their scale development study, eight different lunar phases concept domains including effect of location on phases of the moon, motion of the moon, location of the moon in the sky, moon's period were determined. Therefore, it was concluded that concept of phases of the moon was not limited with

reason of each phases and eclipses. Therefore, questions regarding appearance of the moon from different location in the earth and daily movement of the moon and sun inserted to part three and part four respectively. More specifically, questions of part three covers prediction of appearance of the moon in case of change of an observer's coordinates. On the other hands, movement of moon and sun in the sky, visibility of the moon in day, apparent face of the moon were some of the issues in part four.

The pilot study of the current research was conducted one year before the main research. Four senior pre-service science teachers were participated to pilot interviews. Depending on responses of pre-service teachers, researcher some of the questions were modified to prevent confusion of pre-service science teachers. Some of the questions were combined since responses overlapping each other. In addition, three-dimensional models utilized during the interview were modified. A jointed solar system model involving the sun, the earth, the moon and other seven planets was utilized in pilot study since phases of the moon was a phenomenon under solar system concept. However, it was revealed that pre-service science teachers perceived it a clue that other planets should have roles in phases of the moon. Thus, number of items in the model reduced three objects as the moon, the sun and the earth. They were able to utilize separately in this modified model.

Expert opinion was also taken for interview questions. Five researchers in the field of astronomy educations were examined question with respect to clarity, consistency with research aim and correctness of terminology of astronomy. Some of the questions were revised considering feedback of experts. For instance, specific location as Istanbul, Trabzon were inserted questions regarding appearance of the moon from different latitude and longitude in order to improve clarity. Furthermore, order of the questions was also arranged considering their feedbacks. Final versions of interview questions were presented in appendix A.

3.6 Apparatus

Pre-service science teachers were provided some of the materials in order to elaborate their ideas during the interviews. After their verbal answers to each

question, A4 papers and pencil were given to participant for drawing. If they want to change their drawing, they were provided new paper rather than erasing previous. Other materials provided to participants to responded to question was three-dimensional model. After participants verbal response and drawing, they were asked to demonstrate via three dimensional models. They were provided with three balls which have different dimensions, which modeling the sun/earth/moon. These balls were supported with wooden stick so as to improve their feasibility for demonstration. Then, they were mounted on plastic brackets as shown in Figure 3.2. Additionally, two unmounted model were also available during the interview as seen in Figure 3.3.

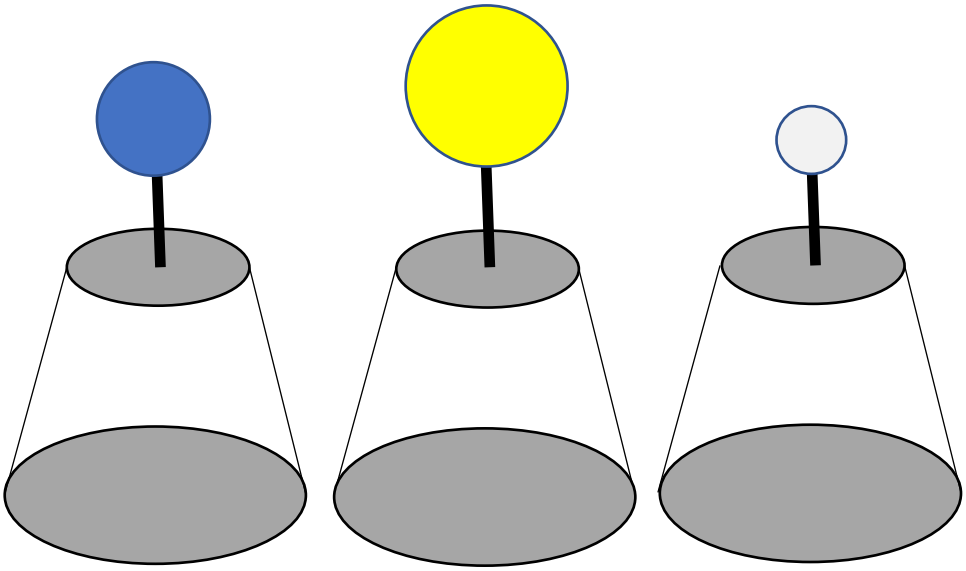


Figure 3.2 Apparatus Utilized in Interview

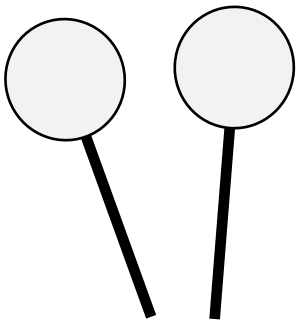


Figure 3.3 Other Apparatus Utilized in Interview

3.7 Role of the Researcher

Researcher of the current study have three years' experience on conducting interview. During these three years, researchers conducted interviews with in-service and pre-service in order to fulfill different research objectives.

Researcher of the study have two fundamental responsibility in the current study. Firstly, the researcher aimed to obtain richer and deeper information during the data collection process. Therefore, three types of questions for an issue were also directed as an oral question, model demonstration and drawing. In addition, researcher will ask participants with further questions in order to clarify and elicit their ideas on each question.

The second role of the researcher is to provoke participants' conceptions without any manipulation or instruction. Knowledge pieces generally fit together (Parnafes, 2012), which constituted coherence structure. However, as a consequence of available contextual clues, knowledge pieces may be conflicted and; therefore, individuals re-organized their knowledge pieces. They produced more sophisticated structure explaining the phenomenon. However, this process may not be automatically developed. Individuals sometimes may not consider different perspectives and may not be aware of inconsistency between their knowledge pieces (Sherin et al., 2012). Therefore, considering this rationale, researcher provided interview questions including different four sub-categories. It was considered that questions from different sub-categories may provoke pre-service science teachers' conceptions. In addition, inconsistency in their explanation were explicitly pointed out and directed as further question to participants. For instance, in case of explanations on eclipses questions conflicted with explanation on phases of the moon, participants' eclipses explanations reminded them. By this way, how participants understanding on phases of the moon may change during a clinical interview was revealed.

In addition to two fundamental objectives, it is critically important to create relaxing environment in order to ensure participant comfort. Therefore, researcher will be sensitive while determining location and condition of the interview room.

3.8 Data Analysis

Focus of the analysis process of the current study is to portray conceptual mechanism or change in conceptual system in a short period of time. During the analysis, researcher attempt to reveal knowledge elements, how these elements interact with each other and how they construct a mental structure considering contextual factors with moment by moment examination.

Researchers that follow knowledge in pieces perspective have preferred to use different languages in order to define unit of knowledge system. For instance, phenomenological primitive (diSessa, 1993), facets (Minstrell & Stimpson, 1996) and mode/node (Sherin et al., 2012) are some of the common name of the knowledge pieces that researchers preferred. In the present study, mode/node framework proposed by Sherin et al., (2012) was utilized in order to determine knowledge pieces of pre-service teacher candidates. One of the most favorable aspect of this framework is that variety of knowledge types (e.g., propositions, general schema, mental images, mental models) were grouped as node, which facilitates examination of complex interview process (Sherin et al., 2007). In addition, it is relatively easy to perform this framework since it just includes three entities such as node, mode and DMC. According to this framework, node covers variety of fragmented knowledge pieces which may have different type of characteristics. Nodes connected each other, and these connected nodes are called as modes. The last component dynamic mental construct (DMC) is operational form of modes and nodes. Although nodes and modes permanent mental entities, DMC is temporal and may change rapidly. Following conversation was adopted from the studies of Sherin et al., (2007) and show a sample analysis in order to determine nodes and dynamic mental construct of a participants.

Interviewer: First thing I want to know is why is it warmer in the summer and colder in the winter.

Participant: (1) Well. Umm, you know times saving?... Daylight saving time in the summer we have more time, like, with, like, daylight and that's why it gets warmer. (2) And with the circulation of the earth and the axis that it's on just has to do with like summer and winter….

Considering the excerpt above, Sherin et al., (2007) determined activated nodes and dynamic mental construct of the participant as shown in Table 3.4.

Table 3.4 Sample Analysis Regarding Node/Mode Framework

Sentence	**Activated Nodes**	**Dynamic Mental Construct**
1	*Daylights savings time* *Days are longer in the summer* *More source more effect*	*Days are longer in the summer. Longer days mean more daylight which makes it warmer.*
2	*Axis* *Earth moves*	*Earth movement and axis somehow are related to the season.*

Since the present study follows node/mode framework, knowledge pieces correspond to nodes. Development of participants dynamic mental construct will be examined with moment by moment in interview process. As explained earlier, interviews cover related four parts of questions. In addition, participants responded questions utilizing three different media in each part. Data analysis process contains determining activated nodes and dynamic mental construct of the participants for each parts of question. Furthermore, while changing the questions and media for responses, changes on their dynamic mental construct and reason behind these changes examined.

This study followed analytic perspective and data was coded in order to generate inferences regarding the research aim. Accordingly, constant comparative method (Glaser & Strauss, 1967) was utilized for data analysis. Although this analysis generally preferred for developing grounded theory, it is possible for other types of qualitative studies due to its comparative and inductive characteristics (Merriam, 2009). This analysis also provides opportunity to compare differences and similarities among cases.

In the first step of the analysis, data was coded considering theoretical perspective of the current study which is knowledge in pieces. Researcher attempt to

find each node which shape participants mental construct from their explanations. Prior to analysis, previous studies on conceptual change in the context of phases of the moon are examined in order to determine possible knowledge pieces. It is revealed that many of them (e.g.,Targan, 1988; Trundle et al., 2002) followed analytical perspective and utilized codes. These codes were adopted from these studies to coding schema of current analysis. In addition, some of the knowledge elements were also found from the studies considering (e.g., Nielsen & Hoban, 2015; Parnafes, 2012) designed knowledge in pieces perspective. In the second phrase, it is examined how these knowledge pieces constituted participants dynamic mental construct. Finally, knowledge elements and dynamic mental construct were compared for each participant in order to generate conclusion regarding research questions.

3.9 Validity and Reliability of the Study

Researchers followed qualitative paradigm face an issue what extent they trust on data they obtained (Fraenkel, Wallen, & Hyun, 2012). Therefore, researchers should ensure that natural structure and characteristics of an issue should fit between their data collection process concerning an issue (Bogdan & Biklen, 1992). There are different types and terms of validation process. Creswell, (2007) stressed that researchers can choose any terminologies and validation types which are comfortable for them. In the current research, positivist terminologies and validation process that is suggested by Creswell and Miller, (2000) were preferred.

Creswell and Miller, (2000) suggested nine validation procedures for researchers in order to establish credibility of their study. These ways listed as triangulation, member checking, the audit trail, disconfirming evidence, prolonged engagement in the field, researcher reflexivity, collaboration, peer debriefing, and thick, rich description. In addition, it was stressed that researcher should engage with at least two of them to validate their studies (Creswell, 2007). In the current study, triangulation, peer debriefing, and rich and thick description procedures were utilized so as to ensure validate the current study.

Triangulation is a method in order to portray complex nature of a phenomenon from more than one standpoints (Cohen, Manion, & Morrison, 2007). There are four different type of triangulation such as data, investigator, theory and methodological triangulation (Denzin, 1978). In addition, Denzin (1978) noted that there are two forms of methodological triangulation as with-in method or across method triangulation. Accordingly, with-in method triangulation are suitable multidimensional units. Researcher utilize one method with its multiple strategies. On the other hand, researcher employed alternative methods to measure units in the form of across method triangulation. Since methods have different strength and weak aspects, employing multiple methods enhance credibility of study. In this way, researcher combine multiple methods and eliminate deficiencies of each methods.

In the current study, with-in method triangulation was employed in order to enhance validity. Pre-service science teachers responded to same interview question three different way such as verbal answer, drawing and three-dimensional model demonstration. Each of the data analyzed independently. Results of each strategy were compared with others. For instance, following example indicates how utilizing different data sources improves credibility of the study.

> *Interviewer: Why do we observe different phases of the moon?*
> *Participant: It is related to going close or away. It moves closer or away due to the earth's horizontal axis. Therefore, there is no stable distance between the moon and the earth. Larger shape occurs when it is closer to the earth.*

It is plausible to recognize that participant believe the earth spins its own horizontal axis. Therefore, that distance between the moon and the earth changes during this movement is also rational inferences by taking into account above excerpt. However, researcher was asked to draw in order to express different appearance of the moon. Then, participant drew Figure 3.4 in which the moon orbits around the earth. Considering both data sources, it was revealed that participants opinion corresponds to orbit of the moon rather than spin of the earth on its horizontal axis.

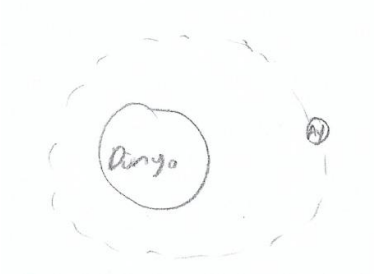


Figure 3.4 Sample Drawing

There are also some debates regarding triangulation in terms of its potential to validate qualitative data. Accordingly, Mathison (1988) argued that each of the data sources utilized for triangulation present different understanding regarding a phenomenon. Therefore, it is usually not possible to reach single view of a case. Mathison (1988) stressed that researcher may encounter inconsistent, convergent or contradict data because of triangulation. It is suggested to researcher to explain rationale behind inconsistent, convergent and contradict part of their data (Mathison, 1988). In this study, it was expected that responses of pre-service science teachers may vary depending on type of question as verbal, drawing and model demonstration. Explanations regarding these differences were presented in the analysis part of this research.

Another procedure employed in the current study was peer debriefing. It refers to review of the study by another researcher who is familiar with phenomenon in the context of the study (Creswell & Miller, 2000; Merriam, 1998). Supervisor of the current study examined all research process including research design, data analysis and findings, and supported the researcher with challenging questions or valuable comments regarding some of the issues. In addition, two other researcher who was member of thesis advisory committee support this study with their valuable feedbacks and comments.

Rich, thick description is a way which cover explanation contextual factors in a study. Accordingly, researchers describe research settings, characteristics of participants and also findings so that other researchers benefit from research (Merriam, 2009). In the current study, these contextual factors were presented in-detailed in method chapter.

Reliability refers to consistency between different coder responses of a data (Creswell, 2007). Accordingly, there should be an agreement regarding coding of data among multiple coder. Two coder who have experiences regarding phases of the moon and qualitative research perspective examined 10 % of collected data. After examination, consistency among the researcher were calculated and 82 % agreement was found. Then, three coder discussed inconsistencies and reach an agreement regarding codes.

3.10 Ethical Issues

Content of the current study was examined by Middle East Technical University Institutional Review Board of Ethical Issues and it was approved that the current research does not involve any violation with respect to ethical issues. Report of Institutional Review Board of Ethical Issues was presented in appendix B. In addition, all the participants were informed concerning purpose of the research and interview process. The data gathering from the participants were protected and nobody has potential to access videos, drawings and interview scripts except researcher of study.

Real name of the participants was not used any part of the present study. There was no information that identify participants. Pseudonyms were utilized in order to ensure the anonymity.

3.11 Assumptions

In the current study, it was assumed that pre-service science teachers' responses toward questions regarding phases of the moon reflects their understanding. To put it another, pre-service science teachers' explanations was external reflection of their knowledge structures. Therefore, changes of participants' responses were considered as changes their conceptual understanding. Another assumption in the current study is that pre-service science teachers responded interview question honestly.

CHAPTER 4

FINDINGS

The purpose of the current study is to portray dynamic mental construct of middle school science teacher candidates regarding phases of the moon issues. Besides, exploring changes in their mental states during a short time period is also the main goal of this study. For this specified purpose, the current study followed closely in Knowledge in Pieces perspective's footsteps and data obtaining via clinical interviews. Recall that it is aimed at addressing the following main and sub-research questions.

- What is the mental construct behind pre-service science teachers' responses on phases of the moon?
    - Which knowledge elements activated while explaining phases of the moon?
    - Which factors shape pre-service science teachers' response on phases of the moon?
- How do pre-service science teachers alter their dynamic mental construct during clinical interview designed with multimedia approach?

In this chapter, the findings of the current study were presented. First, findings regarding mental structure and knowledge elements behind these structures were presented. Then, changes in their mental states were examined considering different media and different contextual questions.

4.1 Mental Construct on Phases of the Moon

Findings on pre-service science teachers' dynamic mental constructs on phases of the moon were presented in this part of the current research. Specifically, this part referred to the first research question and its first sub-research question which focus on pre-service science teachers' dynamic mental constructs and activated nodes in

their explanations. Therefore, pre-service science teachers' nodes and dynamic mental construct regarding appearance of the moon, reason for phases of the moon, eclipses and apparent movement of the moon were presented respectively.

4.1.1 Appearance of the Moon

Reflecting knowledge structure on different appearance of the moon, pre-service science teachers stated the name of different phases of the moon. Then, they were asked to draw figure of each of these different appearances with appropriate order. Findings regarding appearance of the moon covers approximately the first fifteen minutes of interview interaction. Specifically, this part only covers students' attempts to find, order and entitle of phases of the moon. As a consequence of data analysis, it was revealed that pre-service science teachers activated knowledge elements as seen in Table 4.1 while stating different appearance and their sequence.

Table 4.1 Activated Nodes Regarding Different Appearance of the Moon

Nodes	**Description**
Completing cycle	Phases of the moon follows a cycle which is repeated.
Gradual change	Illuminated part of the moon gradually change.
Opposite phases	Some phases have reverse appearance.
Observable	All the moon phases are observable.
Illumination	The sun shines on the moon.

Pre-service science teachers performed nodes as seen Table 4.1 in order to state and draw shape and sequence of phases of the moon. "Completing a cycle" is one of the nodes that elementary science teachers activated. They attempted to predict the moon's different appearances and sequence of these appearances considering progressively change of shape of the moon in a cycle. Thus, pre-service teachers generally entitled some phases as starting and ending phases of cycle of phases of the moon.

"Gradual change" refers to change of dark or illuminated part of the moon slowly or gradually. Pre-service science teachers generally showed and explained that illuminated or dark partition of the moon changed gradually during specific period. They generally stressed that this time period was completed between 27 and 30 days.

Accordingly, illuminated part of the moon should increase from new moon to full moon, and dark portion of the moon should decrease from full moon to new moon during this time period. Pre-service science teachers shaped their explanation and drawings considering this phenomenon.

"Opposite phases" is another knowledge element utilized by pre-service science teachers. Quarter, gibbous and crescent moons appear two different shapes as first/last or waning/waxing. For instance, right side of the moon is illuminated for first quarter moon while the left side is illuminated for last quarter for an observer from the northern hemisphere. Many pre-service teachers benefited from this node and inserted opposite shapes of phases to their diagrams.

Another knowledge element shaping pre-service science teachers' ideas regarding appearance and sequence of these appearance is "illumination". Pre-service science teachers activating this node consider potential influence of sun or sunlight on different phases. Therefore, drawing of these pre-service science teachers generally includes sun and sunlight symbols.

Finally, the last node pertaining sequence of phases of the moon is new moon. Some of the pre-service science teachers did not draw or symbolize a new moon shape. Comparing other moon shapes, the new moon is different since it is not observable. Some of the pre-service science teachers focused on what they can observe; therefore, their diagrams did not contain new moon phases. It was considered that this situation may stem from the fact that the moon should be observable. To put it in another, a knowledge element "observable" shapes pre-service science teacher' ideas regarding phases of the explanations. Thus, this knowledge element entitled as "observable". There is a dissimilarity of this node comparing other nodes in the list. Accordingly, pre-service science teachers may activate other four nodes to illustrate appropriate sequence of the moon phases. However, existence or activation of "observation" node causes lack of new moon phase in their phases of the moon drawing. Therefore, it is expected from students to

activated “completing cycle”, “gradual change”, “opposite phases” and “illumination” but not “observable”.

In addition to sequence of phases of the moon, students’ knowledge about name of the phases were also examined. However, sequence of the moon phases and name of the moon phases are not the same type of concept. Activating a set of knowledge elements are required for explaining rationale behind their sequence as stressed at the beginning of this section. However, they simply tried to recall names and guessed what these names refers to. Specifically, pre-service science teachers simply tried to determine whether different shapes reflect characteristic of phases of the moon or not. Therefore, pre-service science teachers’ responses regarding name of the phases of the moon explained descriptively in the following paragraphs.

Two different approaches were detected considering pre-service teachers’ responses. The first approach covered showing different phases within a circle, which corresponds to orbit of the moon around the earth. This demonstration generally includes the sun or sunlight. Pre-service teachers activated mainly illumination node and utilized sunlight in order to predict dark or illuminated side of the moon. Another group of teacher candidate initially preferred ordering them side by side. The second approach included prediction of next phases comparing illuminated and dark part of previous phases. In other words, these participants tried to order phases considering increasing or decreasing of illuminated part of the moon. Therefore, they usually underlined that existing of gradual and cyclical change among different phases in this process, which showed activation of gradual change and completing cycle nodes. In addition to these two approaches, two of pre-service science teachers utilized both side by side and circle diagram.

To illustrate preservice science teachers’ mental construct on phases of the moon, Aydan stated that there must be a different appearance of the moon for all the thirty days of its revolution. According to her, there was a gradual and step by step alteration among lunar phases as seen in following excerpt.

I do not know period of phases of the moon. However, as far as I observe, the moon does not change from today to tomorrow. Appearance of the moon is very similar... I think the moon appearance changes gradually.

In addition to this explanation, she produced the diagram in Figure 4.1 in order to indicate these changes. According to her viewpoint, there is a sequence between the moon's appearance from one to five. After shape 5, the moon returns its shape of the 1, which showed that Aydan activated completing cycle knowledge element.

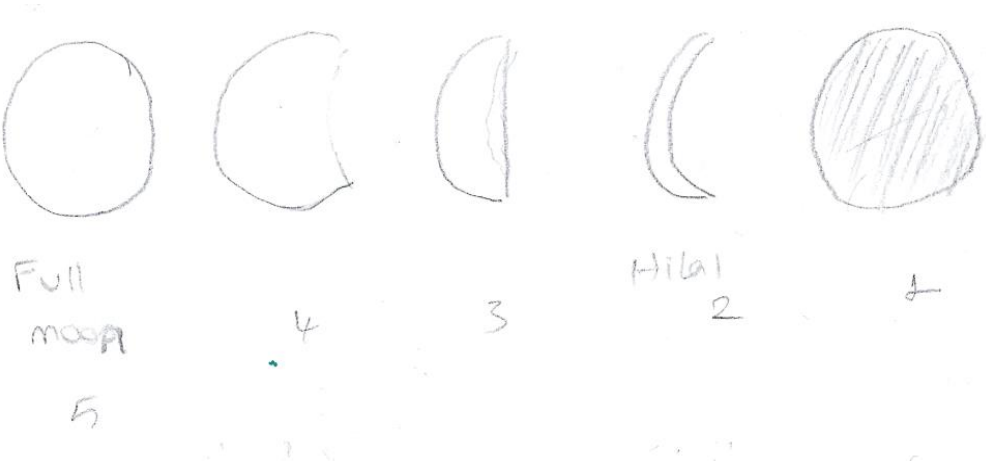


Figure 4.1 Aydan's Drawing of Lunar Phases

Drawing of Aydan includes new moon but does not include waxing crescent, waxing gibbous and first quarter. In addition, she could not remember the name of lunar phases enumerated as 1, 3 and 4. There are five shapes of the moon from number one to five, which represent their appearance order. She stressed that after full moon, shape of the moon would be like in point one and there are five or six days between from one of its appearance to another. Considering her explanations, it is plausible to conclude that she activated "gradual change" and "completing cycle" nodes while explaining phases of the moon. She explicitly explained that visible part of the moon gradually changes. In addition, her drawing showed that apparent part of the moon gradually changes from number one to five as seen in Figure 4.1. However, she could not activate "opposite phases" knowledge elements. Therefore, her model did not include opposite shape of quarter, crescent and gibbous moons.

Another participant, Aytolun made a diagram shown in Figure 4.2, which includes four different appearances of the moon. She explained that there are some other appearances that she could not remember. Although she drew shapes of the first and last quarter, she could not be sure which of them is first or last quarter. According to her perspective, after 29.5 day later, shape of the moon again become new moon. She explained;

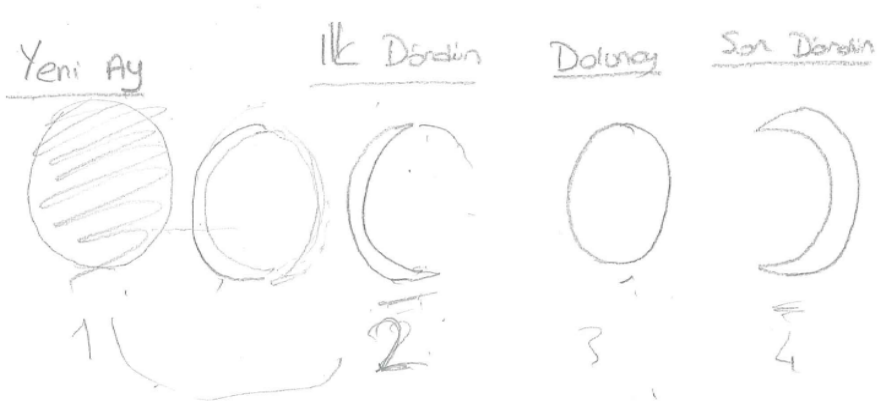


Figure 4.2 Aytolun's Drawing of Phases of the Moon

I think we could not see any part of the moon in new moon phase. When it is first quarter, we observe crescent shape. Its edge faces right. It is completely visible when It is full. Finally, in last quarter, it is again crescent moon. But, it is edge faces left side.

Considering her drawing and explanation, there are some problems of shape of the first and last quarter. She drew shape of the crescent moons instead of the first and the last quarter. In addition, her drawing did not include waxing and waning gibbous moon. Unlike Aydan, Aytolun activated "opposite phases" node and drew opposite shapes of crescent moon. However, she could not perform "gradual change" knowledge element as seen following utterance.

Interviewer: Are there any moon appearance except these four?
Aytolun: Yes. There are other appearances between them. But I cannot draw them. If I observed the moon day by day, I would draw these appearances.
Interview: How long-time span exist among these four moon phases?
Aytolun: One weak. First weak, new moon was observed. Then, first quarter, full moon and last quarter were observed in second, third and fourth weak respectively.
Interviewer: What is its appearance in tenth day?

Aytolun: It is between first quarter and full moon. Full moon shape become visible at the end of second weak and beginning of third weak. It is not crescent shape, since it become full moon.
Interviewer: Could you draw?
Aytolun: (drawing Figure 4.3), it is not full moon. It will be full moon at third weak. So, this part of the moon is explicit and rest of it is inexplicit. Like these dashes. It is neither completely visible nor absent.

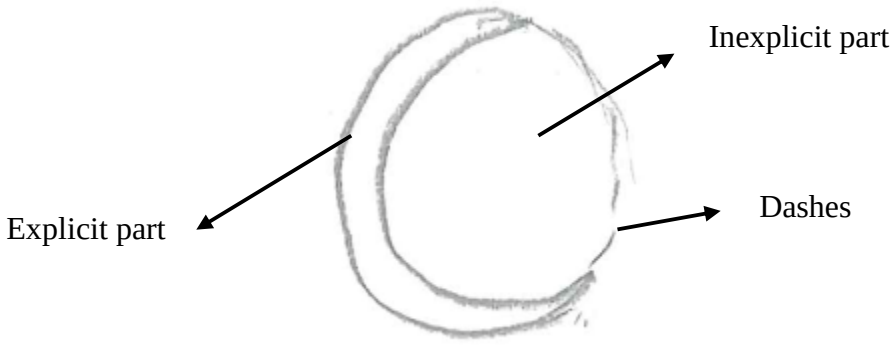


Figure 4.3 Aytolun's Drawing of Explicit or Inexplicit Parts of the Moon

According to Aytolun, illuminated part of the moon does not change gradually. Between second and third weak, crescent portion was observed explicitly while rest of it was observed inexplicitly. Then, inexplicit part gradually become explicit; therefore, full moon appeared. In other words, gradual change corresponded to slow change of inexplicit part of the moon to explicit, which is completely different from gradual change of illuminated or dark part of the moon.

Another participant Ayten initially considered specific moon shapes such as full moon and half-moon. Then, she considered rest of them. At the beginning of the interview, she stated;

Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?
Ayten: I would observe the moon in different shapes if I looked the moon every night at the same time. if it is half moon, it may complete (increase illuminated part). On the contrary, may it decrease if it is full moon? I do not know.

Ayten preferred two reference point as full moon and half-moon. She considered that full moon is completely visible and visibility of it slowly decreases. However, she did not consider new moon while explaining increase of illuminated

part. She stated that visibility of half-moon increases instead of new moon. It is plausible to conclude that she focused visibility and ignored new moon phases.

After her response, Ayten was asked to draw shapes that she stated. She produced the diagram in Figure 4.4. She firstly drew the full moon which is in the middle of shapes, then predicted others. She stressed that apparent portion of the moon increases from first quarter to full moon. Then, it decreases after full moon and shape of the moons would be reverse. She explained that;

Figure 4.4 Ayten's Drawing of Phases of the Moon

Interviewer: What happens in your diagram?
Ayten: Part of the moon I see increase gradually.
Interviewer: (Pointing full moon), after this?
Ayten: After this point, I think it gradually decrease. These are reverse of those (pointing the first three shapes).

Ayten's both explanation and drawing were dominated by the same set of nodes. Considering her diagram and explanations, it was revealed that she activated "gradual change", "opposite phases", "completing cycle" and "observable" nodes. She considered that a cycle lasts thirty or twenty-nine days from the first quarter to last quarter. After this sequence, next cycle starts from last quarter to first quarter, which follows reverse order of previous cycle. Furthermore, there was no new moon in her diagram, which shows she activated "observable" node. On the other hand, she faces problems while entitled moon shapes. She only entitled the full moon appropriately. She entitled last quarter as half-moon. Furthermore, she utilized half-moon in order to name last quarter, and last quarter for crescent moon.

Interviewer also asked next phases after last quarter (which is on the right of Figure 4.4). She stated that visible part of the moon gradually increases, and the moon competes its cycle. However, while explaining, she noticed that visible part of the moon is inconstant each other as seen following utterance.

Ayten: But, now it does not seem logical.
Interviewer: Why?
Ayten: While lasting like that (pointing from her first shape to full moon, how can it be like that (pointing rest of shapes). (considering a couple of seconds). Anyway, I had better not question regarding this issue. My response may be unreasonable.
Interviewer: You can consider… Alright, which point make you uncomfortable?
Ayten: Visible area of the moon increase in this way (pointing right side of the moon in her three shapes), it is full moon in here. Then, visible part of the moon decreases in that its other side (pointing left of the moon). But then it will increase again. It is strange. I could not visualize it. Let me visualize. (silence 20 seconds).
Ayten: It resembles these shapes. Anyway.

As seen this utterance, Ayten detected that there is inconsistency considering visible and invisible part of the moon before and after full moon phase. It is plausible to consider that she encountered difficulties to visualize change on appearance of the moon. Although she considered about this issue, she did not change her drawing and ignored the issue.

Another participant whose response was categorized as relatively stable explanation was Aynur. Her drawing included five different moon appearance. However, there is no new moon phases inside them. She stressed that there was an astronomical phenomenon entitled lunar conjunction instead of new moon. She drew Figure 4.5 and explained them as shown following excerpt.

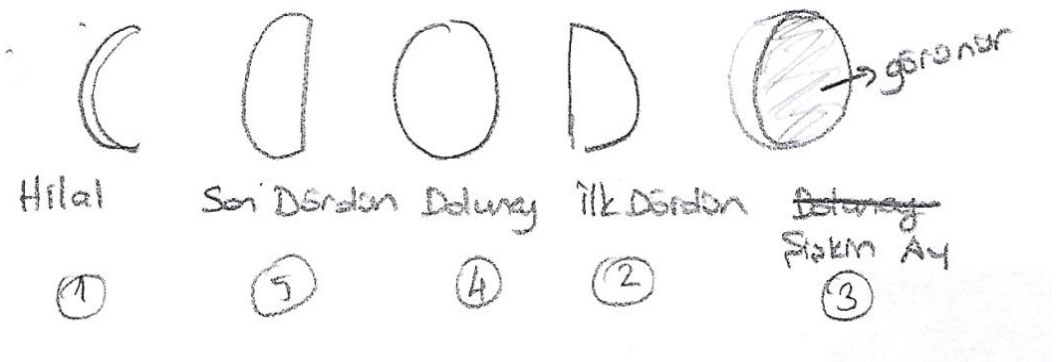


Figure 4.5 Aynur's Drawing of Phases of the Moon

Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?
Aynur: Crescent, first quarter, last quarter, full moon. We sometimes cannot observe. It is called as conjunction. I have learned it.
Interviewer: When did you learn?
Aynur: While preparing an assignment for an undergraduate course. I read it from a scientific magazine regarding the moon.
Interviewer: What was the meaning of conjunction?
Aynur: The name of invisibility of the moon from the earth is as lunar conjunction.
Interviewer: Can you draw all these different appearances?
Aynur: (drawing Figure 4.5) there is also gibbous moon, somehow resembles full moon.

As seen excerpt above, her drawing does not contain any symbol refers to conjunctions. She stressed that there was a phenomenon entitled conjunction. In addition, she stressed that change of the moon shapes lasts 28 days, after this period of time, it become crescent moon again. That is to say, Aynur have "observable" node; therefore, there is no symbol refers to conjunction among phases of the moon.

Aynur considered that cycle of the moon phases lasts 28 days and each phase appears approximately four or five days. She articulated;

Interviewer: Is there a period regarding these phases?
Aynur: I think, a cycle is completed after twenty-eight days from its beginning points. We observe them about four or five days. Four-five days for crescent, four-five days for full moon, four-five days for last quarter and also first quarter.
Interviewer: Are there any order?
Aynur: Yes. Firstly, crescent. First quarter, gibbous moon, (numerated as seen Figure 4.5) and last quarter.
Interviewer: Then, what happened after last quarter?
Aynur: It becomes crescent again.

It was revealed that Aynur activated node of "completing cycle" since she stressed that phases of the moon cycle repeated after last quarter. However, she could not activate "opposite phases" and "gradual change" nodes. Accordingly, change of illuminated or dark parts of the moon was not gradually change in her drawing. Although left side of crescent moon was illuminated, it became first quarter moon which have right side illuminated shape. In addition, drawing of Aynur did not include reverse shape of gibbous and crescent moon, which showed Aynur did not activate "opposite phases" node.

Some of the pre-service science teachers preferred showing different phases of the moon with a circle diagram. This circle generally includes the sun or sunlight. Therefore, pre-service science teachers' responses were formed due to influence of the sun. The main difference of pre-service science teachers' drawing of circle diagram from other type of demonstration is that they consider potential role of sun. To put it in a different way, these pre-service science teachers activated "illumination" node besides possible other nodes.

Ayfer integrated the sun in her circle diagrams. Therefore, the sun influences her consideration while determining different appearance of the moon. Following excerpt and Figure 4.6 indicates Ayfer's opinion pertaining to lunar phases.

Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?
Ayfer: Hımm. I think I should explain phases of the moon. Actually, children are confused with this issue. They could not imagine themselves while looking the moon from the earth. Which shapes do we observe? Hımm, new moon, we observe crescent moon. As first quarter and last quarter, I mean half. Finally, full is the shape that we can observe the moon.
Interviewer: By the way, have you ever participated in an instruction on phases of the moon as an intern. Did you observe students' reactions?
Ayfer: No, I did not. I pursue instruction of sixth and seventh grade level. Astronomy issues located at the end of their programs. So, I have not yet.
Interviewer: I see. Could you draw appearance of the moon that you mentioned?
Ayfer: Alright.

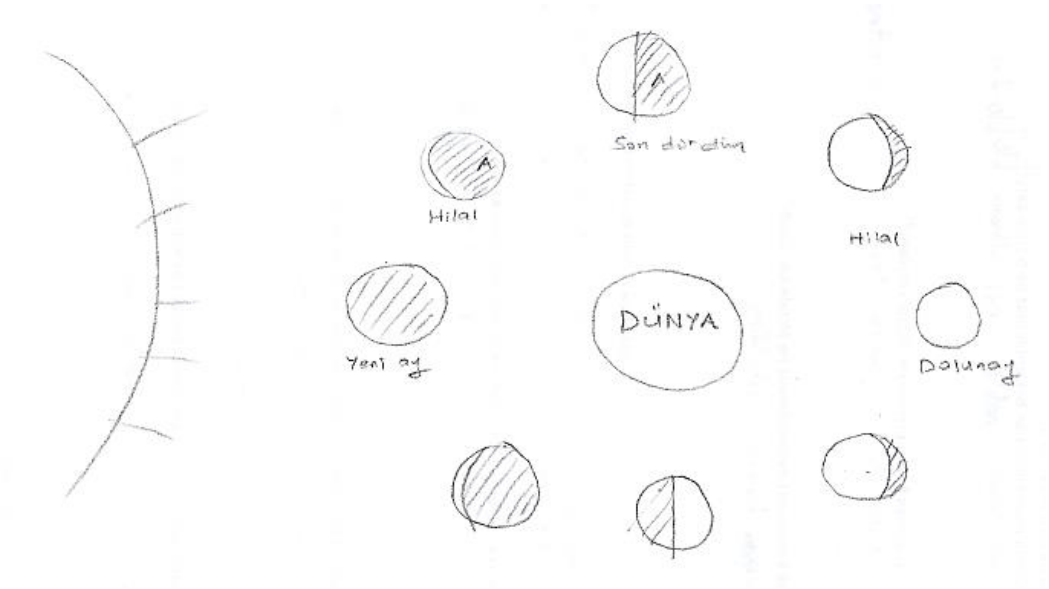


Figure 4.6 Ayfer's Drawing of Phases of the Moon

Interviewer: Can you explain what does happen in your diagram?
Ayfer: The sun and the earth. While looking from the earth, the moon is dark since the sun behind it. Then, it slowly become light and we observe as if its illuminated part increases. However, we actually observe the same of the moon. That point (pointing full moon), we observe that the moon fully illuminated by the sun. Afterwards, dark part of the moon increases.
Interviewer: How long does it take?
Ayfer: It completes in a month.

Dark and illuminated side of the moon gradually changed in her diagram. In addition, opposite shape of crescent, gibbous and quarter moon existed. She explained that the moon completes its cycle in a month, which indicates that she activated "competing cycle" node. It was revealed that Ayfer also activated nodes of "gradual change" and "completing cycle". Moreover, she underlined that sun illuminates the parts of the moon that we see. However, she encountered difficulty while determining their name and sequence. Not only crescent moons but also gibbous moons were entitled as crescent moon in her production. She categorized gibbous moons as crescent moon. In addition, each gibbous and crescent moon were identical each other. To put it differently, the part of the moon closest the sun illuminated while other part was always dark except last quarter. It is plausible to consider that sunlight and sun in her diagram influence reasoning of Ayfer.

After her explanations, she realized that visible part of the first and last quarter are different although the same side of them received sunlight as seen Figure 4.6. Then, she considered why appearance of first quarter is different from last quarter. Ayfer stated the problem she encountered as shown following excerpt.

Ayfer: The problem is that I cannot visualize how we observe the moon from the earth. Do we observe the moon differently in these positions? We observe different phases in these positions. However, it is the same in my drawing. I do not know why it is. They should not be the same.
Interviewer: Why did happen like this?
Ayfer: I am confused. Let's consider that we observe the moon from the earth. In here, if its right is dark and left is illuminated, looking from there (indicating a point over the earth) we observe right is illuminated and left of it is dark. It is because of my drawing.

Ayfer's problem is related to her spatial ability rather than knowledge elements that she should activate. Considering her drawing, it includes both earth and space-based framework. She could not differentiate both perspective; therefore, her drawing reflects combination of them. Shapes of the moon reflects their appearance from the earth, which is earth-based perspective. However, position of the sun, earth and moon reflects their actual orientation in space, which is space-based perspective. Due to utilizing these two perspectives, she was confused. In addition, she encountered problems while locating herself a point observing the moon, which showed she could not perform spatial projection ability. As a consequence of wrestling this dilemma, she noticed that our perspective changes depending on earth. Specifically, she realized that while position of the moon change, we perceive changes illuminated part of the moon from right to left depending on our perspective in the earth. Therefore, although her drawing did not include opposite phases, her later explanation covered how we observe opposite appearance of crescent and gibbous moons.

Ayşıl initially memorized name of the three moon phases such as first quarter, last quarter and full moon She stressed;

Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?

Ayşıl: Crescent, first quarter I observed this side like "C" symbol. If I observe the other side, it is last quarter. When it is round, it is full moon. There is also a phase that we could not see the moon. The rationale behind this phenomenon I that sunlight received the moon but not location we settle.
Interview: Soo, what is the number of phases that we observe?
Ayşıl: There are many. We only entitled specific shapes. For example, it starts from invisible phases, then full moon appears as a result of tiny changes. After full moon, it decreases with tiny changes and crescent and invisible phase occur. It lasts thirty days. I mean one month.
Interviewer: Can you draw?
Ayşıl: These are name of the general shapes. It increases up to full moon, after full moon it decreases. There are days among these shapes. I can explain it like that;
Ayşıl: Crescent, first quarter, full moon does not appear suddenly. Angle of sunlight increase and shape of the moon changes. Firstly, crescent is very tiny. But it becomes thicken. After full moon, system reverses and this part (pointing illuminated part) reduces.

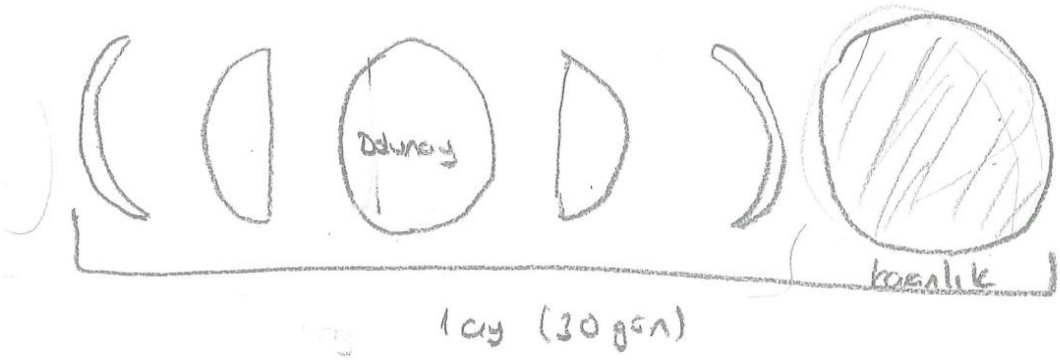


Figure 4.7 Ayşıl's Drawing of Phases of the Moon

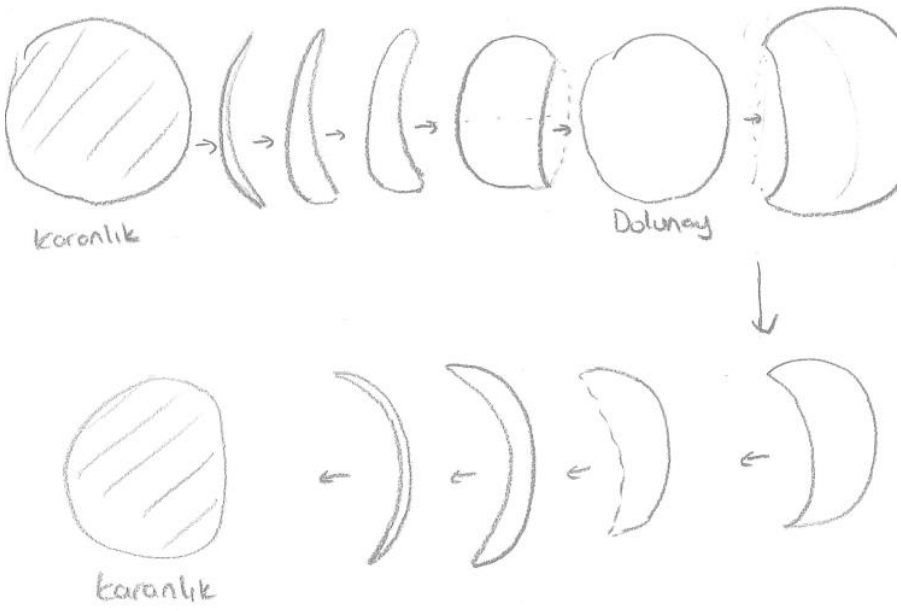


Figure 4.8 Ayşıl's Drawing of Change of Phases of the Moon

Expression and drawing of Ayşıl showed that she activated "gradual change", "completing cycle" and "opposite phases" nodes. Figure 4.8 explicitly showed shape of the moon gradually changes and completing its cycle. In addition, both of her diagrams include "opposite phases" such as waxing and waning crescent and gibbous moon and first and last quarters. Although there is no symbol regarding sun or sunlight in her figures, she expressed that the phases that she produced changed as a result of change of angle of sunlight. That is, she activated "illumination" node. However, Ayşıl encountered problem regarding her spatial ability. She drew different gibbous moon from its original appearance. Taking into account her drawing, she drew concave gibbous moon although it is convex. In addition, she could not memorize name of some lunar phases such as new moon, gibbous moon.

Aytaç drew demonstrated phases of the moon with five different moon shapes from crescent and full moon. However, he could not remember any name of lunar phases. he articulated;

Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?

Aytaç: I observe round shape. This round is slowly completing.
Interviewer: Can you draw the shape you observe? (Drew Figure 4.9)

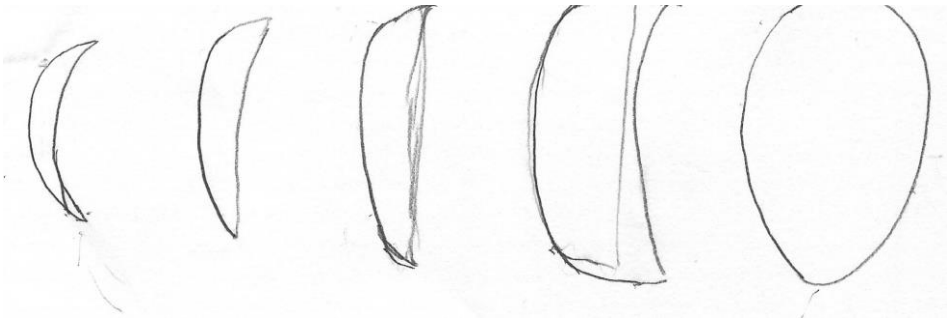


Figure 4.9 Aytaç's Drawing of Phases of the Moon

Aytaç: I wanted to show that the moon completes its round shape.
Interviewer: What do you mean by completing?
Aytaç: It is appearance of visible part of the moon.
Interviewer: Do you know name of these phases?
Aytaç: I do not know. Unfortunately.
Interviewer: Are there any order that these appearance follows?
Aytaç: Sequence of them is related to viewpoint. It may start from here (pointing shape in the left) to reach it (pointing right) or reverse path is also possible. It may start from here (pointing right) and transforms it (pointing left).
Interviewer: How long time does it take to complete this period?
Aytaç: (silence 20 seconds), I could not remember.
Interviewer: Which possibilities did you consider?
Aytaç: There are many numbers in my mind. I do not want to say something meaningless.
Interviewer: You can share or tell whatever you consider.
Aytaç: I think it is not related hours. And, not related days. I think it can be related weeks. They are very big masses although they are rapidly move. Therefore, it lasts a couple of weeks.
Interviewer: Does this period refer to between your first and last shapes?
Aytaç: No, it is a complete phase. It starts from one point and reach it again.

Explanation and drawing of Aytaç showed that he only activated "gradual change" and "completing cycle" knowledge elements during the interview. Accordingly, he stated that appearance of the moon slowly changed, and it becomes full as seen in Figure 4.9. In addition, he stated that it completes the cycle in weeks. Accordingly, it starts from the shape on the lefts and reached the shape on the right. Then it followed reverse direction and reach its beginning point.

As stressed previous method chapter, Aysu has experience regarding teaching phases of the moon. She prepared educational materials, assistant middle school science teachers regarding phases of the moon. In addition, she planned and implemented a teaching activity in order to reinforce students' understandings. Therefore, her responses showed that she has constrained conceptual structure regarding phases of the moon.

Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?
Aysu: I think, number of phases is eight. It starts with new moon, then crescent is minor phase. Afterwards, first quarter and gibbous moon. I am considering the activity we performed with pupils in order to visualize these phases. Then, it is full moon. There are gibbous and crescent moon between them. But, in all phases, different parts of the same moon were illuminated.
Interviewer: Can you draw them?

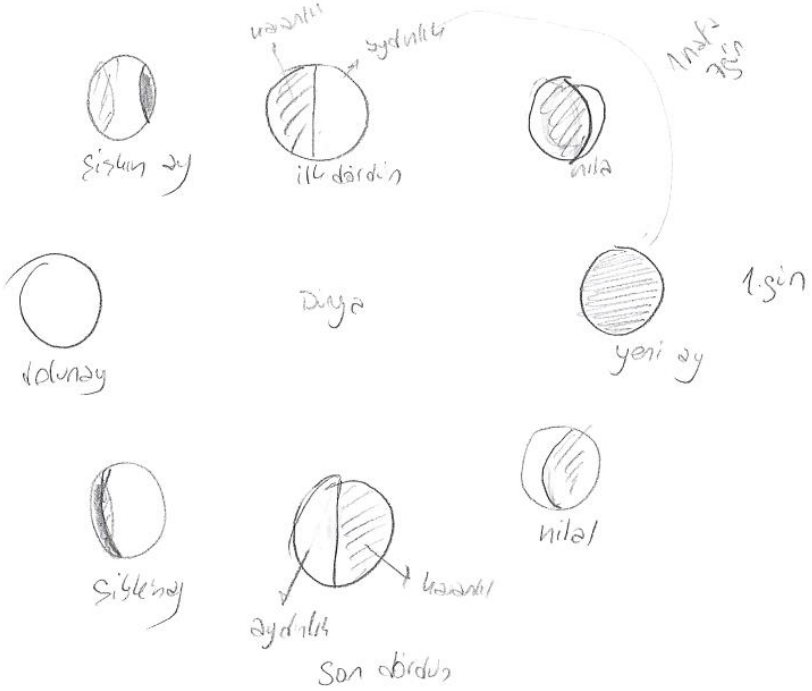


Figure 4.10 Aysu's Drawing of Phases of the Moon

Interviewer: Can you explain what this diagram is?
Aysu: New moon is starting point of this circle. It lasts 29,5 days. Distance among two different phases (pointing between new moon and first quarter) is one week.

Aysu preferred to show phases of the moon with circle diagram. Initially, she easily placed new moon, full moon, first and last quarter moons to circle, and determined dark and illuminated part of them. Then, she located rest of phases. While drawing crescent and gibbous moon, she spent more time comparing the other moon shapes she previously drew. More specifically, she could not decide illuminated part of the gibbous moon and shapes for a while as seen in the Figure 4.10. Considering her final model, she demonstrated that the moon completed its cycle and underlined that the visible or invisible part of the moon was determined by sunlight. For these reasons, it is plausible to conclude that she actively utilized "completing cycle" and "illumination" nodes. Moreover, she also activated "opposite phases" node. Her final diagram includes first and last quarter, waning and waxing crescent and gibbous moons. However, there was no enough evidence that shape of the moon gradually changes. Illuminated parts of the gibbous moon in her drawing supported that she did not activate "gradual change" node. After her initial attempt, she realized that both gibbous moons have the same shape. Therefore, she changed invisible part of the waxing gibbous moon. While changing, she was influenced by node of "opposite phases" instead of "gradual change". Therefore, she did not check whether or not appearance of gibbous moons was consistent with previous and following lunar phase. In addition, shape of the gibbous moon was convex, which showed that she could not perform spatial transformation ability.

Ayşin initially considered daily movement of the moon and explained that there are differences with respect to time when we can observe the moon. But she did not elaborate this idea. Then, she stated that appearance of the moon also changes day by day as seen following utterance.

> *Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?*
> *Ayşin: As far as I know, I could not observe significant change of the moon in one month. But I remember that the moon appears one or two hours late in each day. Essentially, there may minor changes in day by day, but our eyes could not detect it. After one month, we observe that the appearance of the moon changed to next phase. It was full moon. It now becomes gibbous moon. Phases of the mon changes.*
> *Interviewer: What is the thing observed day by day.*

Ayşin: For example, if it was last quarter, we would observe slowly change to gibbous moon. Visible part of it increases.
Interviewer: Can you draw these phases?

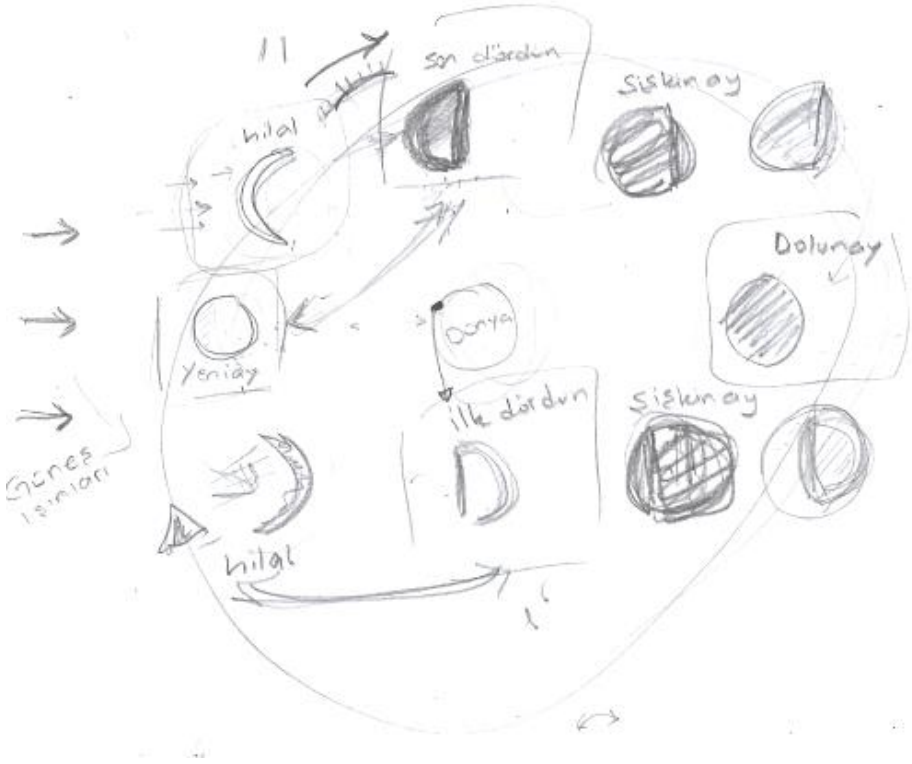


Figure 4.11 Ayşin's Drawing of Phases of the Moon

Ayşin: In here, (pointing new moon phases) when receiving sunlight and the moon between the sun and the earth, it is new moon phase. I could not observe it from the earth, since dark side of the moon face the earth. It must be crescent and then last quarter. Afterwards, illuminated part increases and becomes gibbous moon. Full moon is completely visible phase from the earth. Then, illuminated part gradually decreases. We experience first quarter and crescent.
Interviewer: How long does it take?
Ayşin: It takes one month. Twenty-nine days. Observing a new phase. From new moon to last quarter, actually observing main phases. observing main phases takes one month.
Interviewer: What would happen at the end of one month?
Ayşin: A new cycle starts. After one month, a new phase appears.
Interviewer: For instance, how long time take to new moon to first quarter? One month?
Ayşin: No, I do not mean it. Should I consider like that? I am considering it now. One month among these two phases. As far as I remember, all the cycle lasts in one month.
Interviewer: Why do you think like that?
Ayşin: It may be wrong. I am confused. (silence a couple of seconds) According to my observations, full moon becomes new moon. As stated previously, after one month it become a new phase. There is a month among the phases. Now, it is more rational for me.

Considering drawing and explanation of Ayşin, it was revealed that she activated "gradual change", "opposite phases", "illumination" and "completing cycle" nodes. Comparing other participants, she produced diagram showing order and appearance of phases of the moon more accurately and more quickly. In another word, she has more constrained a group of nodes, which available before interview. However, Ayşin encountered problems while determining duration of cycle of moon phases.

Aybüke is also preferred side by side demonstration to show different appearance of the moon. She drew eight shapes. However, some of them repetition of the same moon. For instance, there are two waning crescent and two waning gibbous moons in her diagram. In addition, she remembered name of the moon except gibbous phase. She stated different appearance of the moon as shown in the following excerpt.

Interviewer: What are the shapes of the moon that we can observe while looking from the earth. If we observe the sky at the same time in each day, what shapes would we observe?
Aybüke: I observe new moon, crescent, full moon and such phases. If I observed the moon every night, it grows from non-appearance to crescent moon. Then, it becomes full moon. Afterwards, it keeps as a cycle.
Interviewer: Can you draw these appearances?

Figure 4.12 Aybüke's Drawing of Phases of the Moon

Considering her brief explanation and drawing, it was revealed that Aybüke activated "completing cycle" node. However, her drawing does not include "opposite phases" and does not follow a "gradual change". In addition to, there is no reference to role of sun both in her explanation and drawing.

Majority of pre-service science teachers explained that moon's appearance changes gradually. However, there was no consensus starting point and followed way of gradual changes. To illustrate, Ayten stated that the moon followed reverse of its half pattern and reached its initial appearance. On the other hands, Aytolun, Aydan and Aynur considered that after its latest appearance in cycle, it returns to the first appearance. Full moon, first quarter, last quarter and crescent moons are more frequently appeared than gibbous and new moons in their drawings.

Participants preferred circle diagram in order to demonstrate phases of the moon predicted more accurately lunar phases than the participants preferred side by side demonstration. For instance, Ayfer, Ayşin and Aysu located eight major lunar appearance to their circle diagram. Only problem that Ayfer and Aysu faced regarding their demonstration is shape and sequence of gibbous moon. Ayfer presented more sophisticated demonstration comparing other participants. In addition, she rapidly produced her diagram, which indicate that she had constrained mode before interview. On the other hand, Ayşıl had the most appropriate side by side demonstration. Lack of her diagram was that there is no first and last quarter. Table 4. 2 presents pre-service science teachers' drawings and their activated nodes.

Table 4.2 Summary of Pre-service Science Teachers' Dynamic Mental Construct

Participants	Activated Nodes	Sample Explanations	Sample Drawings
Aydan	Gradual change Completing cycle	*".....as far as I observe, the moon does not change the next day. Appearance of the moon is very similar... I think the moon appearance changes gradually."*	
Aytolun	Opposite phases Completing cycle	*"...So, this part of the moon is explicit and rest of it is inexplicit. Like these dashes. It is neither completely visible nor absent."*	
Ayten	Gradual change Completing cycle Opposite phases Observable	*"I observe the moon in different shapes every night. For example, if it is a half, its illuminated parts increase in order to complete the circle shape of the moon. On the contrary, illuminated part decrease if it is full moon."*	
Aynur	Completing cycle Observable	*I think, a cycle is completed after twenty-eight days from its beginig points. We observe them about four or five days. Four-five days for crescent, four-five days for full moon, four-five days for last quarter and also first quarter.*	

Table 4.2 (Continued)

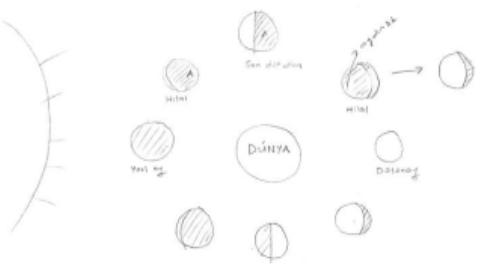
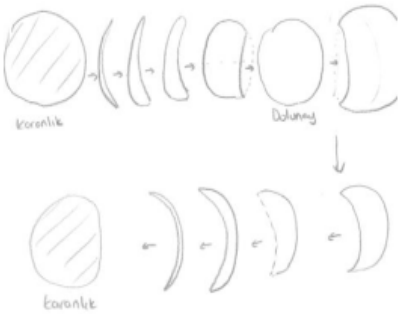
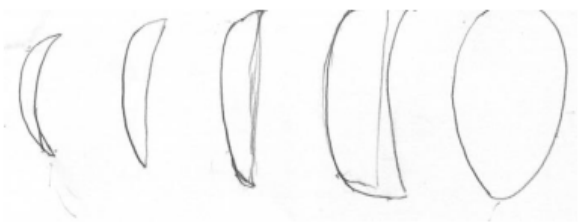
Ayfer	Gradual change Completing cycle Opposite phases Illumination	*"...Then, it slowly become light and we observe as if its illuminated part increases. However, we actually observe the same of the moon. That point (pointing full moon), we observe that the moon fully illuminated by the sun. Afterwards, dark part of the moon increases"*	
Ayşıl	Gradual Change Completing cycle Opposite phases Illumination	*"...it starts from invisible phases, then full moon appears as a consequence of tiny changes. After full moon, it decreases with tiny changes and crescent and invisible phase occur. It lasts thirty days. I mean one month."*	
Aytaç	Gradual Change Completing cycle	*I observe roud shape. This round is slowly completing.*	

Table 4.2 (Continued)

Aysu	Completing cycle Opposite phases Illumination	*I think, number of phases is eight. It starts with new moon, then crescent is minor phase. Afterwards, first quarter and gibbous moon. I am considering the activity we performed with pupils in order to visualize these phases. Then it is full moon. There are gibbous and crescent moon between them. But, in all phases, different parts of the same moon were illuminated.*	
Ayşin	Gradual Change Completing cycle Opposite phases Illumination	*"...There may minor changes in day by day, but our eyes could not detect it. After one month, we observe that the appearance of the moon changed to next phase. It was full moon. It now becomes gibbous moon. Phases of the mon changes."*	
Aybüke	Completing cycle Illumination	*I observe new moon, crescent, full moon and such phases. If I observed the moon every night, it grows from non-appearance to crescent moon. Then, it becomes full moon. Afterwards, it keeps as a cycle.*	

4.1.2 Mental Construct on Reason for Different Moon Phases

Pre-service service science teachers were asked to explain why we observe the moon with its different phases. They firstly explained general mechanism regarding phases of the moon. Then they were asked to explain each of the lunar phases. Pre-service science teachers utilized their drawing and three-dimensional models while explaining. They activated some of knowledge elements so as to propose a model regarding phases of the moon. In the following table, nodes that were detected during the interviews and their description were presented.

Table 4.2 Activated Nodes Regarding Explanation of Phases of the Moon

Nodes	**Description**
Orbit	The moons orbits earth.
Illumination	The sun shines on the moon.
Parallel	Sunlight are parallel and arrives perpendicular to the moon's terminator.
Half	Only half of the moon can be observed from the earth.
Apparent	Illuminated side of the moon that is seen from the earth determine phase
Shadow/Blocking	Shadow of the earth/moon/other celestial bodies causes lunar phases. The earth/moon or other celestial bodies block the light from the sun.
Location	Location of an observer determines phases of the moon.
Reflection	Extend of reflected light determines the part of the moon we see.
Angle	Angle of the lights receiving from the moon determines phases.
Day/night	The moon and its phases are apparent only at night.
Same face	Only one side of the moon is visible from the earth.
Distance	Distance among the moon and the sun/earth determines lunar phases.
Tilt	Earth's tilt causes different appearance of the moon.
Plane	The earth and the moon should locate in the different plane for lunar phases.
Scattering	Different wavelengths of sunlight scatter before they receive the earth.
Refraction	Direction of sunlight changes before they receive the earth.
Sweeping	The earth sweeps an area while revolving around the sun.
Revolution	The earth revolves around the sun

Although pre-service science teachers activated a couple of nodes while explaining phases of the moon, some of them may be more dominant. That is to say, nodes did not equally perform while pre-service science teachers were constituting dynamic mental construct. Some nodes may higher statues comparing rest of activated nodes. Therefore, dynamic mental constructs listed in this part were entitled considering name of the active node.

Since these models are dynamics, pre-service science teachers' may change their models and propose more than one model during the interview. This part of the analysis focused on pre-service science teachers' dynamic mental models constituted by the nodes above rather than change among them. Dynamic mental states detected during these processes were explained below.

4.1.2.1. Orbit dominated Dynamic Mental Construct

Ayça's explanations covered a couple of knowledge elements. To put it in another, there were more than one activated knowledge elements utilizing in order to clarify why we observe different moon phases. Ayça expressed;

> *Ayça: The moon revolves around the earth. Depending on its different location (in its orbit), for instance, here is the sun and the earth is there (gesturing different positions with her hands), while the moon revolves. The new moon appears, it is between the earth and the sun. Then, it moves away, it appears as first quarter, full moon and last quarter.*
> *Interviewer: Where does the moon move away from?*
> *Ayça: While moving away from the sun and revolving around the earth, depending on the sunlight receiving it and shadowing, we observe different phases of the moon.*

It was revealed that Ayça activated three knowledge elements such as "orbit", "illumination" and "shadow". Initially, she considered that phases of the moon revealed as a consequence of orbit of the *moon. Then, she expressed that* illumination and shadow were also factors for phases of the moon. However, she did not elaborate this idea and did not express specific role of shadow on phases of the moon.

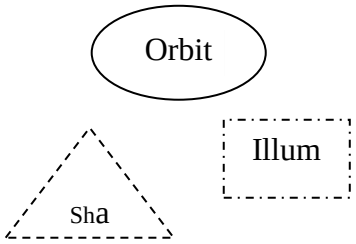


Figure 4.13 Orbit Dominated Dynamic Mental Construct of Ayça

As seen in Figure 4.13, Ayça explained phases of the moon by orbit of the moon. She considered that different appearance of the moon appeared as a result of orbit of the moon around the earth. In addition, she stated illumination and shadow also influence this mechanism. However, she could not explain role of shadow and illumination on phases of the moon. Therefore, these two nodes were demonstrated with dotes. This demonstration means that they related to phases of the moon concept but how they related is not explicit.

4.1.2.2. Shadow Dominated Dynamic Mental Construct

As explained earlier chapters, previous studies regarding conceptual understanding show that participants from different age groups consider shadow of the earth begets phases of the moon. However, there were only a couple of participants that utilized shadow concept in order to explain phases of the moon in the current study. Some participants were directly referred to shadow concept while some other participant utilized blocking term while explaining phases of the moon.

Aygün produced Figure 4.14 and determined a shadow area. Phases of the moon occurred depending on extent of the earth's portion inside this area. He explained;

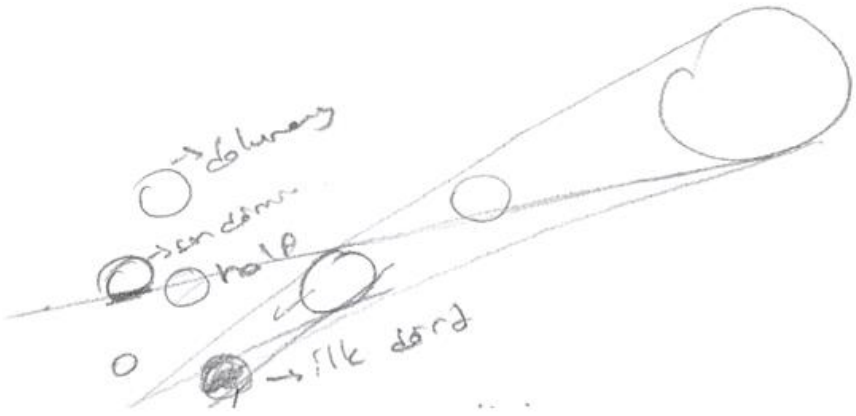


Figure 4.14 Aygün's Drawing of Explanation of Lunar Phases

> *Why do we observe different phases of the moon? It is related to position of the earth and the sun. (drawing), Suppose that the earth is here, this part was lighted up by the sun (indicating half of the earth facing to the sun). This part is dark part (indicating other side). We observe the moon at night. We receive reflected lights from the moon. For instance, when this part of the moon inside shadow of the earth, we cannot see this part.*

Dynamic mental construct of Aygün was explicitly shaped by "shadow" nodes as seen excerpt above. In addition to his shadow explanation, there are other nodes activated. Considering his diagram and explanation, it was revealed that "day and night", "orbit" and "illumination" nodes beget phases of the moon. Aygün drew difference moon figure around the earth, which showed activation of "orbit" node. In addition, he stated potential role of "illumination" in his explanation. He also stated that it must be night in order to observe phases of the moon, which was also seen in his diagram. However, he could not elaborate association between phases of the moon and day and night. Therefore, day and night node was demonstrated by doted square as seen in Figure 4.15.

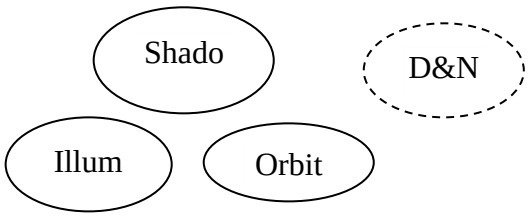


Figure 4.15 Shadow Dominated Dynamic Mental Construct of Aygün

Aynur also activated shadow node in order to explained phases of the moon. Specifically, she utilized the blocking term rather than shadow. In addition, there were no shadow area in her explanation. However, rationale behind her idea that sunlight cannot reach the moon because of the earth has similar characteristics with response of Aygün. She expressed;

> *Like the earth, the moon orbits. Sometimes, how can explain? Since the moon and the earth orbit, the earth blocks the moon. The earth is in the middle. The sunlight comes. The moon sometimes could not receive sunlight.*

As seen in this utterance, she considered blocking as a reason for phases of the moon. In addition, she explained role of moon's orbit and sunlight on different appearance of the moon. One step later, she drew different phases in order to explain phases of the moon as seen Figure 4.16. In addition, she explained why we observe full moon as shown following excerpt.

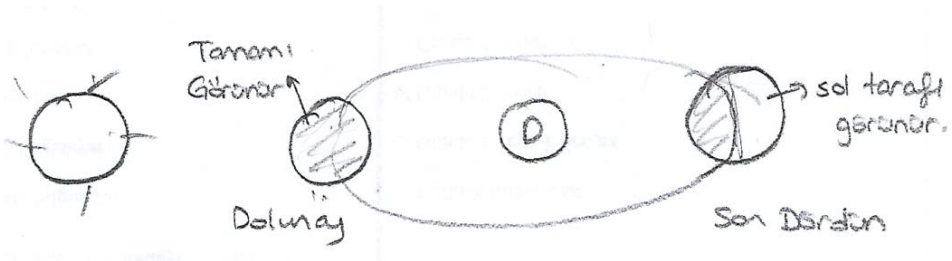


Figure 4.16 Aynur's Drawing of Explanation of Lunar Phases

> *Interviewer: Can you explain how each of lunar phases occur?*
> *Aynur: It occurs in there (the moon is between the earth and the sun), since the moon receives all sunlight. Therefore, it is full moon in here. There is no obstacle which block its surface.*
> *Interviewer: what about last quarter?*
> *Aynur: Last quarter, right side of the moon was blocked. Sunlight…The earth blocks right side of the moon. Left side of it receives sunlight.*

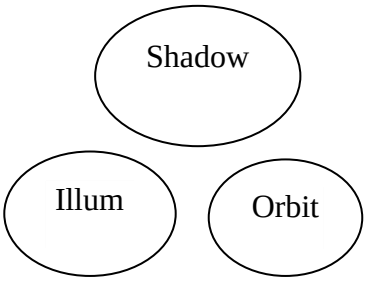


Figure 4.17 Shadow dominated Dynamic mental construct of Aynur

In the utterance above, she tried to locate full moon and first quarter phases to orbit of the moon. As stressed before, she utilized "orbit", "blocking" and "illumination" knowledge elements in order to predict these locations as seen Figure 4.17. In addition to existence of these knowledge elements, her explanation lacks "Half" node. As stressed previously, "Half" node corresponds that we can only observe half of the moon from the earth. When the moon locates between the earth and the sun, we should observe new moon since half of the moon we observe cannot receive any sunlight. However, the moon appeared as full although it located between the earth and the sun in Aynur's Figure 4.16. According to her perspective, we can completely observe the moon rather than its half. Therefore, it is a full moon since illuminated side of the moon can be observed in this position.

4.1.2.3. Location Dominated Dynamic Mental Construct

One of the elements that pre-service science teachers activated while explaining phases of the moon is the location of the observer. According to this idea, besides other factors, location of the observer is important in order to determine phases of the moon. To put it differently, individuals from the different locations in the earth observe different phases at the same time. To illustrate, Aybüke explained why we observe the moon with its different phases;

> *The moon revolves around the earth. The moon reflects sunlight receiving from the sun. Actually, we always observe the same face of the moon since the moon completes its revolution around the earth and its rotation at the same time. Therefore, the same face looks the earth. However, where we observe the moon is also important. Simultaneously, someone looking the moon from the America and I observe differently since they receive lights different part of the moon then me.*

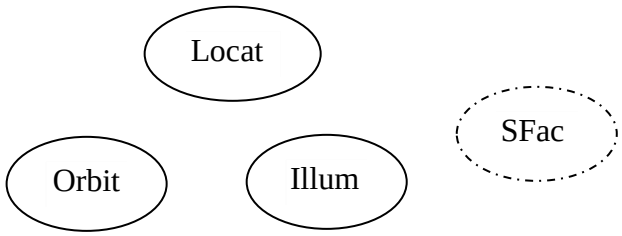


Figure 4.18 Location Dominated Dynamic Mental Construct of Aybüke

Considering this expression, there were four nodes as “orbit”, “same face”, “illumination” and “location” which activated to explain different shape of the moon as seen in Figure 4.18. After her explanations above, Aybüke did not elaborate potential influence of the appearance of the same face of the moon on phases of the moon. Furthermore, as seen diagram below she showed that the half of the moon illuminated by the sun. That is to say, she also activated “illumination” node while explaining phases of the moon. It is plausible to consider that her mental state was dominated by location node. To illustrate, as seen Figure 4.19, Aybüke labeled two points as A and B. While location A observes the moon like gibbous moon, location B observes like a crescent moon.

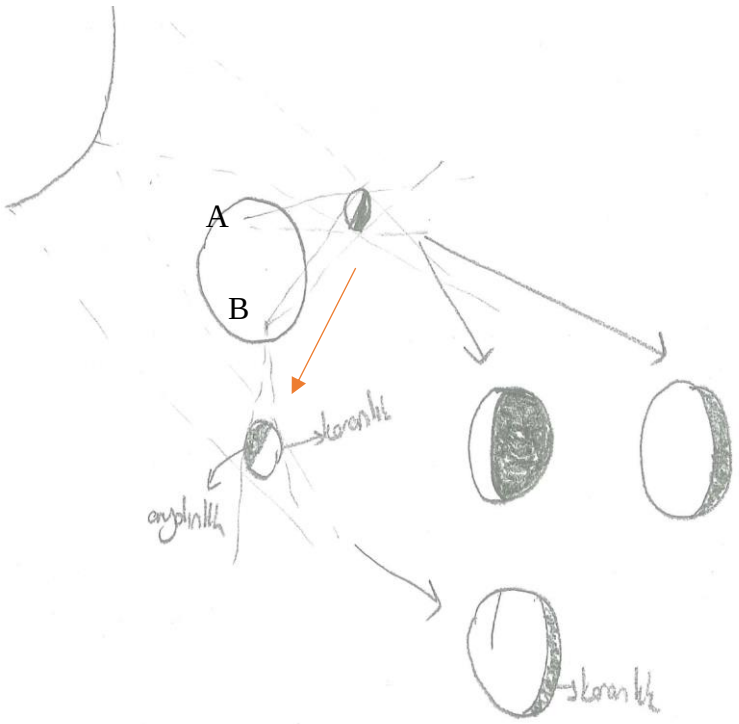


Figure 4.19 Aybüke’s Drawing of Phases of the Moon

Then, Aybüke changed position of the moon as seen from Figure 4.19, which pointed by the arrow. She considered which phases may be observable in new position of the moon and she drew a shape which resemble waning gibbous moon. This drawing was identical to appearance of the moon from the A points of the earth in moon's previous location. According to Aybüke, Phases of the moon was depended on both location of the observer and orbit of the moon.

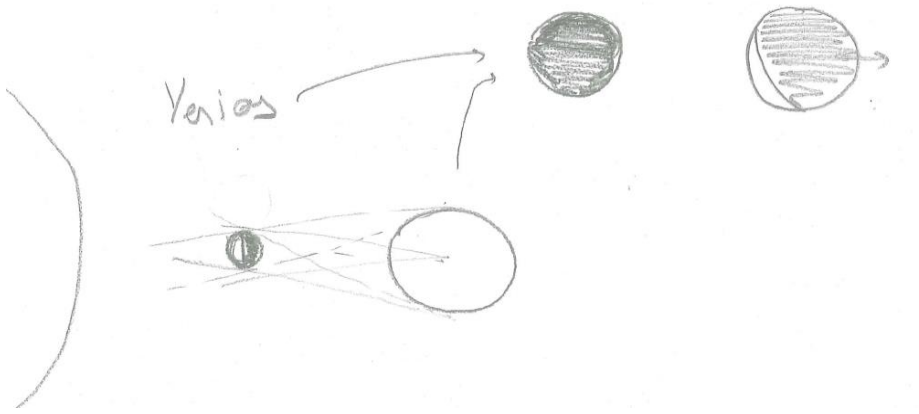


Figure 4.20 Aybüke's Drawing of Appearance of New Moon

Aybüke thought not only situation of gibbous and crescent moon but also other phases. For instance, drawing of the Aybüke pertaining to new moon reflects the same perspective. As seen in Figure 4.20, an individual from the equator observed the moon completely dark. Another person from the north pole observed the moon as crescent moon.

4.1.2.4. Angle Dominated Dynamic Mental Construct

There are pre-service teachers activated their knowledge regarding angles in order to explain why we observe the moon with different shapes. To illustrate, Aytolun considered that angles of the light receiving from the moon determine the phases of the moon. Following statement indicate that she believes that revelation of the moon and the light receiving from the moon determined the phases.

> *While the moon rotates and orbits, the light receiving from the moon most probably aberrates. For example, if we observe the new moon when the angle of the light is ninety degrees, while reducing this degree, the appearance of the moon changes to first quarter.*

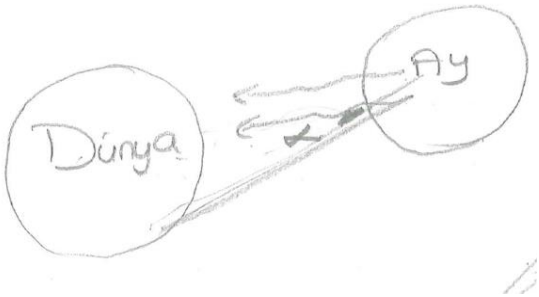


Figure 4.21 Aytolun's Drawing of Phases of the Moon

Aytolun drew Figure 4.21 in order to show role of angle. However, she was not sure which value of angle is appropriate in order to see specific phases of the moon. After wrestling with her confession of angles, she decided that if the moon and the earth located at the same plane, we would observe the new or full moon. According to her, it was observed first and last quarter due to angle is different from 180 degrees between the moon and the earth.

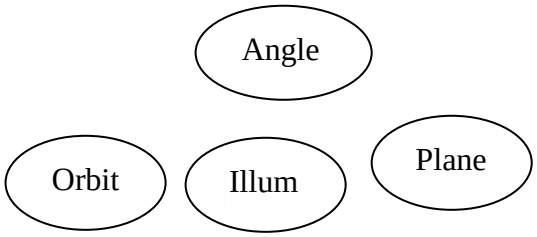


Figure 4.22 Angle Dominated Dynamic Mental Construct of Aytolun

As seen Figure 4.22, Aytolun mainly activated angle node in order to explain phases of the moon. She stressed that while changing angles between the moon and the earth, appearance of the moon also change. In addition, she activated "orbit", "illumination" and "plane" nodes in her explanation. She argued that the earth and the moon locate at the same plane in full and new moon phases.

Pre-service science teachers generally operated angle node so as to explain crescent, gibbous, quarter moons rather than new and full moon. Following example indicates that Ayça considered angle of the light while explaining occurrence of the waxing crescent moon, which is different from explanation of new moon.

Interviews: Would you explained mechanisms that cause different appearance considering each of the lunar phases.
Ayça: This is new moon. It is completely dark.
Interviewer: why is it dark?
Ayça: They do not locate at the same line (while using three dimensional models). For instance, the moon may be in an upper location. The sunlight receiving to this part of the moon (the half faces to the sun) is not reflected to the earth. Therefore, we could not observe the moon.
Interviewer: Then, what about next lunar phases?
Ayça: Waxing crescent moon is appeared. This part (the half part of the moon faces to the sun) is luminousness and this part (the half part does not face the sun) will be dark.
Interviewer: Why?
Ayça: The sun illuminates only crescent part of the moon. The other part is dark; therefore, I observe the moon as crescent. But I do not know why it is observed as first quarter at that position and waxing crescent at this position. It may be related to angles of the sunlight.

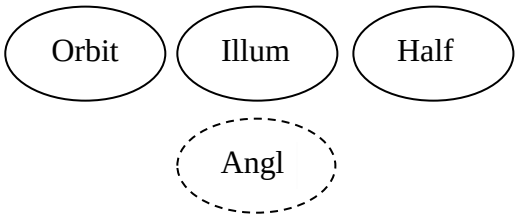


Figure 4.23 Angle Dominated Dynamic Mental Construct of Ayça

As seen Figure 4.23, Ayça activated four knowledge elements. She demonstrated half of the moon was illuminated while the moon orbit around the earth, which means that she activated "orbit", "illumination" and "half "nodes. Unlike Aytolun, "angle" was not dominate node in Ayça's explanation. She could not explain role of angle on appearance of different phases.

4.1.2.5. Day and Night Dominated Dynamic Mental Construct

Pre-service science teachers usually integrated their existed knowledge on some other astronomy knowledge to phases of the moon topic. Day and night concept was one of the issues that pre-service teachers utilized while explaining phases of the moon. Ayten's explanation was a good sample of this issue. While using three dimensional models she locates the earth between the moon and the sun and she considered what it happened in that situation. She stated,

What would happen in this position? Do I observe the moon? (Silence a couple of seconds) It is hard to explain for me. Why I do no not observe the moon? (Silence 40 seconds). Certainly, I see. Actually, the phases I examine are in there. In here, the earth is illuminated. This side of the earth is also at daytime. I need to observe the moon at night side. So, do I observe the full moon in this position? I think… Yes, I observe the full moon in this position. I am sure now. Sunlight receives this part (the part facing the earth) of the moon and completely illuminates this part. This part of the earth is at day and I observe full moon from that side of the earth.

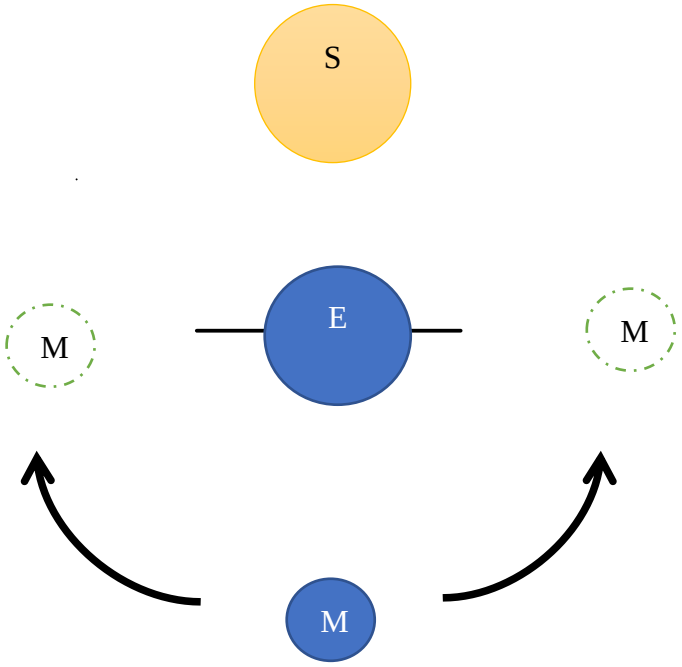


Figure 4.24 Ayten's Demonstration of Phases of the Moon

As seen in Figure 4.24 produced based on video footage, she moved the moon to both side of its orbit and explained that while moving to these directions, illuminated part of the moon decreases. However, she did not pass other side. She expressed;

Interviewer: What would happen then after this point?
Ayten: Then, I passed other side. Side of daytime. I could not see the moon when it's a day in the earth.

It was revealed that only half of the moon's orbit available for observation of phases of the moon taking into account her explanation. In addition, she unconsciously assumed that the earth does not rotate. Accordingly, there were no phases the other half of moon's orbit. She drew Figure 4.25 in order to show how each of the phases appears during orbit of the moon.

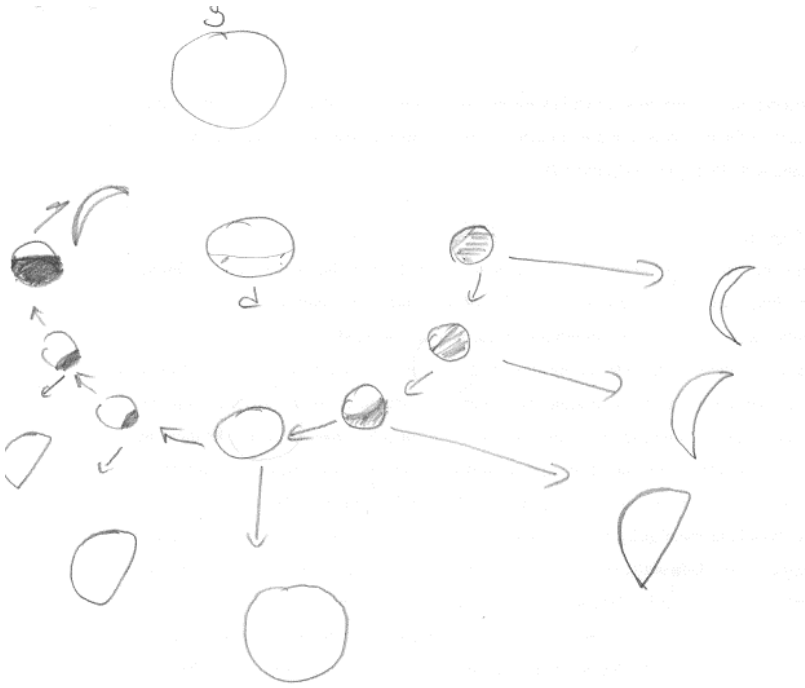


Figure 4.25 Ayten's Drawing of Phases of the Moon

As the above shows, perspectives on day/night shaped Ayten's mental state regarding phases of the moon. But "day/night" was not unique knowledge elements in her explanation. She also actively utilized "orbit" and "illumination" nodes during her explanation and demonstration as seen in Figure 4.26.

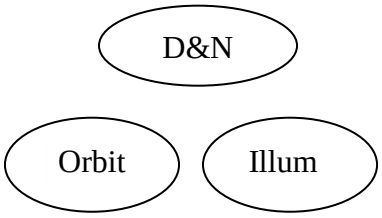


Figure 4.26 Day and Night Dominated Dynamic Mental Construct of Ayten

4.1.2.6. Scientific Explanation of Phases of the Moon

There were only four participants possess dynamic mental construct highly determined by active a set of nodes while explaining phases of the moon. They immediately responded question regarding phases of the moon with confident tone. For instance, Aybilge utilized a set of knowledge elements including "orbit",

"illumination", "apparent", "half" and "parallel" in order to explain rationale behind phases of the moon. Her explanation was, therefore, consisted with scientifically supported explanation. She explained lunar phases;

Interviewer: what is the reason behind different appearance of the moon?
Aybilge: Because, the moon orbits the earth. It receives sunlights and reflects them. While the moon orbits, sunlights reflected by the moon is different since its location change. I mean illuminated part because it is location is different.
She explained rationale behind phases of the moon while drawing figures and demonstrate via three-dimensional models. For instance, her explanation while demonstrate phases of the moon with three dimensional models was presented below.
Aybilge: It is full moon. This half completely receives sunlights. We can observe whole illuminated part. Let's demonstrate new moon. Sunlights reach back of the moon. This side is dark, therefore. Since we are in front of the dark side, we could not see the moon. In this position (last quarter) the sun illuminates this side and other side is dark. Therefore, we observe half of the moon like reverse D letter. But in there (first quarter), it is like D letter.
Interviewer: What about other phases?
Aybilge: (Waxing crescent) The sun illuminated this half of the moon. But we observe only this little portion of it. In there (Waxing crescent), the sun illuminated this side. But we could not observe only little portion in its left.

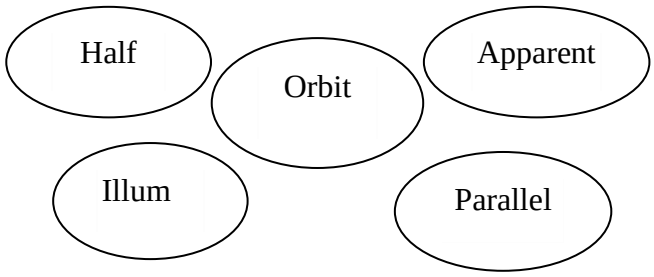


Figure 4.27 Active Nodes of Scientific Explanation of Phases of the Moon

While demonstrating and explaining phases of the moon, she changed position of the moon in its orbit. Furthermore, she showed as illuminated only half of the moon that looks the sun and determines apparent phases considering illuminated part that is observed from the earth. This indicated that Aybilge's dynamic mental construct was constrained by the mode including "orbit", "illumination", "half", "parallel" and "apparent" nodes as seen Figure 4.27. There were no hierarchy among these nodes. In addition, she gave an answer the question immediate responses without any doubt or

contradiction. That is to say, her dynamic mental construct was highly constrained by this mode.

4.1.3 Eclipses

Participants of the current study experienced at least one solar eclipse. Almost all of them remembered this phenomenon and stressed that they observed with their teachers and classmates in middle school students. They reminded that sky became dark during a couple of minutes and then the sun appeared again. Although teacher candidates more clearly remembered solar eclipses, their experiences on lunar eclipse was fuzzy and not coherent each other. Some of the pre-service teachers could not remember whether or not they observed lunar eclipse, while some of them stressed that they observed change appearance of the moon to dark. In addition, some of them stressed that they heard about bloody moon from different media sources. In this part of the current study, pre-service science teachers' responses regarding lunar and solar eclipses were examined with respect to two perspective. Initially, activated nodes and dynamic mental construct of pre-service science teachers were presented. Difficulties encountered by pre-service science teachers regarding lunar and solar eclipses and possible sources of this difficulties were also explained. Later, their perspective on linkage between lunar/solar eclipses and phases of the moon were presented.

4.1.3.1. Location of the moon

As stressed previously, it was more difficult to explain lunar eclipses then solar eclipses for pre-service science teachers. Some of the teachers could not propose any models regarding lunar eclipses. In the below passage and diagram, it was revealed that Aykut activated shadow/ blocking node and articulated that solar eclipse reveals as a result of occultation of the sun by the moon. However, he was not sure what exactly lunar phases was and how this phenomenon occurred. He drew Figure 4.28 and explained,

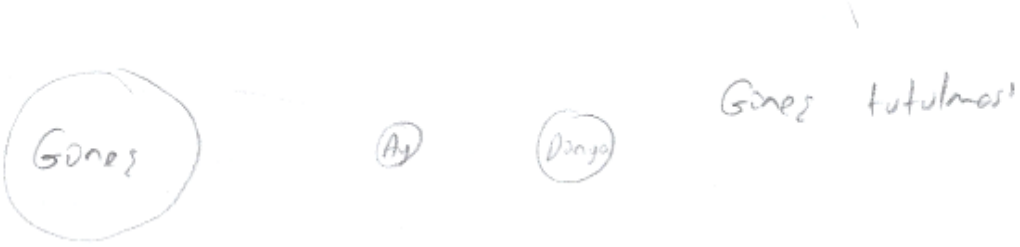


Figure 4.28 Aykut's Drawing of Solar Eclipse

Interviewer: Have you ever observe lunar eclipse or solar eclipse?
Aykut: I could not remember when it exactly happened, but it was my middle-school years. Suddenly, it became dark for a while.
Interviewer: Could you explained what did happen that day?
Aykut: I think the moon was between the earth and the moon. (drawing Figure 4.28), it was temporary darkness. Sunlight was blocked by the moon. They could not reach us.
Interviewer: What is the name of this phenomenon?
Aykut: Solar eclipses. We did not see the sun. But I could not remember what lunar eclipses is.
Interviewer: Have you ever observe lunar eclipse
Aykut: If I observed, I can remember. I remembered my middle school years when I heard solar eclipse. (silence 15 seconds, considering lunar eclipse), I think the sun became red. (silence thirty seconds), I could not remember lunar eclipse.
Interviewer: Alright, you may consider lunar eclipse via utilizing these three-dimensional objects.
Aykut: (He tried out different alignment of the sun, earth moon models) This is solar eclipse (the moon is between the sun and the earth). (Then, he locates the sun between the earth and the moon). it is nonsense.
Interviewer: Why do you think that it is nonsense.
Aykut: When we look to the sun, the moon has small volume, we directly observe the sun. We do not have any linkage with the moon. I could not understand whether it occurs in day or night.
Interview: Why did you change your idea?
Aykut: The other location does not cause a difference (the earth is between the moon and the sun). But this is different (the sun is between the sun and the earth). But I could not describe this difference. I do not have any idea what would happen during lunar phases. If this figure is solar eclipse, blocking of the sun by the moon; it should be lunar eclipse, which the moon blocking by the sun.
Interviewer: What would you observe during lunar eclipse?
Aykut: I am not sure…Normally, we cannot look the sun with naked eye, but we can look it during lunar eclipse. The moon shades the sun.
Interviewer: So, what is the difference between the lunar and solar eclipses?
Aykut: The sun is visible during the lunar eclipse. Its color resembles orange or red, which is different its usual color. I could not describe that color.

As the above shows, Aykut explained why we observe solar eclipses via activating "shadow" and "illumination" nodes. However, he could not propose any model pertaining to lunar eclipses. He waved some of the ideas while considering lunar

eclipses. Accordingly, it was revealed that he compared lunar eclipse with solar eclipse with respect to perceived meaning of terminology. He argued that if blocking of the sun by the moon is solar eclipses, blocking of the moon can be lunar eclipse. Therefore, he placed the sun between the moon and the earth via three-dimensional models. However, he realized this position is impossible considering size of these three celestial bodies. Interestingly, he could not consider that the moon revolves around the earth; therefore, it should be located somewhere in its orbit around the earth. This situation showed that Aykut could not activated orbit node while considering lunar eclipses. But, as stressed previously, he activated "orbit node" while explaining phases of the moon. In other words, "orbit node" was activated in phases of the moon context but not in lunar eclipses context. This situation indicated that activation of knowledge elements was depended on context.

Considering try outs via three-dimensional model, Aykut also located the earth between the moon and the sun. However, as seen from his response, he stressed that it is ordinary and there is no exceptional case that may cause lunar eclipse. In other words, since lunar eclipse is rarely observed, he tried to show a rare situation among the sun/moon/earth.

In a similar vein, Aytolun also considered terminology to predict lunar and solar eclipses. She explained,

> *In my opinion, it is an eclipse (the moon located between the earth and the sun). I think it is a lunar eclipse. The moon blocks the receiving light. Therefore, the moon blocks the light incoming. Therefore, it become dark for a short while.*

As shown excerpt above, Aytolun considered it should be lunar eclipse since the moon blocks sunlight. Although she described solar eclipse phenomenon, she entitled it as lunar eclipse. In addition to terminological confusion, she expected to show unusual situation while explaining lunar eclipse. She stressed;

> *Solar eclipse. How does solar eclipse occur? I think the earth locates between the moon and the sun (while drawing figure). But it is very ordinary arrangement. The solar eclipse is… I actually could not remember what happen in solar eclipse. We may explicitly observe the sun. There is no unusual thing in my figure.*

Considering this utterance, Aytolun also believed that solar eclipse should be extra ordinary event. However, her drawing corresponded usual orbit of the moon around the earth. She, therefore, looked for an extraordinary situation changing arrangements of the sun, earth, moon, which was resemble viewpoint of Aykut. However, she could not find appropriate explanation regarding solar eclipse.

One of possible sources of pre-service science teachers' problem regarding lunar eclipses was originated from their lack of observational knowledge. They generally stressed that they did not observe any lunar eclipse, or they could not remember what would happen in such a phenomenon. Although Aysu draw position of the sun/earth/moon pertaining to lunar and solar eclipse as seen Figure 4.29, she could not be sure. She stressed;

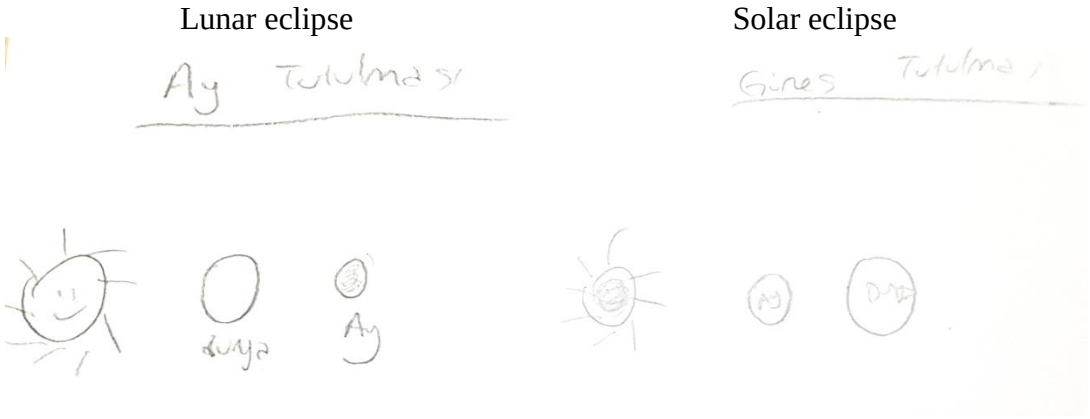


Figure 4.29 Aysu's Drawing of Lunar and Solar Eclipse

Aysu: The moon locates between the sun and the earth in solar eclipses. Lunar eclipse... (silence a couple of seconds) I doubt about this issue. (drawing lunar eclipse figure), the moon become dark in lunar eclipse and the sun became dark in solar eclipse.
Interviewer: What is your doubt about lunar eclipse?
Aysu: I could not remember that I clearly observe lunar eclipse. In this situation (pointing the figure) we… (silence). I consider whether we observe lunar eclipse may happen in daytime or not. Considering my drawing, it should be full moon phases… I doubt… I may not remember since it was dark even I observe the lunar eclipse.

Although Aysu appropriately drew position of the sun/earth/moon during lunar and solar eclipse, she could not be sure appearance of lunar eclipse because of lack of observation. This situation showed that observational knowledge is significant factor in order to activate appropriate knowledge elements and built a linkage among them.

However, observational knowledge is not enough singly. Aydan explained her experiences regarding lunar eclipses as shown following utterance.

Interviewer: Have you ever observed lunar eclipse?
Aydan: Lunar eclipse. It was night. Lunar eclipses happened more frequently. I remember that I saw number of lunar eclipses. The moon became dark. We could not observe it. It was appeared again after eclipses. I think there was something like transit. Half of the moon would become dark such a case. But, it was complete dark while I observe lunar eclipse.
Interviewer: Could you draw how lunar eclipse occurs?
Aydan: Where I should locate the moon for lunar eclipse? I cannot remember. (Drawing Figure 4.30) This is the earth. Shadow of the earth cause lunar eclipse. I do not know that specific angle, but it is because of shadow of the earth. It is the sun. I have to locate the moon so as to receive shadow that is earth's tilt. Therefore, the moon may be there. But I am not sure.

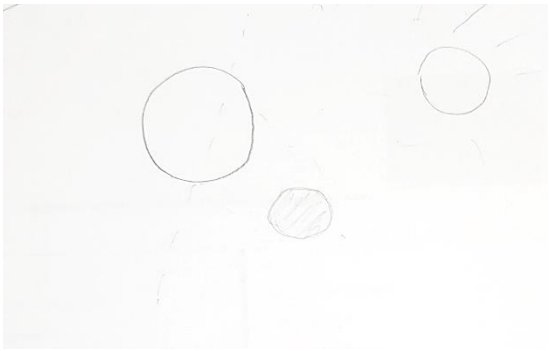


Figure 4.30 Lunar Eclipses with respect to Aydan's Perspective

Interviewer: Could you explain what happened in this drawing?
Aydan: We have perpendicular shadow while the moon approaches. Afternoon, our shadow become longer. In here, the earth should possess large shadow in order to cover the moon. Therefore, it takes long time to reach position that the tilted side of the earth cover the moon.

As seen utterance above, Aydan experienced a couple of lunar eclipses. She explained what happened during lunar eclipses considering her observations. However, her explanation regarding rationale behind lunar eclipse did not overlap scientific viewpoint. She activated not only "shadow/blocking", "orbit" nodes but also "tilt". In addition, she could not activate "plane" node, which contribute to differentiate lunar phases from eclipses. Therefore, she could not locate the sun/moon/earth appropriate position for lunar eclipses. To conclude, although Aydan observed lunar eclipses, her experience did not ensure suitable organization of knowledge elements.

4.1.3.2. Association between eclipses and phases of the moon

Participants in the current study directed the question whether there was a relationship between phases of the moon and the eclipses after explaining each concept separately. The question did not make sense for some of the participants due to characteristics of their mental model for phases of the moon. But many teacher candidates stressed that eclipses were rarely observed due to tilted orbit of the moon. In other words, they were aware of the fact that eclipses cannot be observed in each month. There were also some pre-service teachers stressed that eclipses rarely observed but suggested different reason except tilted orbit of the moon. In this section, these teachers' expressions were examined.

Aybüke explained phases of the moon considering our location in the earth and the moon's orbits. According to her viewpoints, it was possible to observe the moon with its different phases at the same time from different locations. With respect to new moon phases, as it was expressed previously, she located the moon between the earth and the moon and expressed that equator region observed the new moon while regions near the north polar observed as crescent moon. However, she drawn the same figure in order to express the solar eclipses as seen Figure 4.31. Afterwards, she differentiated the eclipses and phases points as it seen Figure of 4.32.

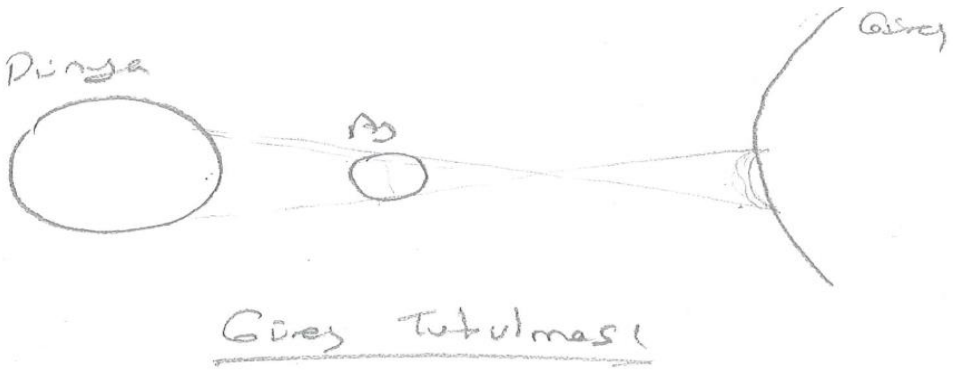


Figure 4.31 Aybüke's Drawing about Solar Eclipse

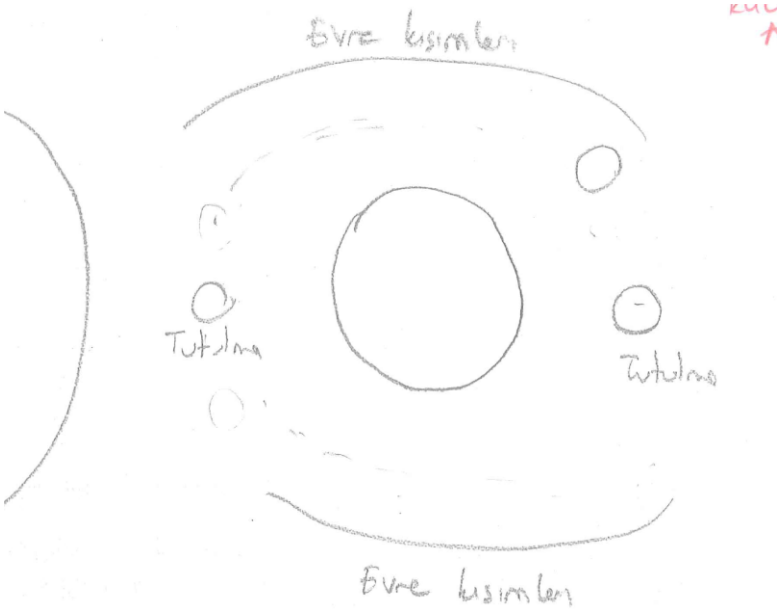


Figure 4.32 Aybüke's Drawing about Eclipses and Lunar Phases

As seen from Figure 4.31 and 4.32, Aybüke considered that eclipses occurred when these three celestial objects line up. She differentiated position of eclipses and phases considering orbit of the moon. In other words, there were some points in which only eclipses were visible. Accordingly, eclipses could be occurred at two points as seen in Figure 4.32 and phases can be observable just before and just after from these points.

Aytolun is one of the pre-service science teachers stated that the eclipses were rare events. However, she considered that these celestial objects rarely located at the same line. She stressed;

Aytolun: As far as I remember from the Astronomy courses, the moon located between the sun and the earth. But number of the eclipses we observe are too few. It is eclipses if they are located at the same line. Since it is not a specific case, eclipses occur once 29,5 days.
Intervivewer: Why do not we observe eclipses once a month?
Aytolun: The moon completes its orbit in 29.5 days. It locates at the same line with the sun in 27.5 days. Because of these 2 days, we cannot observe eclipses every month.
Intervivewer: Why is that so?
Aytolun: They always do not locate at the same line. They locate at the same line after a long time. Eclipses occurs that specific time. There are two days between 27.5 and 29.5. After 29.5 days, the moon and the earth could not locate the same line, but the sun and the moon. Eclipse occurs when the moon, the sun and the earth locate at the same line.
Interviewer: How often they locate at the same line?
Aytolun: Two days in a month. We can calculate it considering their lowest common multiple.

After this question, Aytolun was asked to indicate what exactly 27,5 and 29,5 correspond? She indicated orbit of the moon around the earth as 27,5 days while 29,5 for revolution of the moon around the sun. Considering her responses, it is ambiguous what exactly these figures equal. She firstly stressed that duration of orbit of the moon is 29,5. However, then she showed that this figure corresponded to revolution of the moon around the sun. Actually, the moon completed its orbit after 27,3. However, the moon and the earth turn around the sun during this time period. Therefore, the moon should move two days distance in order to locate in the same line with the earth and the sun, which ensure its new moon phases. It seems that Aytolun aware of these concepts from the astronomy course. However, she could not remember what exactly they were. Therefore, she activated her these knowledge elements in order to explain relation between eclipses with lunar phases. In addition, one of the interesting points is that Aytolun considered the moon separately moves around the sun. It seems that Aytolun did not consider the moon obit the earth.

Ayten encountered problem to describe position of the moon/earth/sun during lunar eclipses. However, sources problem of Ayten was originated from her previous explanation regarding phases of the moon. Accordingly, as explained previously, her dynamic state regarding phases of the moon were dominated by day/night node. In other words, the moon was only visible half of its orbit. Therefore, according to her viewpoint there were overlap between lunar eclipse and full moon. Ayten explained;

> *Ayten: I do not have any idea about lunar eclipses… (silence for 30 seconds) may the moon can be complete dark? But how? (She located the earth model between the sun and the moon). But I said that it was full moon… I do not have any idea. I do not have a logical explanation.*
> *Interviewer: Why do you think so?*
> *Ayten: Because, it is conflicted with my previous explanations. In this position (the earth locates between the moon and the sun), I said we observe the full moon and that position (the moon locates between the earth and the sun) is solar eclipses. So, how do we observe the lunar eclipses?*

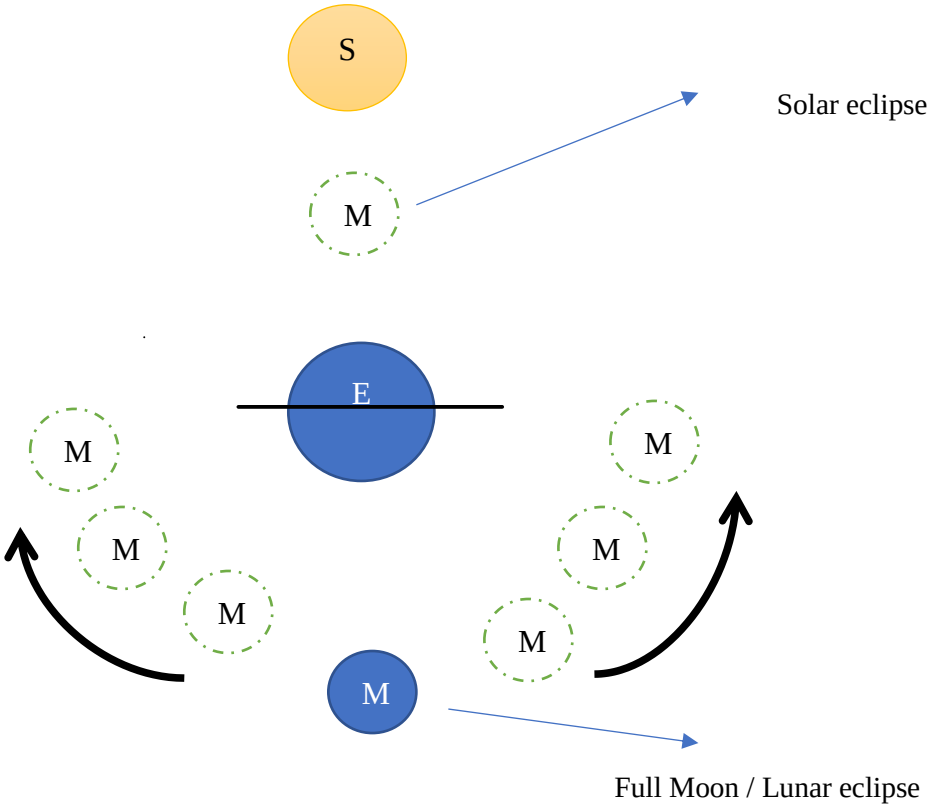


Figure 4.33 Ayten's Demonstration of Phases of the Moon

As seen from her explanation and Figure 4.33, she initially considered that lunar eclipses occurred when the earth located between the moon and the sun. However, she noticed that the position of new moon would overlap in such a position. Therefore, she abandoned from this explanation and could not propose any other model for lunar eclipse.

4.1.4 Appearance of the Moon

Pre-service science teachers were also directed questions regarding when the moon appear in the sky and whether we observe the moon in daytime. To illustrate, Aykut considered that we cannot observe the moon daytime.

Interviewer: When does the moon appear and disappear?
Aykut: According to my observation in my village, the moon appears with its phases. The apparent part of the moon constantly changes. It seems as first quarter, last quarter, full moon shapes. We observe sometimes a little part of the moon. It becomes observable after a specific time rather than as soon as getting dark. I observed this, but I do not know when the moon disappears. I rarely observe the sky at midnight.
Interviewer: What about morning?

Aykut: I do not observe the moon after getting up in the morning. (silence a couple of seconds) … I think there are several cases that I observe the moon in the morning. Vaguely the moon…I think it become funny.
Interviewer: Is the moon visible during the day?
Aykut: The moon cannot be seen in the day. This is probably due to too much sunlight that we receive from the sun and dim light of the moon. How should I say? Because of wavelength.
Interviewer: How does wavelength influence visibility of the moon?
Aykut: Because our eyes cannot see all wavelength…How should I say? Hmm! We can see only specific wavelength and other is out of scale. (silence a couple of seconds). I have just thought about it, but It is not rationale.
Interviewer: Why did you change your idea?
Aykut: I could not link to moon with lights such ultraviolet, gamma. Ultimately, the moon is a material and there is no linkage with these wavelengths.
Interviewer: Alright, you are in doubt whether or not the moon is visible at daytime.
Aykut: I could not be sure. We get up early in town. I think I see the moon in morning after getting up. But I could not be sure about it.
Interviewer: So, is the moon visible during the day?
Aykut: May be, in daytime, because of sunlight that is reflected by the sun to our eyes…or, I think we cannot observe because of the location of the moon. Its location may not inside of area that is described as our perspective or viewpoint.
Interviewer: What does this mean?
Aykut: (pointing out via model) If we are in this side of the earth and the moon is that side, we cannot see the moon. However, when the moon comes this side, we see it at night.

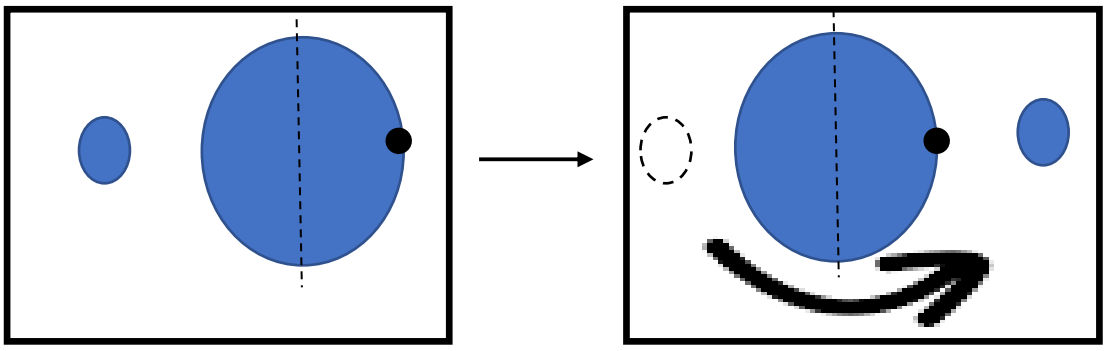


Figure 4.34 Aykut's Drawing about Appearance of the Moon in Daytime

As it seen from the excerpt presented above, Aykut shifted his explanation after a new question directed to him. This mean that he attempts to find appropriate answer therefore he visited to different modes. At the beginning, he considered phases of the moon, then he stressed that the moon would be visible after a specific time after evening. In order to elaborate his idea, interview responded a further question regarding visibility of the moon in daytime. Although it was not clear, he remembered that the moon was appeared in the morning. However, the idea is that the moon is not

visible in daytime was more dominant, therefore, he ignored his observations. Aykut attributed this phenomenon to much light from the sun and less light from the moon, which are somehow related to wavelength. He asked to explain how influence wavelength to visibility of the moon. Afterwards, he realized that type of the lights is not suitable way. Then, he suggested location of the moon determines whether or not the moon visible as shown in Figure 4.34. Accordingly, an individual cannot see the moon because it is not their viewpoints. In order to observe to moon, they should wait movement of the moon which equals its half orbit.

4.1.5 One face of the moon

Some of the pre-service teachers mentioned that we observe only one face of the moon while explaining lunar phases. Appearance only one face of the moon is not a phenomenon associated with our observation of different phases of the moon considering scientifically accepted viewpoint. Considering their responses, it seems that they did not acquire what it refers; therefore, they tended to integrate this phenomenon to lack point of their explanation on phases of the moon. In addition, it is plausible to consider that they were familiar with these concepts as a consequence of their formal education. Following excerpt from the interview on the Aytaç show this reasoning:

> *Interviewer: Alright, why, in your opinion, why do we observe the moon with its different shape?*
> *Aytaç: We see only sunlight reflected to us. We observe only a specific part of the moon because of its own rotation, which has the same ratio with the earth's movement. Therefore, the moon has a back part we never see from the earth.*
> *Interviewer: Why do not we see that part?*
> *Aytaç: Because, the moon has also a movement. While we rotate, the moon also rotates itself. Therefore, we never see the back of the moon. If the moon did not move, we would observe the back of it.*

Aytaç showed the movement of the moon and the earth with the help of his hands. He indicated as if the moon and the earth fulfilled their orbital period at the same time. This indicated that Aytaç could not acquire rationale behind why we observe the same face of the moon. As it is also seen from the utterance, he could not link this phenomenon with phases of the moon and he did not stress anything regarding dark side of the moon rest of the interview. Like Aytaç, Ayça also mentioned that we

observe only one face of the moon while considering reasons for phases of the moon. She stressed;

> *Ayça: Actually, there is nothing as dark and illuminated side of the moon. The moon and the earth rotate synchronously. Therefore, we observe the same face of the moon.*
> *Interviewer: Why do we observe the same face of the moon?*
> *Ayça: Because, the moon and the earth orbit. Both rotates synchronously. Moreover, since they fulfill at the same time their rotation, we observe the same face of the moon. (Utilizing with her pen and eraser, she demonstrates that the moon and the earth spin in their own axis while the moon orbits around the earth). While rotating, we see this part of the moon as illuminated (last quarter). In this position we could not observe anything in this position (new moon).*

Ayça has almost the same consideration with Aytaç. Both participants could not acquire rationale behind observing the same face of the moon; therefore; they attempt to utilize this phenomenon to explain phases of the moon. To put it in another, they utilized same face of the moon while "shopping around" or "mode skimming" so as to find relevant response for the question.

4.1.6 Factors Shapes Pre-service Science Teachers' Responses

Factors that shape pre-service science teachers' responses on the phases of the moon, which is second sub-question of first research question, examined in this part of the current dissertation. It was showed that pre-service science teachers activated variety of node in order to explain phases of the moon. However, there were factors which influence activation process. These factors were revealed as pre-service science teachers' spatial ability, their lack of observation, their superficial astronomy knowledge and their misinterpretation of physical rules. Furthermore, it was revealed that nodes may differentiate because of these factors. Although pre-service science teachers' responses referred to the same node, these nodes may not be identical. For instance, although many pre-service science teachers participated in the current study activated "orbit" node, meaning of the "orbit" may be different for each of them. Therefore, new codes emerged to analyze pre-service science teachers' responses and factors that shaped these responses. In the following table, emerged nodes and source of emerging were presented.

Table 4.3 Emerged Nodes on Appearance and Reason for Phases of the Moon

Original Node	Emerged Node	Factors
Illumination	Two-dimensional Illumination	Spatial ability
Illumination	Peripheral Illumination	Misinterpretation of Physics
Gradual change	Concave gradual change	Spatial ability
Gradual change	Holistic gradual change	Lack of systematic observation

4.1.6.1. Spatial Ability of Pre-service Science Teachers

Pre-service science teachers' responses regarding phases of the moon were intensively shaped by their spatial abilities. Their responses revealed pre-service science teachers encountered problems originating from their geometrical spatial ability, spatial transformation and spatial transformation abilities.

Geometrical spatial visualization ability referred to ability of visualize objects considering their three-dimensional nature. Pre-service teachers should perform their spatial visualization abilities and consider three-dimensional nature of the moon, sun and earth. However, pre-service science teacher may not perform. To illustrate, Aynur drew following Figure 4.35 and stressed as shown following excerpt.

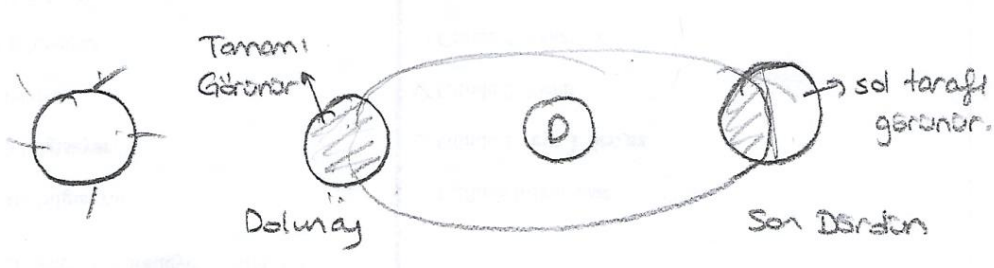


Figure 4.35 Aynur's Drawing of Lunar Phases

> *Interviewer: Can you explain how each of lunar phases occur?*
> *Aynur: It occurs in there (the moon is between the earth and the sun), since the moon receives all sunlight. Therefore, it is full moon in here. There is no obstacle which block its surface.*

It was revealed that Aynur located full moon phases between the earth and the sun, and stressed that the moon received sunlight, which make it completely visible. Aynur could not visualize three-dimensional nature of space in this example.

Considering her drawing and explanation, it was revealed that she activated "two-dimensional illumination" node. She considered that the moon completely illuminated by the sun. However, the sun illuminates only half of the moon, which is not possible to observe from the earth. In a similar vein, she considered that it would be last quarter when the earth located between the moon and the sun. Since she could not visualize three-dimensional nature of space, she perceived that sunlight was blocked by the earth.

Another problem regarding spatial ability of pre-service science teachers is related their spatial projection ability. Ayfer showed that shape of waxing crescent and gibbous moons are the same with waning crescent and gibbous moon. Namely, left side of all these phases was illuminated by the sun. Ayfer articulated the problem as seen following excerpt.

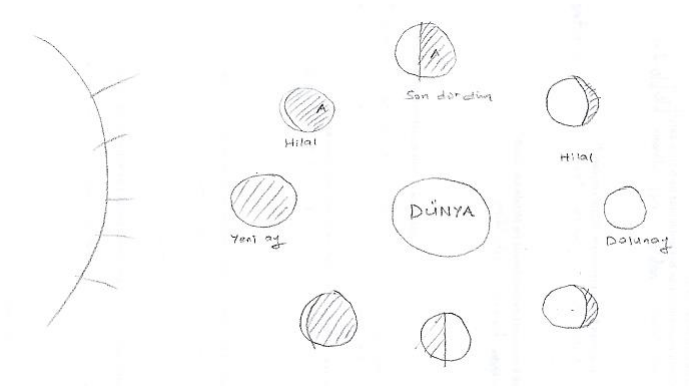


Figure 4.36 Ayfer's Drawing of Phases of the Moon

> *The problem is that I cannot visualize how we observe the moon from the earth. Do we observe the moon differently in these positions? We observe different phases in these positions. However, it is the same in my drawing. I do not know why it is. They should not be the same.*

As seen in Figure 4.36, both the same side of the crescent and gibbous moon were illuminated. This situation showed that Ayfer considered illumination with two-dimensional system of her drawing rather than its' three-dimensional nature. Therefore, Ayfer activated "two-dimensional illumination" node. However, right side should be illuminated waxing crescent and gibbous moon while left side should be

illuminated for waning crescent and gibbous. As stated by herself, she could not visualize herself while observing the moon in a location in the earth.

Final problem regarding spatial ability is that pre-service science teachers encountered difficulties while transforming their observation to two-dimensional drawing. Since pre-service science teachers lack spatial transformation ability, they could not draw appropriately shape of some lunar phases that they observe. To illustrate, some pre-service science teachers drew gibbous moon with concave shape while explaining gradual change of the moon phases. Therefore, this node was entitled as "concave gradual change". As seen in the Figure 4.37, Ayşıl drew waxing gibbous moon which had concave shape although its' actual shape is convex.

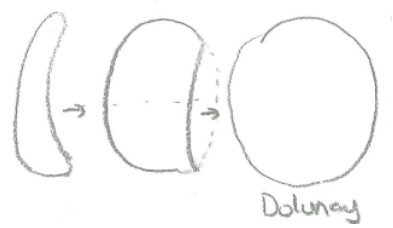


Figure 4.37 Concave Shapes Related to Gibbous Moon

4.1.6.2. Lack of Systematic Observation

Pre-service science teachers' some of responses showed that they lack systematic observation regarding the moon. To illustrate, Aytolun drew Figure 4.38 as shown below and stated that the invisible part of the moon become visible after a period of time.

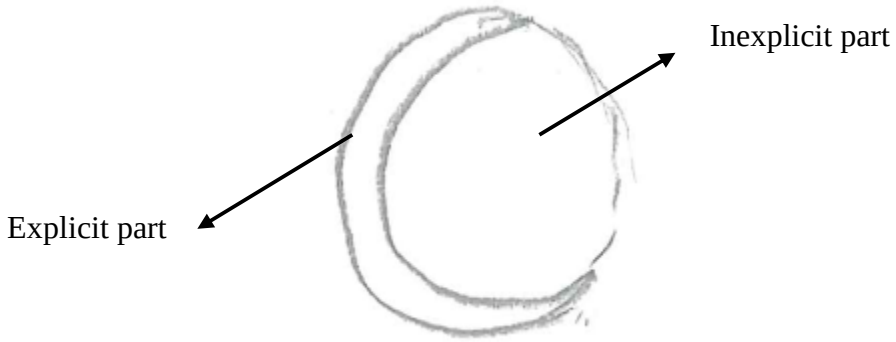


Figure 4.38 Aytolun's Drawing Change from Crescent to Full Moon

According to Aytolun, waxing crescent changes full moon after a period of time since total of inexplicit part of the moon become explicit. In other words, she could not consider that the shape of the moon gradually changes from new moon to full moon. She considered that complete invisible part of the moon slowly become visible. Therefore, this node entitled as “holistic gradual change”. It was plausible to consider that Aytolun lack of observable knowledge which ensure her gradual change explanation. However, explanation of Aytolun was not unreasonable. Most probably, she observed earthshine which refers to reflection of sunlight from the earth to surface of the moon.

Figure 4.39 Earthshine

As seen in Figure 4.39, sunlight reflected from the earth may partially illuminate other part of the moon which should be invisible. Aytolun may observe Earthshine and considered that partially illuminated part of the moon would be visible in the next phase. In other words, she activated complete gradual change node. She could not differentiate change of phases of the moon from Earthshine due to her lack observational knowledge.

4.1.6.3. Misinterpretation of Physical Rules

One of the sources of pre-service science teachers faced regarding phases of the moon was originated from their lack of understanding of physical rules or their

misinterpretations of these rules. Most of the pre-service teacher expressed that the moon illuminated by the sun, which is a first step of the explanation of the phases of the moon. However, some of the cases showed that they were not sure which part of the moon receive the sunlight because of their lack of understanding of light propagation. Namely, they were not aware that light of the sun is parallel and reached perpendicular to the lunar terminator line. In addition, pre-service science teachers could not visualize that the Sun illuminates half of the moon. They determined specific part of circle of the moon symbol in order to show illuminated part. Therefore, pre-service science teachers activated "peripheral illumination" node while explaining different appearance of the moon.

In the following drawing of Aytaç reflected the idea that the moon appears as full moon in it is essentially last quarter phases since the part of the moon seen from the earth receive the sunlight.

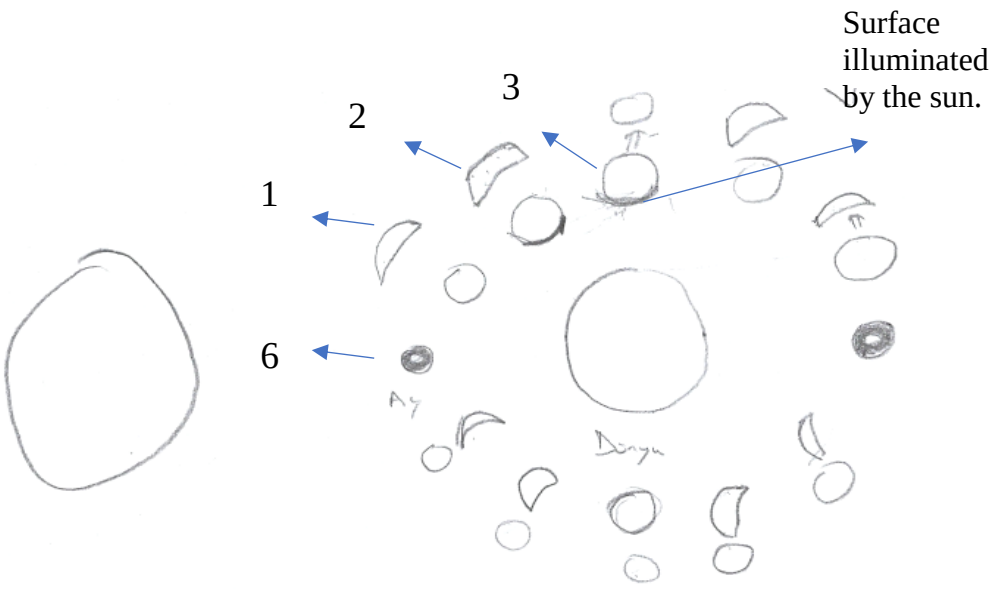


Figure 4.40 Aytaç's Drawing of Lunar Phases

While drawing Figure 4.40, he explained why we observe different phases of the moon. Aytaç stressed;

Aytaç: We observe all of them, since sunlight illuminated whole the moon (position 3). Sunlights cannot illuminate whole moon in these positions (positions 1 and 2);

therefore, only this part of the moon is visible. We can complete this circle with other phases.
Interviewer: Could you fill the circle with other phases?
Aytaç: This is dark phase (position 6).
Interviewer: Why is it dark phase?
Aytaç: Lights cannot arrive to the moon because of the earth.
Interview: Can you explain why this phase (position 3) is completely illuminated?
Aytaç: I think sunlight can arrive completely.
Interviewer: Where do they arrive?
Aytaç: Surface that we observe. They arrive completely. This portion of the moon is visible from the earth. The sun illuminated completely this portion. We see reflected lights therefore we observe whole moon.

In addition to his explanation, he advocated his opinion while demonstrating the occurrence of each phase via three dimensional models. He stressed;

I think, this part receives the sunlight, therefore, the moon can be completely seen from the earth. Since the sun is very big, sunlight reaches this part of the sun.

As showed above, according to Aytaç, the moon was full in its last quarter position since he considers half of the moon facing to the earth receive sunlight. That is, he could not apply parallel propagation of sunlight. and activated "peripheral illumination" node. Similar to Aytaç, Ayten also considers that we observe the waning crescent moon in the position of last quarter as seen in Figure 4.41. According to her idea, the sun illuminated the part of the moon which face the earth. While explaining, she draws intersecting lines from the sun to the moon, which is not consistent with appropriate model of illumination of the moon.

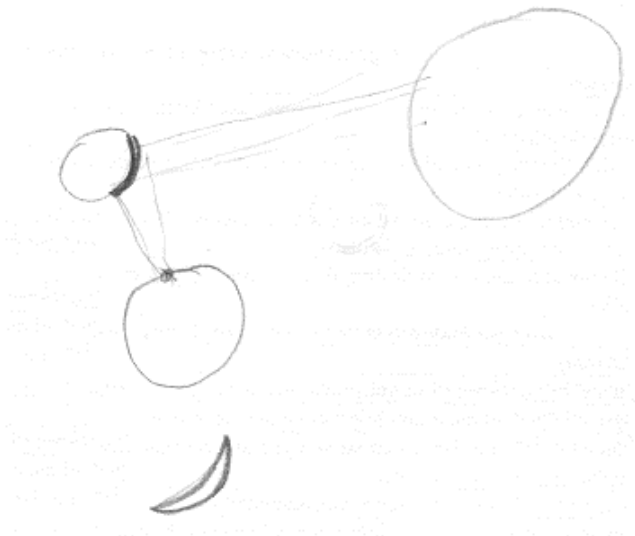


Figure 4.41 Ayten's Drawing of Lunar Phases

As seen in Figure 4.41, Ayten showed that sun rays were not parallel each other and they did not reach perpendicular to the terminator line of the moon. She demonstrated a portion of the moon's circle in order to show illuminated part. This shows that she activated "peripheral illumination" node. Therefore, she stated that we observe the waxing crescent moon, although it is first quarter phase.

The last example regarding this issue is explanation of Ayşıl. She explained full moon and first quarter as seen in Figure 4.42. She moved the moon from the position seen in the left of the figure to position seen in right of the figure. As a result of this short movement, she stated that illuminated part of the moon changed and the moon become full moon.

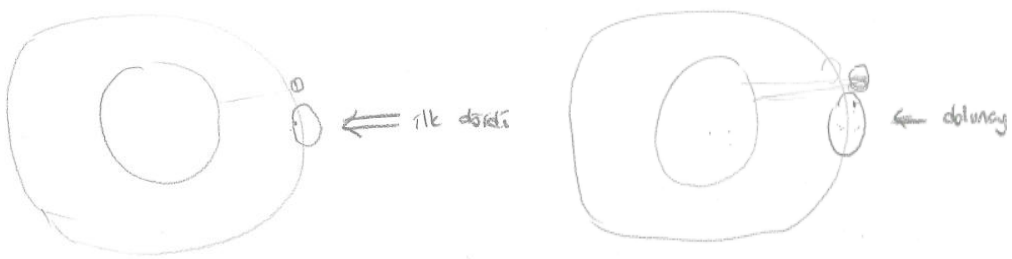


Figure 4.42 Misinterpretation of Ayşıl Regarding Light Propagation

She stated;

Interviewer: Alright, what is the difference in your first and second drawing?
Ayşıl: position of the sun and the earth are constant. But the position of the moon is different. Different part of the moon receives sunlight.
Interviewer. Where is the moon in these shapes?
Ayşıl: It's located at right side comparing the first shape. But it is at the same orbit. It also depends on some other factors. Observer in here (left figure) looks only quarter part of the moon. But, the observer there (right figure) has an angle, which observe the complete moon. The position of the moon and the earth, and our location determine. The moon is observed differently from the different location on the earth.

As it is seen in the figure above and utterance, Ayşıl could not visualize that sun light should be perpendicular to lunar terminator line. In other words, she could not activate "parallel" node. Therefore, she labelled almost the same drawings as first quarter and full moon.

4.1.6.4. Superficial Astronomy Knowledge

Pre-service science teachers tried to explain phases of the moon considering some other astronomical phenomenon, although there is no direct linkage among them. Since pre-service science teachers were lack of sophisticated understanding regarding some astronomy issues, they easily integrated these issues to their explanation on phases of the moon. As previously explained, Aynur stated a phenomenon entitled as conjunction. To recall, she stressed that conjunction referred to invisibility of the moon as seen in the following utterance.

Interviewer: What is the shape of the moon that is observed from the earth?
Aynur: Crescent, first quarter, last quarter, full moon. We sometimes cannot observe. It is called as conjunction. I have learned it.
Interviewer: When did you learn?
Aynur: While preparing an assignment for an undergraduate course. I read it from a scientific magazine regarding the moon.
Interviewer: What was the meaning of conjunction?
Aynur: The name of invisibility of the moon from the earth is as lunar conjunction.

Lunar conjunction referred to position of the moon (A), earth (D) and sun (G) are in straight line as seen in Figure 4.43. Accordingly, the moon completed its orbit around the earth in 27,3 days. However, they could not locate in a straight-line since the earth orbits around the sun. Therefore, the moon should move from A1 point to A2 point in order to appear as new moon again. It lasts 29,5 days and called as lunar conjunction. In another words, lunar conjunction corresponds to duration between two new moon phases.

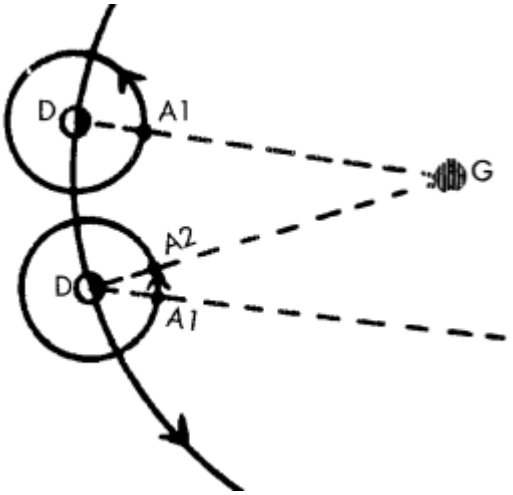


Figure 4.43 Lunar Conjunction (Moore, 1996)

Considering what exactly lunar conjunction refers, understanding of Aynur regarding lunar conjunction is not appropriate. It is plausible to consider that she could not develop comprehensive understanding as a consequence of examination of scientific magazines. Therefore, she integrated her superficial understanding regarding lunar conjunction to phases of the moon concept.

In addition to idea of Aynur regarding lunar conjunction, Aytolun also considered Kepler Laws may explain rationale behind phases of the moon. As seen in the following utterance and drawing, Aytolun tried to explained phases of the moon via “sweeping” and “distance” nodes.

> *While the moon orbits… The Kepler Law also is applicable for this situation. Its velocity and the area sweeped… I could not remember what exactly the theory contains. That is the sweeping area. I think it is not linked to its distance. It is because of refraction.*

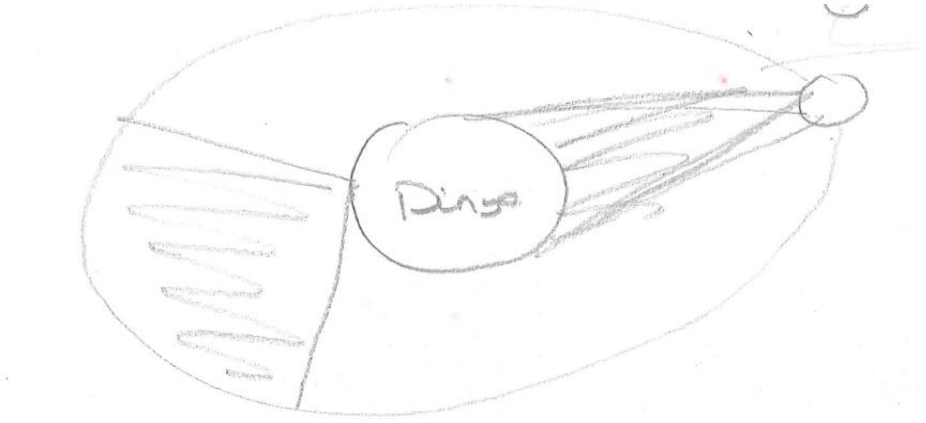


Figure 4.44 Aytolun's Drawing about Kepler's Law

Kepler laws includes three rules which describe mechanism of the planets orbiting around the sun. According to the first and the second laws, all planets move around the sun in elliptical orbit and their speed changes depending on distance between the sun and planet. Furthermore, the third law showed that there is a direct proportion among planets' cube of semimajor axis of their orbits and square of their orbital period. Taking into account these rules, it is revealed that there is no linkage between phases of the moon and Kepler Laws. However, since Aytolun does not have sophisticated understanding regarding Kepler laws, she considered that "sweeping" and "distance" may be associated with phases of the moon.

4.1.6.5. Source of their knowledge

Pre-service science teachers activated variety knowledge elements obtaining from different sources. While responding interview questions, they generally stressed sources of their knowledge. Accordingly, pre-service science teachers mostly referred to their unsystematic observation. For instance, Aykut, lived a rural area when he was a child, explained;

> *Considering my observation in my village, the moon appears with its phases. visible part of the moon changes. First quarter, last quarter, full moon are its apparent shapes. We sometimes observe small portion of it. The moon appears at a specific time. It does not appear when sky get dark. I observe it. But I do not have any idea when it disappears. I could not observe it at midnight*.

Pre-service science teachers' experiences always did not contribute to them to have appropriate explanation. Some of their experience cause confusion or dilemma. For instance, interviewer asked to Ayşıl how appearance of the moon change after twelve hours. Ayşıl draw the following figure and explained:

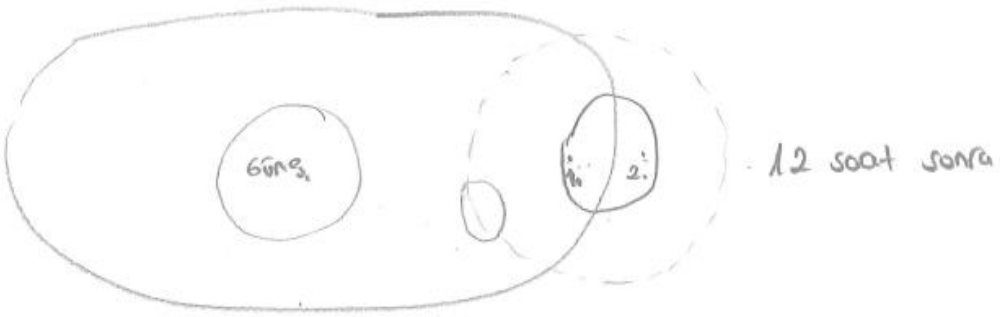


Figure 4.45 Ayşıl's Drawing of Earth's Spin

Position of two observer would change after twelve hours. It is something like day and night. The earth spins. This position reflects appearance of the moon in daytime. I would observe the moon in daytime. But I observed it in summer. But it is winter in this figure. It should be winter when it (the earth) is far away from the sun and summer when it is close to the sun. However, I think I observed the moon in daytime in summer. I did not observe it in winter. Person can observe the moon from this location (location 1 in the figure above). But it is winter. Do we observe the moon in daytime in winter?

As shown utterance above, Ayşıl considered her previous observation regarding the moon. Accordingly, she activated "day/night" node and explained that the moon can visible in daytime. However, she could not explain what would happen after twenty hours since she did not sure whether or not the moon is visible in daytime in winters.

Pre-service science teachers' experience regarding astronomy and knowledge sources was not limited with categories underlined in the current research. For instance, Aysu memorized a scene from a movie she watched while she considered appearance of the moon for two observers from different longitude. She explained;

Aysu: ... While we observe full moon, may an observer does not observe full moon? But they observe. Movies includes such event. They observe the moon at the same time.
Interviewer: Who did observe the moon?
Aysu: As far as I remember, his girlfriend is in Italy and he is in Istanbul. These cities are almost at the same latitude. They were talking about the moon while looking it.

Therefore, they should observe the same thing. I changed my opinion. Appearance of the moon depends on longitude.

Some pre-service science teachers stated that they remember some figures from printed sources. To illustrate, Aykut stated that he remembered figures that exists in his middle school science book. He drew first and last quarter shapes which have edges and resemble a concave lens as seen in Figure 4.46.

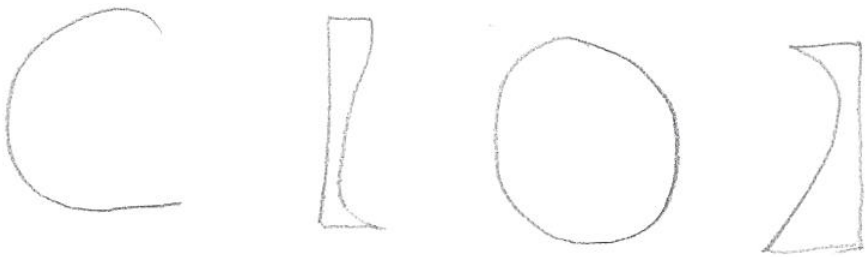


Figure 4.46 Aykut's Drawing about Appearance of the Moon

Aykut pointed that his second and fourth shapes referred to first and last quarter. Interviewer emphasize that his drawing regarding last and first quarter have edges in order to understand rationale behind these shapes as shown in the following except.

Interviewer: Did you observe your drawing pertaining to first and last quarter moon?
Aykut: Actually, it was not my observation. It is the shapes that I remember from the middle school science book. It is thicker than crescent and not circle. It is straighter comparing with crescent moon, therefore, they (author of the textbook) drew these shapes.
Interviewer: Have you examined the middle school textbook?
Aykut: Nope! I have memorized from my middle school years.
Interviewer: Could you specify these difference in more detail.
Aykut: Crescent moon contains specific curvature, but first and last quarter have less. I memorized that they have thin body.
Interviewer: But yours have edges.
Aykut: It is appearance of them.
Interviewer: What cause these edges?
Aykut: I do not know the reason regarding edges, but it is necessary transition from crescent to full moon. It is more plausible.

As seen in this excerpt, Aykut stated he memorized these shapes from his middle school textbook. Although he did not know reason behind these shapes, he was not in doubt about these shapes. It is not plausible to consider that Aykut may see some

shapes as in his drawing of first and last quarter in textbook. Most probably, figures in the textbook was not sufficient for Aykut to develop appropriate mental images regarding different phases of the moon. In addition, Aykut may be highly impressed some of the courses physics courses he pursued. For example, his interaction with optical devices such as mirror, lens may be shaped his consideration.

4.1.6.6. Surplus of node

Pre-service science teachers sometimes activated a lot of nodes in order to explain a situation. However, organization of these activated nodes may become a challenging task for pre-service science teachers, and they could not propose a model regarding to problem situation. For instance, Ayşıl explained issues she encounters while predicting next phases after new moon. She explained;

> *It is getting bigger (illuminated part). But I could not reach anything, the moon completes its orbit. It is completely different issue. When it arrives this position (from full moon to new moon) half year should last. I mean a year of the moon. I could not think about this issue. I am going to observe the moon and its phases in this night. I could not visualize. (silence 10 seconds). I am sure how lunar eclipses occur. I could not interpret them while considering movement of the earth and the moon, revolution around the sun, and speed and duration of these movements. I perceive them as if all these factors conflict each other. It is invisible phase of the moon (the earth is between the moon and the sun). While the moon moves, I initially could not think that the earth should also moves. Then, I move both; therefore, the moon receive sunlight from its side. However, the earth should move faster. I could not explain since I consider all these factors.*

As stressed previously, she initially activated a set of nodes to explain phases of the moon. While considering about phases of the moon she realized that the earth should also move around the sun. Therefore, she attempted to integrate speed, duration of movement of both the earth and the moon. However, she could not consider all the factors together. Although she has more appropriate dynamic mental construct at the beginning, activating new knowledge elements make the sun/earth/moon system more complicated to organize new dynamic mental construct.

Further questions directed by interviewer also triggered activation of new nodes. For instance, interviewer asked why Ayfer drew the same figure for both new

moon and lunar eclipse. Ayfer activated day/night node as a consequence of this question and she could not organize activated nodes.

Interviewer: Your drawing of lunar phase drawing and new moon are the same. Why are they the same?
Ayfer: I observe one of them in day and other in night.
Interviewer: But you said that we did not observe anything in new moon.
Ayfer: Yes, but it is night. I mean it is day. They are confused since it is night. I do not know.
Interviewer: What is issue you encounter?
Ayfer: I could not explain why we observe the moon in daytime. It is new moon because it occurs only at night. If it occurs in daytime, we call it as lunar eclipse.
Interviewer: Can you explain which phases appear in daytime or night.
Ayfer: (Utilizing three dimensional models), day and night refers to… This side of the earth is night and other side is daytime. In this situation (full moon), the moon is not visible in daytime. But the moon can be seen such a situation (new moon). Since the sun is also here, it causes an eclipse.
Interviewer: But you said that it was new moon at night.
Ayfer: Yes but now… I am confused. I have to consider again. I could not find a way.

As seen in excerpt above, Ayfer activated "day/night" node in order to explain differences between lunar eclipse and phases of the moon. However, this new activated knowledge element cause confusion; therefore, she could not organize these nodes in order to propose a model to explain differences between eclipse and new moon.

4.2 Changes on Mental States Regarding Phases of the Moon

Some teacher candidates changed their initial explanation on phases of the moon concepts during the interview. Some of the changes occurred since they noticed problematic points in their previous explanation. Participants sometimes changed their explanation while drawing figures and demonstrating with models. Furthermore, there were some cases in which participant changed their explanation after a further question directed by the interviewer. As seen utterances below parts, there were pauses on response of pre-service science teachers. They considered over interview question of their initial responses, which showed they re-organize their knowledge elements during the interview.

4.2.1 Changes on Appearance of the Moon

Pre-service science teachers' responses on different appearance of phases of the moon and their sequence were dynamic. Almost all pre-service science teachers constructed their responses during the interview. Since it was not constrained, they easily changed their initial responses considering some other aspect of the issues of directed problem. Therefore, they changed some of their responses and restated them or modified their drawings. In this part, change of four pre-service science teachers' responses were presented.

Aygün drew different appearance of the moon considering that there should be gradual change among different moon phases. As seen in Figure 4.47, he merged some of the different phases and declared existing of four different phases such as first quarter, half-moon, last quarter and full moon. He articulated that the moon follows the sequence from one to seven and after seven it returns to one following reverse of the same pattern. He stressed that this process lasts less than one month and approximately equals to twenty-six days considering his observation. He stated;

It depends on time we observe since it changes. Firstly, a portion of the moon is bright. Then it became dark. I mean percentage of illuminated and dark part change.

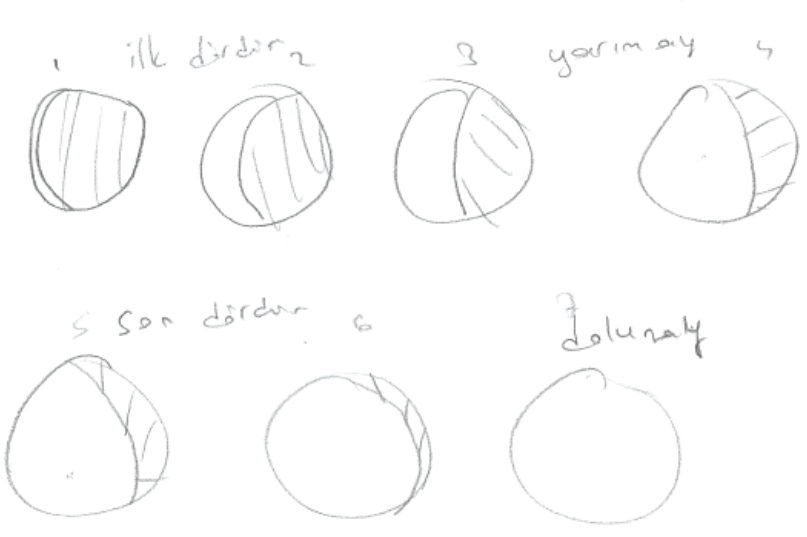


Figure 4.47 Aygün's Drawing of Phases of the Moon

It was revealed that Aygün activated “gradual change” and “completing cycle” nodes. Illuminated part of the moon increases shape one to seven. In addition, these shapes follow a pattern one to seven and then reverse of it, which referred to completing cycle. However, there is no new moon in this diagram. Interviewer asked next phases after shape of number seven. Aygün stated;

Interviewer: What will happen one step later?
Aygün: One step later is in there… It is full…It resembles black. Not black. It returns to starting point.
Interviewer: What do you mean by black?
Aygün: I could not remember any phases that the moon is invisible. Therefore, I ignore it.

Aygün changed his diagram regarding phases of the moon. After drawing, further questions were directed to Aygün. While explaining details about his figure, he noticed problems with her diagram and modified them. Following excerpt indicated how Aygün needs this change in his diagram.

Interviewer: You entitled your first and second shapes as first quarter. How would you define first quarter?
Aygün: I think it is related to illumination of quarter part of the moon.
Interviewer: Is it quarter part of the moon in your shapes?
Aygün: (examining his diagram) This is… How can explain… Since quarter of the moon illuminated… I may possibly make a mistake, I am not sure. My drawing may not be accurate.
Interviewer: You can correct it, if it is not accurate.
Aygün: (drawing Figure 4.48), It is first quarter, then half-moon, afterwards last quarter and full moon. It follows this direction and then it returns.
Interviewer: Can you draw…
Aygün: Actually, it does not return with the same shape. Dark and illuminated side change.
Interviewer: Could you draw them?
Aygün: (keeping draw from left to right in bottom line in his diagram). This part is dark. Then half is dark. Afterwards this part.

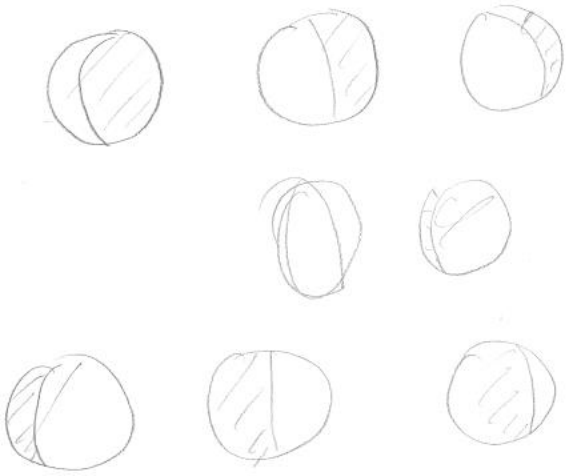


Figure 4.48 Aygün's Modified Drawing of Phases of the Moon

As seen from this utterance, he initially refined number of the moon shapes from seven to five, as a consequence of further question directed by interviewer, which points there are some appearance having the same name. Then, he realized that there must be opposite shapes of the moon in order to fulfill its gradual change and he inserted three new appearances as seen in the bottom his figure. That is, although Aygün's first drawing did not contain opposite appearance of the moon, his final drawing included in opposite appearance of quarter, crescent and gibbous moon. In another word, he activated "opposite phases" node while modifying his model. On the other hand, path that phases follows changed. He stated that moon's appearance changed from the seven to one after twenty-six days. However, he explained that illuminated parts would be different side after full moon. Therefore, the moon completed its cycle via following these moon phases. Contrary to this enhancement, he again utilized four different names for these appearances.

Ayça firstly draw the appearance of the moon side by side demonstration as seen Figure 4.49. She stated that the moon has different phases and these phases weekly changes. In addition, she explained that the moon revolves around the moon and position of the moon in orbit of the earth determines appearance of the moon.

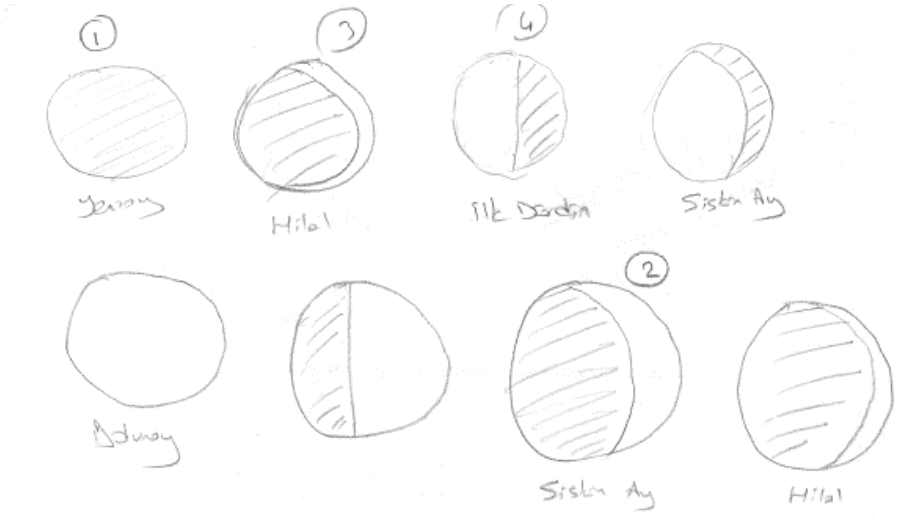


Figure 4.49 Ayça's Drawing of Phases of the Moon

While drawing, she encountered with difficulties. She stressed that she could not remember gibbous moons. In addition, she pondered shape of the crescent moon in top line in her figure. She initially drew a concave shape in order to demonstrate crescent moon as seen Figure 4.50. But then, she changed this shape and drew waxing crescent moon. At the end of this drawing, she stated that she could not draw them with their appropriate order.

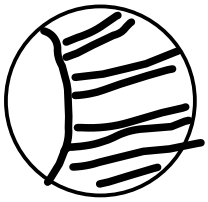


Figure 4.50 Ayça's Drawing of Concave Gibbous Moon

Immediately after she drew phases in Figure 4.49, she located them to a circle around the earth as seen Figure 4.51. It was plausible to consider that she tried to indicate sequence of the moon shape via circle demonstration. Comparing her products, it was revealed that she changed not only sequence but also appearance of some of the phases. That is to say, she changed shape of the gibbous moon and location of the gibbous and crescent moon. She articulated,

The order of my first drawing was false. The sequence should be like that (pointing her circle diagram and assigning number in order to show new order). There is also

problem with shape of the moon. Appearance of the crescent and gibbous moon should be reverse.

Figure 4.51 Ayça's Drawing of Circle Diagram of Phases of the Moon

It was revealed that Ayça activated nodes of "opposite phases" and "completing circle". She underlined that phases of the moon were a cycle which fulfilled approximately thirty days. Opposite shapes of the moon phases were also existed in her diagram. However, her both diagrams did not reflect gradual change of phases of the moon. Although left side was illuminated of first crescent, it became right side illuminated crescent. Furthermore, she encountered problems regarding spatial ability. For instance, she drew concave shape in order to indicate crescent moon. Finally, there is no evidence that Ayça activated illumination nodes. Although her drawing includes symbol of Sun, she did not utilize sun or sunlight while ordering phases of the moon.

Figure 4.51 was not final consideration of Ayça. While explaining rationale behind different appearance of the moon, she realized that the shape of gibbous moon was not appropriate. She noticed that figure of gibbous moon resembles crescent moon. She stressed that shape of gibbous moon should closely approximate to full moon. Therefore, she modified her production as it seen in Figure 4.52.

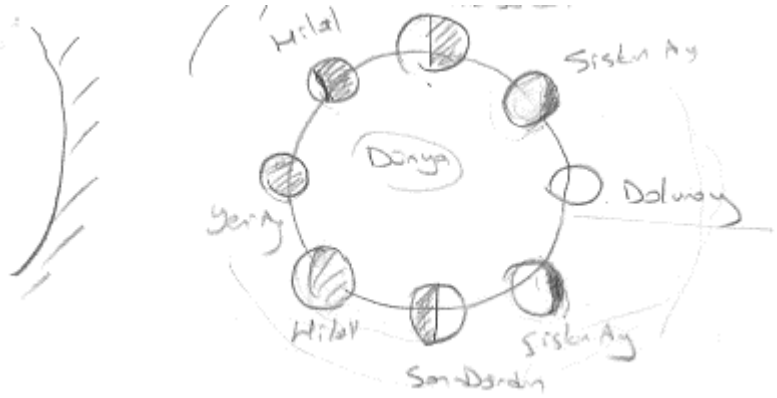


Figure 4.52 Ayça's Drawing of Circle Diagram of Phases of the Moon

Comparing these two figures, it was revealed that she changed appearance and position of the crescent and gibbous moon. Accordingly, Ayça activated node of "gradual change". All the moon shapes in the circle in Figure 4.52 gradually changed. In addition, all the moon's illuminated parts face the sun, which refers to activation of "illumination" node. She considered that left sides of the moon receive sunlight; therefore, they should be visible from the earth. However, last quarter shape was drawn as reverse of first quarter and it was not consistent Ayça's perspective on gradual change and illumination. Following excerpt showed that interviewer expose to Ayça with a problem in her diagram.

> *Interviewer: Why did you change your model considering your first drawing of phases of the moon?*
> *Ayça: First of all, changes from new moon to full moon should be meaningful. According to my first model, while one part is illuminated, but suddenly it become dark. In the second drawing dark part of the moon changes gradually.*
> *Interviewer: But, considering your second drawing, last quarter shape did not match with your explanations.*
> *Ayça: Yes, it may be like that… I am wrestling the same issue… There are some points that is not reasonable for me. It should increase gradually.*

The question of the interviewer points a problem and possibly provokes Ayça for shifting her diagram again. As a result, she initially changes position of the waning gibbous and crescent. Since this move could not solve the problem, she changed illuminated side of crescent and gibbous moon locating at the bottom. Gradual change was ensured by this move but it was caused a new problem of illumination. Ayça was confused why part of the moon closer to sun is dark even receiving sunlight, which

has got similar characteristics with Ayfer's consideration. However, unlike Ayfer, she could not propose any model with the purpose of overcoming this problem. Essentially, she may have changed illuminated part of last quarter in order to ensure gradual change of the moon cycle. But she did not. This shows that shape of the last and first quarter dominated her consideration. That is to say, "opposite" knowledge elements were more dominate comparing with "illumination" for Ayça.

Aybilge initially drew lunar phases that she remembered first line of Figure 4.53. Then, she tried to order them. Although she immediately drew the first three figure in the second line of her diagram, she stopped and considered the fourth. She stated that she was confused because of two-dimensional nature of drawing. She fulfilled her diagram and explained as shown in following excerpt.

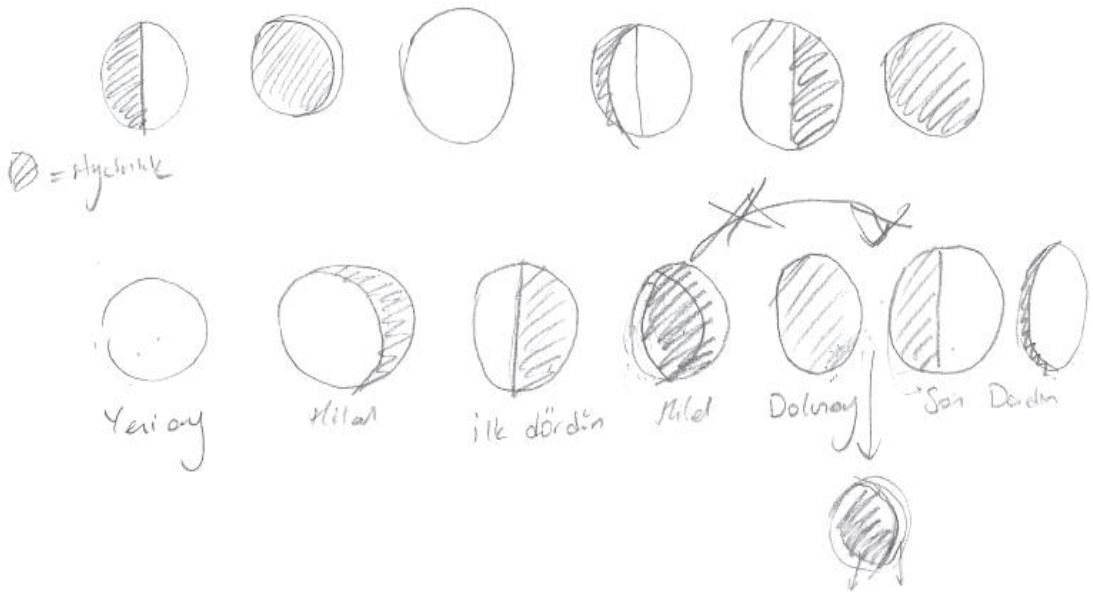


Figure 4.53 Aybilge's Drawing of Phases of the Moon

Interviewer: Could you explained what happened here?
Aybilge: Because of it is liner, I could not appropriately demonstrate them. If I drew the sun and the earth and the moon around them, it would be easier. In here, it is light (pointing new moon). It became dark. In there, half of the moon is dark (pointing first quarter). (she located crescent moon between full moon and last quarter as seen arrow). I thought it should have more dark part. It is my fault. Then, it become full moon. Afterwards, last quarter.
Interviewer: Why did you change?
Aybilge: I know that crescent is at this location according to my observation and books. But it was not like in my drawing.

Interviewer: Why?
Aybilge: Because it is linear. I could not visualize location of the earth and the sun.
Interviewer: Can you explain your reasoning?
Aybilge: I continuously tried to increase light and dark side of the moon. Light part of the moon continuously increases, and it will be full moon here. Then, dark side increases (silence a couple of seconds). Hımm, it was not wrong. But there must be one more phase (drawing additional crescent moon above and cross the arrow she previously drew).

The initial drawing of Aybilge reflected "gradual change". There was a rationale among illuminated part of different moon appearance. However, she left out only one phase between full moon and last quarter. However, she, then, considered that location of crescent moon is not correct depending on her experience. Although she stressed that sources of this experience is her observations and books, it was not clear how this experience begets change on her diagram. Therefore, researcher asked to explain rationale behind moon shapes. While explaining rationale behind her drawing and she noticed that her previous drawings were not wrong. Then she inserted one additional moon appearance in order to fulfill. One step later, she demonstrated phases of the moon around a circle as seen below figure.

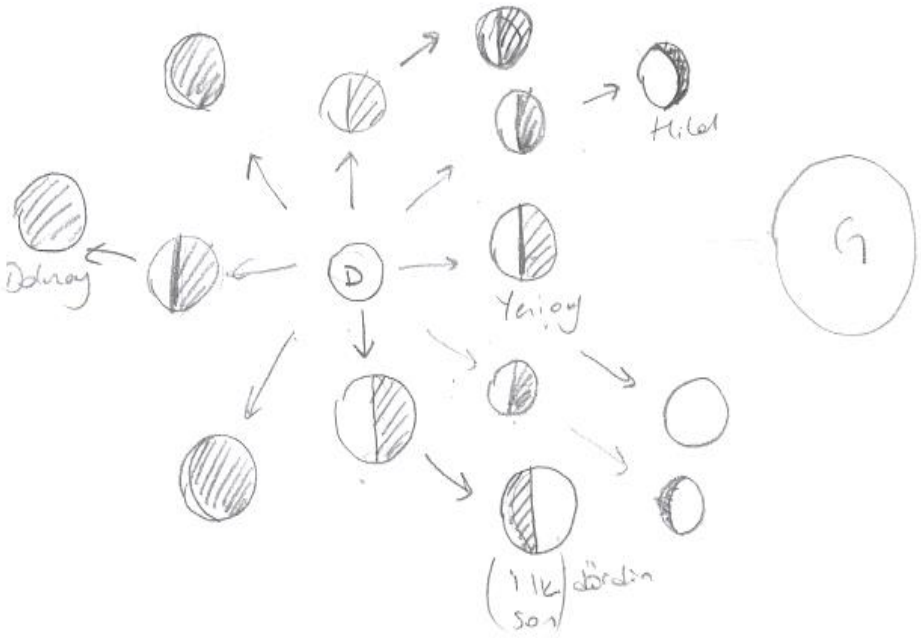


Figure 4.54 Aybilge's Circle Drawing of Phases of the Moon

As it is seen in Figure 4.54, she properly indicated all the phases and their appearance. Both her explanation and drawing regarding appearance of phases of the moon showed that she activated “gradual change”, “completing cycle”, “opposite phases” and “illumination” nodes. She only could not be sure about the name of the gibbous moon. Although she stressed that she remember something like waning and waxing gibbous, she did not write these names on her diagram. Comparing her diagram with other participants, her model regarding appearance of the moon was more constrained. In addition, it was revealed that she aware of earth-based and space-based appearance of the moon. This is, she utilized her spatial ability so as to change her perspective among earth-based and space-based perspectives. There were two layers in her diagram. She located space-based appearance of the moon inner layer. Appearance of the moon from the earth was located outer layer. In addition, she matched space and earth-based appearance for each of lunar phases.

Aykut firstly drew each of the lunar phases via side by side demonstration. However, he changed his first production after his circle drawing. His drawing did not include the new moon phases like many other participants. According to him, phases of the moon starts with crescent moon and ends with the last quarter as shown Figure 4.55. Although he drew waning crescent moon in his first stabs, later he put a cross over this appearance since he could not be sure whether or not there is such an appearance. He stressed that there may be opposite shape of the crescent moon like first and last quarter. However, he changed his opinion considering how waning crescent become waxing crescent as it seen from the following utterance.

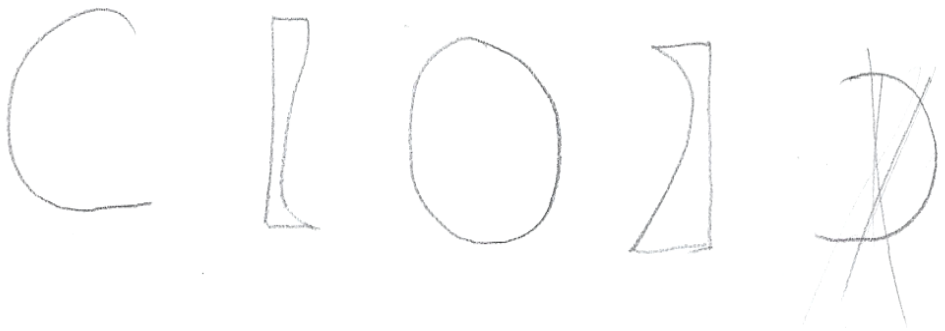


Figure 4.55 Aykut’s Drawing of Phases of the Moon

Aykut: Actually, I memorized like this. But I did not consider about it. While first and last quarter is like that, why crescent does not have symmetrical shape? I did not consider up to now. I consider but I am in a dilemma.
Interviewer: What is the symmetry of the crescent moon?
Aykut: Like that (drawing the shape located in the right of Figure 4.55) similar to first and last quarter. But I could not trust my knowledge. How can I explain? Is it not important direction of the crescent moon? Since it is trivial, we may ignore it.
Interviewer: What do you mean?
Aykut: like that… it may be nonsense, but we may consider zero. It is a similar that we do not start counting with zero. Okay, this crescent has different shape, but it is not perceived as remarkable.
Interviewer: Could you tell me how this process recurs? What would happen after the crescent in the right?
Aykut: Transition from this crescent (on the right) to other crescent (on the left). I am not sure whether or not there is such a crescent (pointing the right). Now, transition among these shapes is absurd for me. These different images do not make sense. It resembles absolute value. The Number inside absolute value is whether positive or negative one is equal to positive one. I think crescent moon is similar to this example. First and last crescent have opposite appearance of each other. But crescent does not have such a opposite appearance since full moon locates in front of it.
Interviewer: What do we observe while looking the sky?
Aykut: When the moon locates in there, we observe crescent. We observe full moon if you reverse it 180 degrees.

Figure 4.56 Aykut's Drawing of Crescent and Full Moon

As it also seen from Figure 4.56, Aykut drew circle diagram in order to show rationale behind full moon and crescent moon. Comparing his diagram with other participants circle diagram, his diagram did not include sun or sunlight. Therefore, he did not utilize "illumination" node in his explanation. He located crescent and full moon opposite location. One of the crescent moons was enough for his purposed model since full moon and crescent moon locates opposite positions. To put it differently,

Aykut activated “opposite phases” nodes. Unlike other participants, he regarded crescent and full moon as opposite phases considering his diagram in Figure 4.56. Therefore, he considered that there should be one type of crescent moon although it is not consistent with his observation regarding crescent moon.

It was revealed that Aykut not only activated opposite phases node but also “gradual change” and “completing cycle” nodes. Following utterance showed his explanation refers to “gradual change” and “completing cycle”.

Aykut: From crescent to first quarter, then from first quarter to its widest phase full moon. After full moon, it becomes last quarter. Afterwards, it is again crescent. Like this, appearance changes as a cycle.
Interviewer: How long does it take to complete this cycle?
Aykut: It is not hourly and daily change. I think it is weakly change since a month is longer period. We can observe the changes earlier than such a long time.
Interviewer: From crescent to last quarter?
Aykut: I predicted that it is between one weak and one month. But I do not know actual figure.
Interview: What is your estimation?
Aykut: hımm… It may.. I am thinking orbit of the moon around the earth and orbit of the earth around the sun. I think it is related to orbit of the moon around the earth. It is twenty-eight days. There are four periods between moon phases. Therefore, it is equal to seven days when we divide twenty-eights to four.

Another interesting point of his drawing is shape of the first and last quarters. As it is also seen from the following utterance, he considered that appearance of the moon should be these shapes.

Interviewer: Did you observe your drawing pertaining to first and last quarter moon?
Aykut: Actually, it was not my observation. It is the shapes that I remember from the middle school science book. It is thicker than crescent and not circle. It is straighter comparing with crescent moon, therefore, they (author of the textbook) drew these shapes.
Interviewer: Have you examined the middle school textbook?
Aykut: Nope! I have memorized from my middle school years.
Interviewer: Could you specify these difference in more detail.
Aykut: Crescent moon contains specific curvature, but first and last quarter have less. I memorized that they have thin body.
Interviewer: But yours have edges.
Aykut: It is appearance of them.
Interviewer: What cause these edges?
Aykut: I do not know the reason regarding edges, but it is necessary transition from crescent to full moon. It is more plausible.

Although Aykut does not observe such an appearance, he drew the moon shapes with edges. He stressed that he memorized these figures from his middle school textbook. In addition, he feels comfortable with his idea because he though edges of quarter moons were necessary for transition to full moon and crescent.

Since pre-service science teachers constructed their explanations, they easily changed their explanation considering inconsistencies or lack points. In addition, they activated additional nodes during they modified their initial explanation. For instance, Aygün activated “opposite phases” nodes and Ayça activated “gradual change” and “illumination” nodes, while modifying their initial explanation. Details regarding pre-service science teachers’ responses and their activated knowledge elements were tabulated in Table 4.5.

Table 4.5 Summary of Pre-service Science Teachers' Dynamic Mental Construct

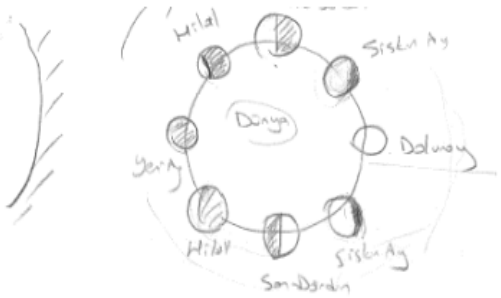
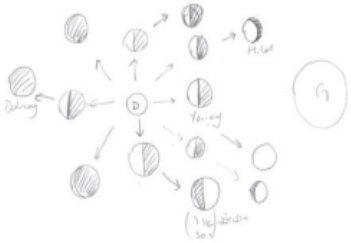
Participants	Activated Nodes	Explanations	Final Drawing
Aygün	Opposite phases Gradual change Completing cycle Observable	*It depends on time we observe since it changes. Firstly, a portion of the moon is bright. Then it became dark. I mean percentage of illuminated and dark part changes.*	
Ayça	Opposite phases Gradual change Completing cycle Illumination	*changes from new moon to full moon should be meaningful. According to my first model, while one part is illuminated, but suddenly it become dark. In the second drawing dark part of the moon changes gradually.*	
Aybilge	Opposite phases Gradual change Completing cycle Illumination	*I continuously tried to increase light and dark side of the moon. Light part of the moon continuously increases, and it will be full moon here. Then, dark side increases (silence a couple of seconds)*	

Table 4.5 (Continued)

Aykut	Opposite phases Gradual change Completing cycle	*From crescent to first quarter, then from first quarter to its widest phase full moon. After full moon, it becomes last quarter. Afterwards, it is again crescent. Like this, appearance changes as a cycle.*	

4.2.2 Changes on Reason for Different Moon Phases

Changes in their mental states may be two ways. Accordingly, they can completely change their previous explanation, or they can integrate new aspect of their previous explanation. On the other hand, there were pre-service science teacher who did not change their initial explanation. Four pre-service science teachers appropriately explained why we observe different appearance of the moon. Although they encountered problems while determining illuminated and dark portion of specific moon phases, they did not change mechanism of lunar phases during the interview. In addition, two pre-service science teachers also did not change their initial explanation although their understanding was not consistent with scientifically accepted view. The list of the pre-service science teachers who change their explanation and do not change their explanation were presented in the Table 4.6.

Table 4.6 Change in Explanation on Appearance of the Moon

Change their Explanation	**Not Change Explanation**	
Not Appropriate Explanation	**Appropriate Explanation**	**Not Appropriate Explanation**
Aytolun	Aybilge	Aybüke
Ayşıl	Ayfer	Aytaç
Aykut	Ayşin	
Aygün	Aysu	
Ayten		
Ayça		

Pre-service science teachers attempted to change their explanation since they did not feel comfortable with their previous explanation. Indeed, they sometimes noticed that their explanation could not cover some points of the phenomenon. Therefore, teacher candidates weaved in some new ideas in order to explain the phenomenon and tried to find a solution they encounter.

Aytolun initially explained phases of the moon via the orbit of the moon and angles of light receiving from the moon to the earth. Then she changed this idea and tried to find a new solution in order to explain phases of the moon during the interview. Figure 4.57 shows the path followed during the interview.

Figure 4.57 Change on Aytolun's Explanation during the Interview

It was detected that Aytolun construct four different dynamic mental states during the interview. The following excerpt showed that her initial explanation is shaped by the orbit of the moon and angle of light reflected from the moon. She explained;

Interviewer: Why do we observe different phases of the moon?
Aytolun: There should be deflection of light as a result of spin and orbit of the moon. For instance, if angle would be 90 degrees, it was new moon. While this angle reduces, appearance of the moon become first quarter. It may be full moon, if angle is zero.

It was revealed that she utilizes "angle" and "orbit" knowledge elements in order to explain phases of the moon. According to her idea, while the moon orbits, angle of light receiving to the earth also changes. Therefore, different phases appeared in the earth. After her this response, she was asked to elaborate her idea and to indicate the mechanism taking into account each lunar phase.

Aytolun: (while drawing Figure 4.58) Here is the earth. The moon orbits. In here, for instance, it is new moon. After reaching this point, it is first quarter. In here full moon and here it is last quarter. I think there is a figure in the course books. If it is ninety degrees in here, for example, it is a hundred eighty degrees… But we face the same face of the moon; Therefore, it is nonsense (while showing her recent drawing and explanation).
Interviewer: Could you explain why it is nonsense?
Aytolun: I want to consider again. (Silence a couple of seconds), The moon starts its orbit from this point. Reaching this point and since it rotates… It is related to refraction... it is because of refraction of light. The moon is here, and it is on the same plane with the earth. But... therefore, being on the same line has become a nonsense idea. The moon is visible or invisible in here or in there. New moon or full moon one of them here other is in there. First and last quarter may locate one of this location.

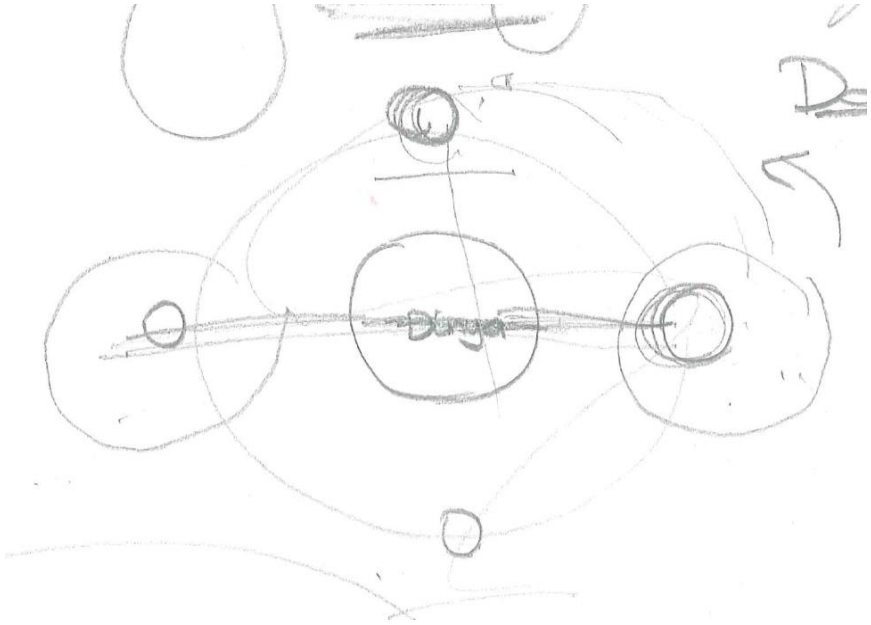


Figure 4.58 Aytolun's Drawing of Phases of the Moon

In the excerpt presented above, Aytolun tried to find out why do we observe different appearance of the moon. She inserted different nodes in her explanation and waved in these nodes. Although some part of her explanation was quite vague to analysis it, she firstly reminded a figure that appears in the science course books. Considering this figure, she engaged mode skimming. That is to say, she superficially referred to some elements such as "angle", "refraction" and "same face". She could not elaborate these ideas and could not present their linkage with the phases of the moon. However, she stressed that there may be the same figure with her diagram in the course book. This situation indicated that she tried to memorize and activate some mental dynamics originated from her formal education.

Many teacher candidates utilized nodes compatible with each other in order to explain phases of the moon concept. For instance, orbit of the moon, sunlight reflected from the moon, angle between the moon and the earth were common knowledge elements that usually preferred. Teacher candidates activated a set of these elements and try to explain phases of the moon. However, some of the pre-service teachers try to explain phases of the moon via beyond these consistent elements.

As explained preceding paragraphs, Aytolun tried to shift her previous explanation since she could not feel comfortable with it. To put it differently, her dynamic mental construct incorporated orbit of the moon and angle of the lights receiving from the moon lacks explaining phases of the moon. Therefore, she put away her previous explanation and considered Kepler Law as it seen in the following utterance and Figure 4.59.

> *While the moon orbits… The Kepler Law also is applicable for this situation. Its velocity and the area sweeped… I could not remember what exactly the theory contains. That is the sweeping area. I think it is not linked to its distance. It is because of refraction.*

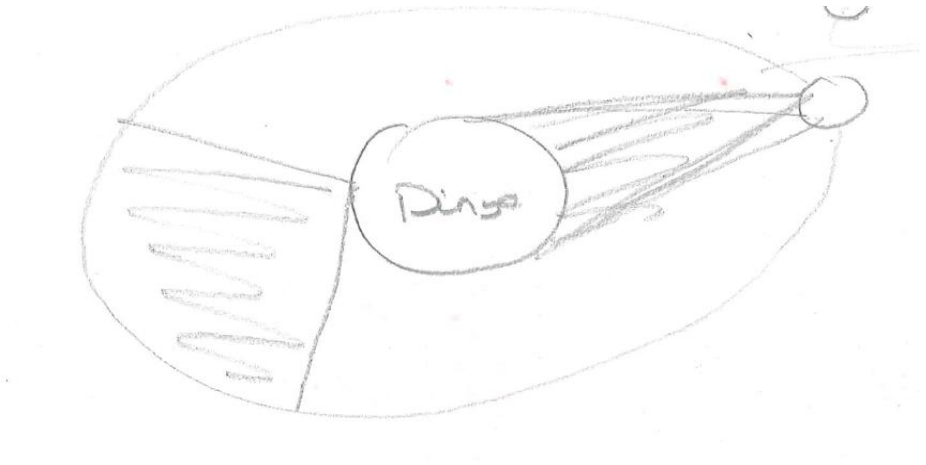


Figure 4.59 Aytolun's Drawing of Kepler Laws

Aytolun spent one minutes and thirteen seconds on Kepler Laws. More specifically, she just focused on the moon's sweeping area and change on distance between the moon and the earth. After this brief time period, she left these concepts and suggested refraction again in order to explain phases of the moon. Although it was not a clear, she most probably realized that she could not explain phases of the moon via of "sweeping" and "distance" nodes and noticed that "refraction" was more appropriate in order to explain phases of the moon.

As a consequence, there was no drastic changes of dynamic mental construct suggested by Aytolun. Finally, she organized her explanation via a set of consisted nodes an explained preceding paragraph. However, she still did not have

comprehensive explanation when we observe full moon rather than new moon or first quarter rather than last quarter.

Similar to Aytolun, dynamic mental construct of Aykut changed during the interview. Although these models have mutual characteristics, he suggested four different models in order to explained phases of the moon. The following figure summarize changes on ideas of Aykut pertaining to reason of phases of the moon during the interview.

Figure 4.60 Change on Aykut's Explanation during the Interview

Aykut considered distance as a factor for observing different phases of the moon taking into account his initial responses. He explained;
Interviewer: Why do we observe different phases of the moon?
Aykut: It is related to going close or away. It moves closer or away since the earth located horizontal axis. Therefore, there is no stable distance between the moon and the earth. Larger shapes occur when it is closer to the earth.

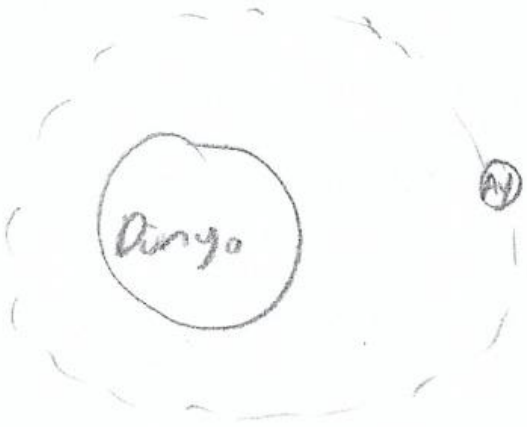


Figure 4.61 Aykut's Drawing of Orbit of the Moon

After this response, Aykut asked to draw a figure in order to explain phases of the moon. He drew Figure 4.61 and showed how distance change between the moon and the earth while the moon orbits. Considering his drawing, it was revealed that "horizontal axis" the expression in his previous utterance actually refers to

"horizontal orbit". The interviewer carried on prompt in order to elaborate opinion of Aykut.

Interviewer: Why do they close each other?
Aykut: Orbit of the moon is not circle. It is a circle, but not a perfect circle. I think there are some bending in its orbit because of gravitational forces. Therefore, it causes different views of the moon.
Interviewer: Alright, how do we observe the moon when it is close and far?
Aykut: It is full moon in location which is close to the earth. When it is far from the earth, it appears as first or last quarter. We can observe a small portion of the moon due to distance. But… I have just noticed… Why do we observe a small portion rather than viewing complete of the moon as small? (Slience about twenty seconds) I think it is related to not only orbit but also tilt of the earth.
Interviewer: How does earth's tilt influence appearance of the moon?
Aykut: As the earth has tilted axis, our angle of view does not cover the whole of the moon. Thus, we observe it as first or last quarter views. But while looking more suitable position, it can be seen as full moon.

As the above show, Aykut changed his dynamic mental construct. Although he initially considered that distance between the moon and the earth determined different lunar phases, then he noticed lack points of his explanation. Thus, he activated node of "tilt" which refers to the earth's tilted axis and integrated it to his dynamic mental construct. After these dialogs, the interviewer was asked to Aykut to draw how difference appearances occur. Aykut drew the following Figure 4.62 and explained phases of the moon considering this figure.

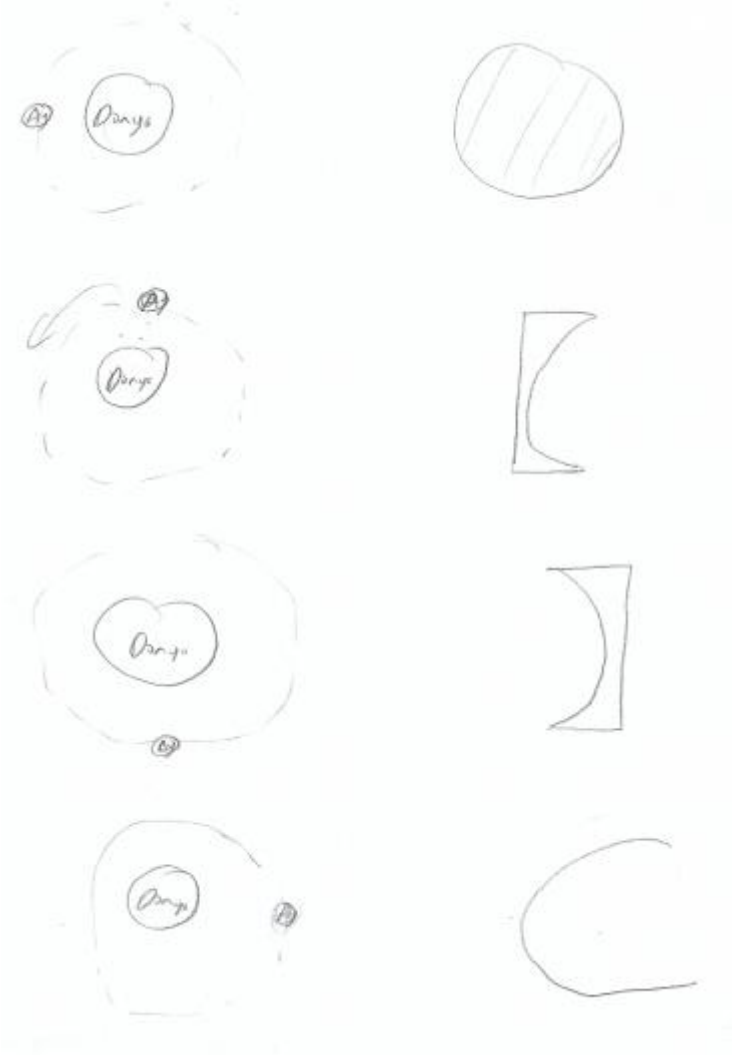


Figure 4.62 Aykut's Drawing of Phases of the Moon

Aykut: As I previously explained, different phases of the moon link to the orbit of the moon and tilted axis of the earth. The orbit of the moon is not perfect; therefore, it sometimes approaches and sometimes moves away from the earth owing to gravitational forces. It is full moon in the closest point and becomes full moon after first quarter. Last quarter position locates 180 degrees opposite of the first quarter. There is crescent moon somewhere between first and last quarter.
Interviewer: Why does it happen in this way?
Aykut: There is gigantic space between them. The moon already can be seen from the earth, but space between them changes drastically. Therefore, we can see full moon or crescent moon depending on distance.
Interviewer: How does appearance of the moon change depending on distance?
Aykut: It is also related to tilted axis. Both influence appearance.
Interviewer: What is their role?

Aykut: When we sum up two large number, the result equals a large number. Similarly, the sum of two small numbers equals a small number. Therefore, tilted axis of the earth and distance between the moon and the earth determine phases of the moon together.

Aykut located different phases of the moon while looking distance between the moon and the earth. Additionally, he considered that first quarter should confront last quarter. Although, he explained that tilted axis of the earth is one of the factors determine different phases, his drawing does not reflect role of tilt. there is no sun or sunlight symbol in line with his explanation.

In the next step, Aykut was provided three globes in order to model phases of the moon. He entitled these globes as the moon, the sun and the earth and he located the earth between the moon and the sun. Then, he tilted both the moon and the earth at almost the same angle. He stressed;

Aykut: It seems there is no influence of tilted axis of the earth on phases of the moon considering these models. It confuses me.
Interview: Why?
Aykut: Since I see these three-dimensional models, I visualize that the moon is also tilted. I imagined like that. I do not know what to do.
Interviewer: You may particularly consider each of phases. For instance, what would happen in full moon phases?

Aykut wrestled with this problem more than one minutes. During this period, he generally conceived orbital period of the moon and the earth. However, he suggested a different solution at the end of his consideration.

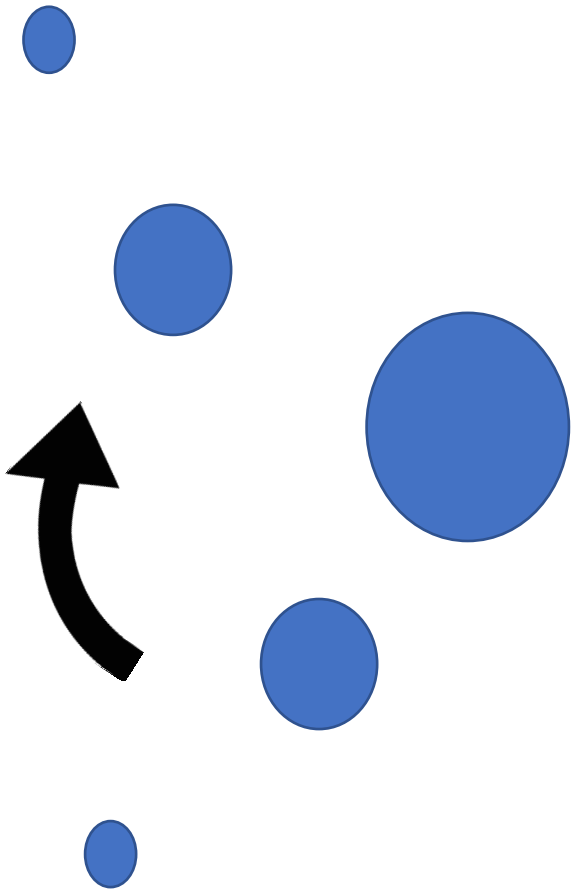


Figure 4.63 Aykut's Demonstration of Phases of the Moon

Aykut explained role of the location and distance on phases of the moon with using three dimensional models as represented in Figure 4.63. While the sun was stable, he changed location of the moon and the earth from position one to position two. In addition to this, he reduced distance between the earth and the moon. Interviewer continued asking question so as to reveal rationale behind this change.

Interviewer: Why did you change your previous opinion which you drew the figures?
Aykut: I could not think appropriately since it is abstract while drawing. However, after utilizing these objects, I noticed that role of tilted is questionable. I could not find any evidence taking into account model.
Interviewer: Why did you consider that tilted axis of the earth influence on phases of the moon?
Aykut: I thought that it influenced the part we seen in first and last quarter phases. However, it is logical to consider that tilt does not influence lunar phases.
Interviewer: So, could you show me again how to occur first and last quarter?
Aykut: First quarter and last quarter link to location rather than axial tilt. A person looking to moon see first quarter (pointing a point on the earth model and then rotate this point 180 degree), it is last quarter when this point comes here. (as portrayed in

Figure 4.63). This point is full moon. (Indicating a point which is shown in Figure 4.64 as C)

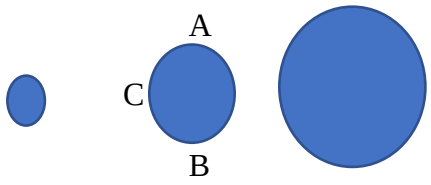
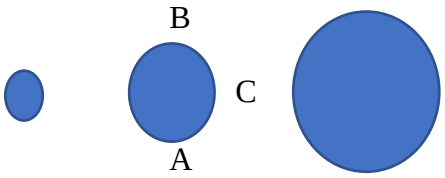
First Quarter (for point A)	*Last Quarter (for point A)*
	

Figure 4.64 Aykut's Demonstration of First and Last Quarter

Interviewer: there is equal distance between the moon and the earth in all your demonstrations.
Aykut: Because I had explained them, I did not mention distance again.
Interviewer: Could you explain again considering role of distance?
Aykut: I consider the moon approaches the earth in full moon phases. In case of phases first and last quarter, distance is not close and not away. Crescent moon far from the earth.
Interviewer: What would happen if an observer sees full moon but there is long distance among them?
Aykut: No way! Humm... It would possibly be full moon. We sometimes observe small full moon and sometimes big full moon. (silence a couple of seconds and then smiles). Therefore, it shows me that there is no linkage with distance.
Interviewer: So, what is the factor or factors that influence appearance of the moon.
Aykut: Phases of the moon, how can I explain. Our viewpoint. The place where we observe the moon. That is to say, location. Nothing else.

As it shown above utterance, firstly Aykut changed his opinion regarding axial tilts after his experience on three dimensional models. Then, another change was occurred after further questions directed by interviewer. It is plausible to consider that these changes occur due to lack of stable mental state of Aykut regarding phases of the moon. Namely, he constructed mental state regarding phases of the moon during the interview. Therefore, dynamic of the interview process and provoking questions of the interviewer encouraged him to change his dynamic mental construct.

Ayça indicated that orbit of the moon, illumination of the moon and shadow determine phases of the moon. However, her explanations and mental state changed during the interview. Figure 4.65 summarized how dynamic mental construct of Ayça changed during the interview.

Figure 4.65 Change on Ayça's Explanation during the Interview

Following excerpt shows consideration of Ayça at the beginning of interview. She stressed;

> *Ayça: The moon revolves around the earth. Depending on its different location, for example here is the sun and the earth is there (gesturing different positions with her hands), while the moon revolves. The new moon is appeared, it is between the earth and the sun. Then, it moves away, it appears as first quarter, full moon and last quarter.*
> *Interviewer: Where does the moon move away from?*
> *Ayça: While moving away from the sun and revolving around the earth, depending on the sunlight receiving it and shadowing, we observe different phases of the moon.*

It was revealed that Ayça activates three nodes as "orbit" "illumination" and "shadow". Firstly, she considered different appearance of the moon was visible due to changing location of the moon around orbit of the earth. However, she integrated "shadow" and "illumination" nodes to her second explanation, since she most probably noticed that revolution of the moon was not enough to appropriately explain phases of the moon.

After her this explanation she was asked to explain each of the phases separately. Firstly, she drew Figure 4.66 and considered why we observe the moon as new phases. While considering, she noticed that shadow concept is not appropriate in order to explain new moon as seen following dialog.

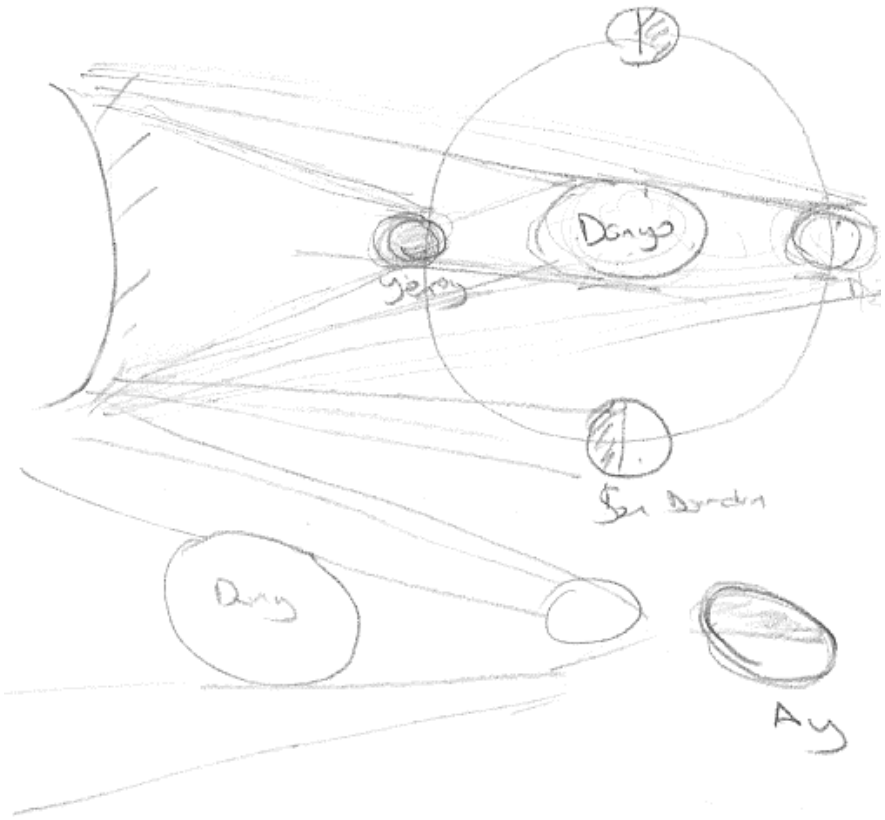


Figure 4.66 Ayça's Drawing of First and Last Quarter

Interviewer: Could you explain how all these different moon appearances are occurred?
Ayça: As I drawn (Figure 4.66), while the moon revolves around the earth, we see it (the new moon position) as dark because of shadow of the earth. Do we see it as dark since the moon shades it...
Interviewer: Are there any points in your explanation that is not satisfy you?
Ayça: According to my explanation, if shade it in that position (new moon) we never see the full moon. The moon completely shades it because the earth is bigger, and the moon is smaller comparing the earth. Therefore, the moon must be completely dark in its full moon phases. Therefore, there is no shade of the earth on the moon.
Interviewer: Alright, why do we see as dark in new moon position?
Ayça: It may be related that… There are many sunlights coming from the sun. These sunlights may scatter. Because of scattering, the earth does not receive any sunlight. The moon's own light cannot reach the earth.
Interviewer: How does it happen?
Ayça: Because of wavelength. The red has the longer, therefore, we must see the moon as red… hımm... But there is a something... We already observe the moon as red. We see it as red in the lunar eclipse and the moon and the earth does not locate at the same plane while revolve. If they are in the same plane, we observe lunar eclipse. Since they are not at the same plane we could not see as red. We see it black.
Interviewer: Could you repeat what happened the sunlight coming from the sun?
Ayça: I am questioning considering lunar eclipse. Sunlight coming from the sun have different wavelength. Blue and purple scattered; therefore, we could not see them. So,

I questioned why we do not see the moon as red. Then, because of the moon and earth are not located at the same plane, we could not see it as red. If they locate at the same plane, we see the moon as red. Since they are not located at the same plane, there is no sunlight receiving from the moon. That is the reason why we observe the moon as dark.
Interviewer: What if they were at the same plane, what would happen?
Ayça: If they were at the same plane, we would observe it as red, which is lunar eclipse. Lunar eclipses occur when the moon locates between the sun and the earth. When they are at the same plane, some of waves as blue, purple scatter, the earth receives red wave. Therefore, we observe the moon as red.

As previously stressed, Ayça activated three nodes in order to explain phases of the moon as "orbit", "illumination" and "shadow". However, while explaining new moon position specifically, she realized that she cannot explain phases of the moon via shadow. She considered if the new moon was occurred because of the shadow, we would not observe full moon due to shadow of the earth. To put it in different way, we would observe dark instead of full moon in such a case. Thus, she ignored role of the shadow and considered another way in order to explain phases of the moon. Then, she advocated that sunlight scatters; therefore, we could not observe the moon. However, there were one more additional problem for Ayça. Sunlight includes different light which have different frequencies. It is possible to scatter for high frequency light such as blue and purple but not possible for low frequency light such as red. According to her idea, we should observe the moon as red color. To reach consistency, she stressed that the moon and the earth generally locates in different plane. It was logical for Ayça since they are in different plane, therefore, the earth would not receive any light from the moon. To sum up, although she listed "orbit", "illumination" and "shadow" as a reason for phases of the moon at the beginning of the interview, she changed this idea while explaining new moon phases. She passivized "shadow" node and activated "scattering" and "plane" nodes.

After her explanation regarding new moon phases, she asked to clarify full moon phase. She explained full moon by activating the same nodes with new moon explanation. However, role of knowledge elements changed in her new explanation. For instance, scattering has trivial role in order explain full moon phase. Following excerpt show explanation of Ayça regarding full moon.

Ayça: There is also no shadow effect for full moon. We observe it as illuminated. Sunlight receives to the moon. Since these three objects (sun, earth, moon) are not at the same plane, we observe it as full.
Interviewer: Can you explain why we observe full moon in-detail?
Ayça: I mean that the sun is very big. (pointing above and below of the earth) sunlight receive the from these ways. The earth cannot block. Therefore, we can observe full moon. Sunlight can reach the moon without scattering. They absolutely scatter but they can reach the moon; therefore, we can observe as full.

Ayça did not utilize "scattering" and "plane" nodes rest of the interview process regarding phases of the moon. She firstly explained waxing crescent, waxing gibbous and first quarter while utilizing "orbit" and "illumination". To illustrate, she explained waxing crescent;

Sunlights can illuminate this part of the moon (pointing crescent). Rest of it could not. Actually, sunlights could not reach all part of the moon.

Ayça explained first quarter and waxing gibbous considering the same perspective with waxing crescent. She pointed specific part of the moon and stressed that this specific part received sunlight. According to her idea, only visible part of the moon referred to illuminated part of the moon. However, she faced with a problem while considering last quarter, waning crescent and gibbous moons. This problem was originated from her circle diagram, which was presented in 4.48 circle diagrams. As aforementioned, she drew different appearance of the moon around the earth while the sun illuminated the moon. Namely, she combined earth based and space-based perspectives in her diagram. Different appearance of the moon referred to earth based since it is corresponded what we observe from the earth. In addition, position of the sun, earth and moon and sunlight reflected space-based perspective. Due to combination of these two different perspectives, she could not explain why illuminated part of the moon change comparing first quarter and last quarter. According to her idea, dark part of the moon also received sunlight, which is shown as Figure 4.67. Therefore, the dark part should be illuminated.

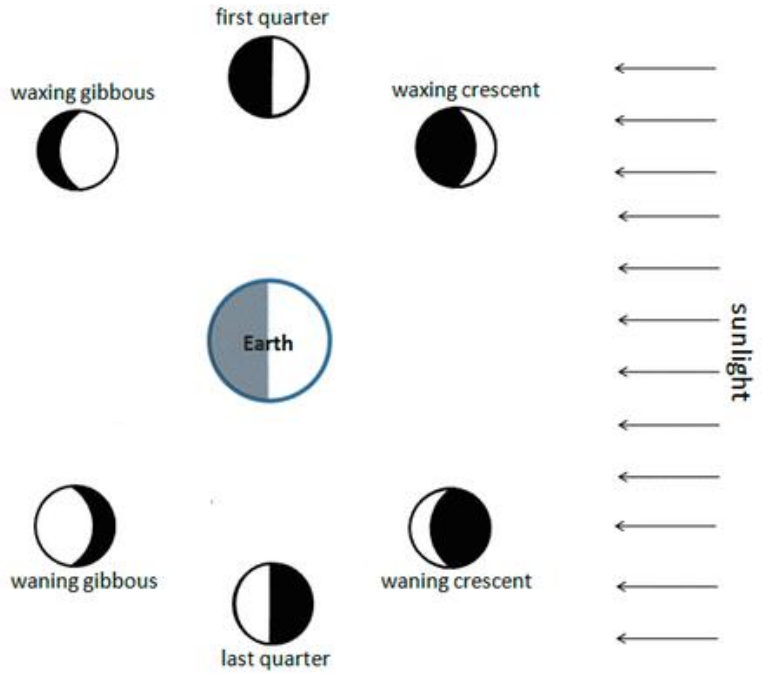


Figure 4.67 Combination of Earth and Space Based perspectives

She could not propose any mechanism that explain appearance of waning crescent, waning gibbous and last quarter. She stressed;

> *I am not sure regarding last quarter. I do not know why these parts are dark. I could not explain last quarter and others. Since sunlight comes from this direction, these parts (pointing dark part of the last quarter, waning gibbous and waning crescent) should also be illuminated. I do not know what the reason for this darkness is.*
> *Interviewer: what may be reason for this darkness?*
> *Ayça: These parts may be illuminated by another celestial body. Other stars… But they locate so far. Comparing the sun, their light is not able to illuminate…. I could not explain why these parts are dark. I do not have any idea.*

Next step of the interview, Ayça was asked to demonstrate each of the phases of the moon via using models. She noticed that only half of the moon can be lightened by the sun while explaining full moon. Previously, she stated that specific part of the moon received sunlight while orbiting around the earth. In addition, she added we observe these specific illuminated parts as different phases. The idea of illumination half of the moon was not consistent with her previous explanation. She considered why we observe crescent, gibbous and quarter moons although half of the moon was illuminated by the sun. She utilized two new knowledge elements in her explanation as shown in the following utterance.

Interviewer: Can you explain why we observe waxing crescent via using these models?
Ayça: This part is light. Rest of it is dark. (silence a couple of seconds). I think the moon can reflect rays only receiving this illuminated part. I observe as crescent moon since rays reflected from the other part is not enough. For instance, if I vertically exposed a lamp to a point, it would be illuminated perfectly. But if lamb was tilted, illumination would reduce some parts of this point. Actually, since the moon is tilted, only crescent part of it perfectly is illuminated. Rays receiving rest of it is not enough to reach to the earth.

As seen in the utterance above, she utilized two knowledge elements as "reflection" and "tilt" in order to explain phases of the moon. She considered that since the moon tilted only specific part of the moon reflect sunlight to the earth. This specific part determines appearance of the moon that is observed from the earth.

Aygün jointed new aspect of their explanation after interviewer directing new questions. Characteristics of his response is that he feels comfortable with their explanation; therefore, he prefers jointing rather than complete change of their explanation. Although his explanations have rationale, there were lack of coherence. Aygün was not aware of coherence problem of his explanations towards different questions.

Aygün explained considering shadow concept so as to explain why we observe phases of the moon. According to him, there is a shadow area between the moon and the earth, and phases were determined considering the part of the moon in this area. He says;

Interviewer: Why do we observe different phases of the moon?
Aygün: Why do we observe different phases of the moon? It is related to position of the earth and the sun. (drawing), Suppose that the earth is here, this part was lighted up by the sun (indicating half of the earth facing to the sun). This part is dark part (indicating other side). We observe the moon in daytime. We receive reflected lights from the moon. For example, when this part of the moon inside shadow of the earth, we cannot see this part.

Afterwards, Aygün was asked to show each of the phases in his drawing. He located different phases as it seen in Figure 4.68.

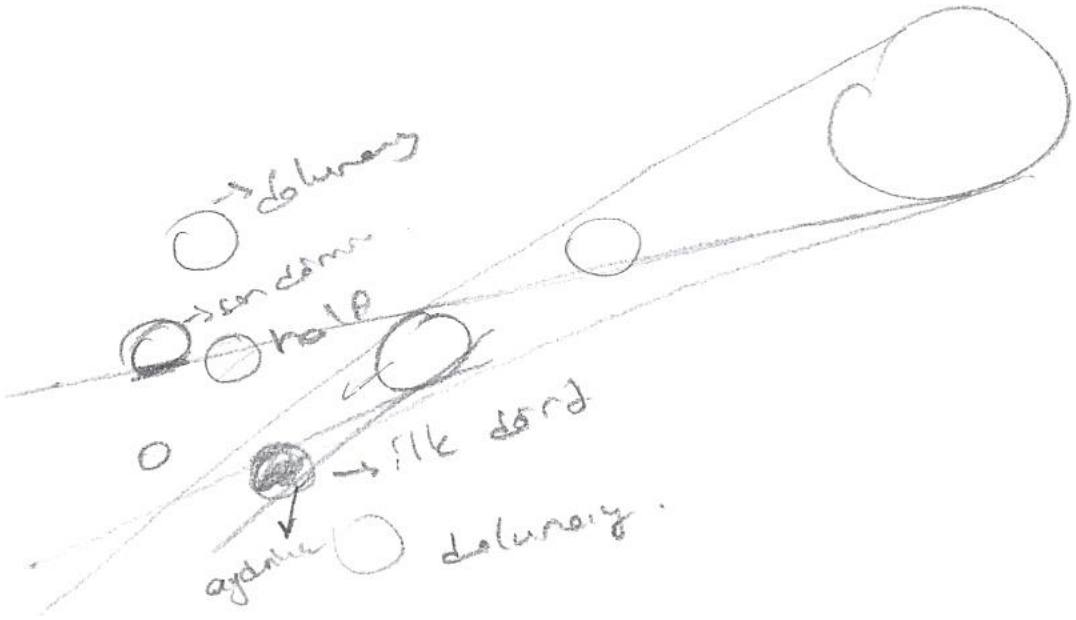


Figure 4.68 Aygün's Drawing of Phases of the Moon

As it can be seen also his drawing, he considered that the moon was visible only at nights. In addition, there was no new moon and crescent moon phases in his diagram. He expressed when the moon located between the sun and the earth and the earth located between the moon and the sun, we observe the eclipses.

Afterwards, interviewer asked whether we observe the moon in daytime. Despite his previous explanation, he explained that the moon can be visible in daytime as seen following utterance.

Interviewer: Is the moon visible in daytime?
Aygün: Yes, it is. But not midday. Mostly in mornings. Generally, with its crescent phases since the sun illuminated small fraction of the moon's body. Or half-moon. But I could not remember that the moon is full.
Interviewer: But you stressed that there was a shadow area and phases of the moon was determined considering it.
Aygün: Daytime… I want to indicate. (taking the three-dimensional models and order them as it seen in Figure 4.50)
Aygün: The lighted part of the moon was limited. Due to its own shape, these parts are dark (indicating part of the moon could not receive sunlights). Even in this position (second picture).
Interviewer: How would we observe the moon?
Aygün: For this (second figure), it is mostly half-moon. And for this (first figure) it is crescent.
Interviewer: what would happen at night?

Aygün: These are for daytime. It is different for night. We observe phases due to shadow of the earth. It is seen in daytime since the sun illuminates but night because of shadow.

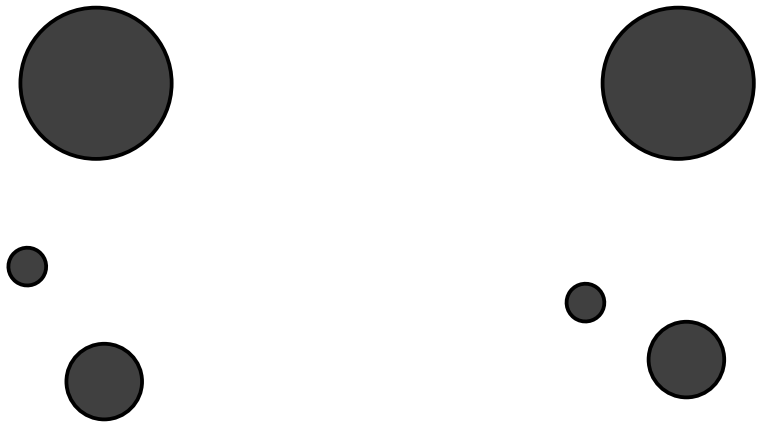


Figure 4.69 Aygün's Demonstration of Phases of the Moon

As the above utterance and the Figure 4.69 shown, Aygün most probably considered that the moon was visible depending on his observation. Therefore, he proposed a model in order to explain it. After previous explanations reminded him, he embraced the both these opinion without any confusion. It seems that he did not aware of discrepancies between these ideas and potential problems of his explanation.

4.2.3 Role of Three-dimensional Models

Pre-service science teachers may activate different nodes due to potential influence of three-dimensional models. Therefore, they may propose different explanation different from explanation while drawing. To illustrate, following utterance showed Ayten's initial idea regarding phases of the moon.

Interviewer: Why do we observe different phases of the moon?
Ayten: It is... For instance, movement of the earth. Sunlight illuminates this dark part of the moon. For instance (drawing left side of Figure 4.70), I am here (point on the figure of earth), I observe crescent moon with this perspective. This is related to it. It is related what extend of light coming from the sun is observable from the point I locate.

Ayten explained phases of the moon considering “illumination” and orbit “nodes”. However, she could not explain each appearance of lunar phases. She initially explained why we observe crescent moon. Then she drew diagram regarding half-moon. But she could not be sure whether her diagram refer to half-moon and full moon.

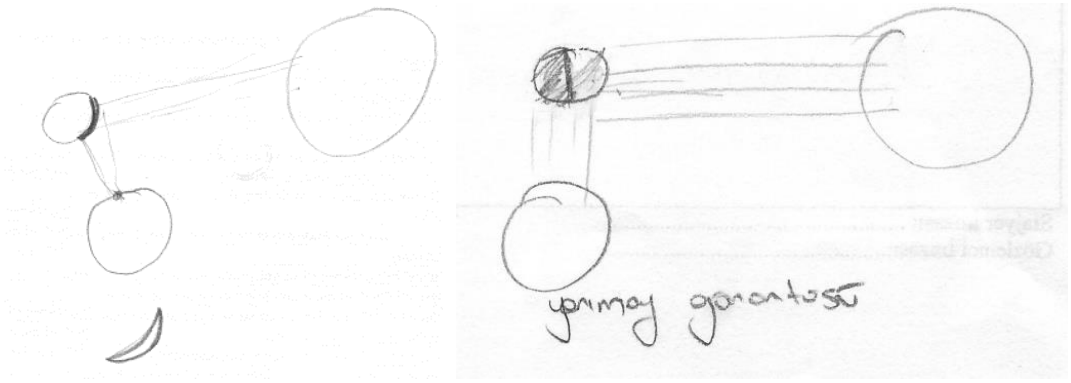


Figure 4.70 Ayten’s Initial Drawing of Phases of the Moon

As it also seen Figure 4.70, She arrange the moon/sun/ earth almost with the same arrangement and stated these arrangements may be related crescent, half-moon and full moon respectively during the interview. It was revealed that she is confused how appearance of the moon change in its orbit of the earth. However, three-dimensional objects were provided to her, she considers the same phenomenon about five minutes and proposed a model dominated by day/night.

It was plausible to consider that three dimensional models triggered activation day/night node. In other words, she noticed that half of the earth is day, while the other half is night via three-dimensional model. She concluded that the moon is observable for night side of the earth and location of the moon in its half orbit determine lunar phase.

Ayşıl ideas and explanation also explicitly showed how three-dimensional models influence their response. Initially, she explained phases of the as a result of some factors including orbit of the moon, angle of sunlight, earth’s tilted axis of rotation. She explained;

Interviewer: Why do we observe different phases of the moon?
Ayşıl: Sunlight arrive at the moon. Considering the optics, it arrives with different angle. Because of the shape of the earth is not constant.
Interviewer: What is the shape of the world?
Ayşıl: Location of the earth is not constant. Its position around the sun, position of the moon around the earth and its own tilted shape… All these influenced appearances of different lunar phases. Sunlight reaching the sun. Since the incidence light must equal to reflected light… It is because… For instance, a specific part of the moon reflects its light to us. In optics, light from an object should arrive at our eyes in order to see it. We see the part of the moon that we receive its light.

Ayşıl explanation was highly dominated by "reflection" node. She mainly considered light reaches us from the moon in order to explain phases of the moon. In addition, she also activated" tilt", "angle", "rotate" and "orbit" nodes. However, she could not explain each of the moon phase considering these nodes. She initially drew Figure 4.71 and Figure 4.72 to show full moon and new moon phases. The she explained,

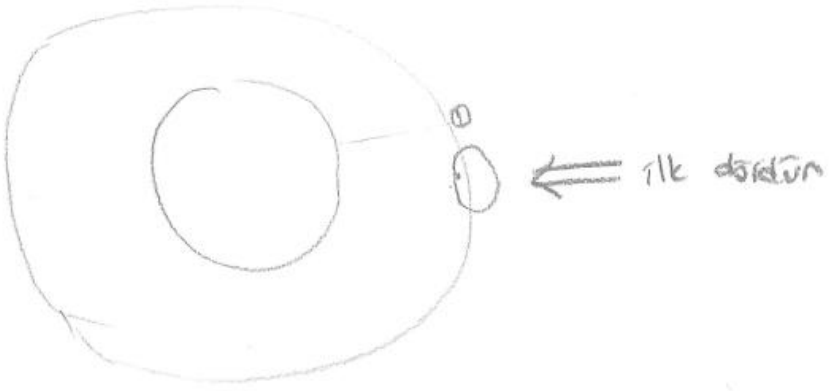


Figure 4.71 Ayşıl's Drawing of First Quarter

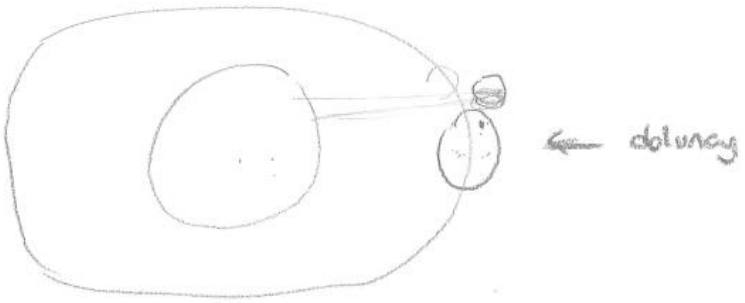


Figure 4.72 Ayşıl's Drawing of Full Moon

Ayşıl: I could not draw rest of it. I could imagine where to look. Where am I? How am I looking? Where is the moon? I am sure that the first figure is first quarter. (pointing first quarter shape), I am here, and the moon is there, sunlight should illuminate half of the moon in order to observe the complete moon.
Interviewer: Alright, what is the difference your first and second drawing?
Ayşıl: position of the sun and the earth are constant. But position of the moon is different. Different part of the moon receives sunlight.
Interviewer. Where is the moon in these shapes?
Ayşıl: It located at right side comparing the first shape. But it is at the same orbit. It is also depended on some other factors. Observer in here (point in Figure 4.71) looks only quarter part of the moon. But, the observer there (Figure 4.72) have an angle, which observe complete moon. Position of the moon and the earth, and our location determine. The moon is observed differently from the different location in the earth.

Ayşıl activated "location" while try to explain differences among difference appearance of the moon. In addition, she did not consider axial tilt of the earth and distance between the moon and the earth, which shows that she disactivates "tilt" and "distance" nodes. She also changed her explanation after provided three-dimensional models. She stressed:

All these celestial bodies have position at the same line (she located the earth between the sun and the moon). It is more logical… I consider different appearance of the moon… I've found it. Humm… Since this part of the earth could not receive sunlight, it is night. Other side is day. A person from this side (faces to the moon) of the moon never observe the moon. Because, the earth blocks the moon. None of the sunlight reach the moon. The moon is smaller than the earth. The earth covers the place the moon locates. After slight movement of the moon (she moves the moon right side in its orbit), it receive light. Therefore, we observe crescent. Sunlight have angle. While it moves, I observe increase of crescent shape. It becomes thick. It is more logical. I considered that the moon is invisible when it is between the earth and the moon.

Three dimensional models highly influence Ayşıl's idea regarding phases of the moon. She underlined that they ensure her produce more rational explanation. As

seen from the previous utterance, she activated “shadow” node via three-dimensional models. Therefore, she argued the moon would be invisible due to block of the earth instead of our location in the earth.

Considering changes of Ayşıl’s and Ayten’s expression during the interview, it is plausible to conclude that three-dimensional influence pre-service science teachers’ expression. They activated different node and disactivated some other nodes they initially utilize. However, pre-service science teachers’ final explanation on phases of the moon was also inconsistent with scientific expression. In other words, three-dimensional models did not contribute to quality of their explanation.

In addition to activation of new nodes, three-dimensional model contributes to elicit pre-service science teachers’ dynamic mental construct more clearly. Accordingly, some pre-service science teachers stressed that they can explain more easily phases of the moon comparing drawing. For instance, Aysu explained;

> *What I mean revealed when I use models. However, it does not happen while drawing. (While using three-dimensional models) I could not observe illuminated side of the moon in this position. While it revolves, this side (right) receives sunlight and I observe crescent since it has round shape. In this position, this side is illuminated; therefore, I observe it as first quarter. Then, illuminated part of the moon increases. In this position (full moon), I observe all the moon. Although its right side is illuminated, now lefts side is illuminated (last quarter). I can show them, but I could not draw them appropriately.*

As stated by Aysu, they can explain phases of the moon more clearly by using three-dimensional model. It is plausible to consider that pre-service science teachers encountered difficulties while transforming their conceptual understanding to two-dimensional from. Therefore, three-dimensional models made easy to explain phenomenon for pre-service science teachers.

4.3 Summary of Findings

The present study showed that pre-service science teachers participated in the current study have fragmented knowledge pieces regarding phases of the moon concept. Pre-service science teachers tried to construct a model in order to explain phases of the moon during the interview. Pre-service science teachers activated

among nodes such as “completing cycle”, “gradual change”, “opposite phases”, “observable” and “illumination” while explaining sequence and appearance of the moon. Explanation of pre-service science teachers who ignored inconsistency in their explanation suggested relatively stable explanation. There was only minor change happened these explanations during the interview. On the other hand, some pre-service science teachers changed their explanations as soon as they realized inconsistency or felt uncomfortable for their explanation. These explanations were entitled as relatively dynamic explanations.

There were variety of different dynamic mental construct that was revealed during the interview. Activation of different type and number of nodes by pre-service science teachers caused detecting different dynamic mental construct. However, a total number of six dynamic mental constructed detected as “orbit dominated”, “shadow dominated”, “location dominated”, “angle dominated” and “scientific explanation” considering dominate node of dynamic mental construct. Participants of the current study changed their explanation during the interview. They generally activated new nodes or inactivated some nodes instead of complete change of a group of nodes.

It was revealed that pre-service science teachers’ spatial abilities highly shape their responses on phases of the moon. More specifically, pre-service science teachers’ geometric spatial ability, changing frame of reference (earth-space based perspectives), spatial transformation and spatial projection ability obstructed them from explaining phases of the moon more accurately. In addition, pre-service science teachers lack systematic observation regarding the moon. For instance, they did not observe daily and monthly movement of the moon. They also did not have clear perspective when the moon appeared and disappeared, whether or not it appears in daytime. Thus, their lack of observational knowledge limited their explanation on phases of the moon.

Pre-service science teachers attempted to explain phases of the moon via some astronomy and physics rules or phenomena, which is not directly related to

phases of the moon. This situation indicated that pre-service science teachers limited understanding regarding some physics and astronomy issues. Therefore, they activated unrelated knowledge pieces while explaining phases of the moon.

CHAPTER 5

DISCUSSION

The last chapter of the current study contains discussion of findings, conclusions and implications for further research studies. Findings were reviewed and discussed in the light of previous studies regarding conceptual change theory and astronomy education.

5.1 Conclusions and Discussions of the Findings

The current study was grounded on knowledge of pieces perspective. The essence of this perspective is that intuitive knowledge is constituted by many independent knowledge elements. This perspective is quite different from some other popular conceptual change paradigms such as knowledge as theory (Carey, 1985) and ontological view (Chi, 2005; Chi & Slotta, 1993) with respect to structure of intuitive knowledge. According to knowledge of theory perspective, intuitive knowledge is coherent structure, which resembles a scientific theory. On the other hands, concepts should be placed appropriate ontological categories with respect to ontological paradigm. Therefore, conceptual change referred to change of ontological categories of concepts for this perspective. Since the current study was grounded on knowledge of pieces perspective, it was not aimed to examine ontological categories or coherent mental structures that pre-service science teachers have.

This study intended to reveal pre-service science teachers' knowledge pieces which are referred to nodes on phases of the moon. Findings showed that pre-service science teachers have fragmented knowledge pieces rather than coherent structures. Pre-service science teachers activated variety of nodes while explaining different appearance of the moon, movement of the moon and other associated issues. These pre-service science teachers tried to construct a model in order to explain topics related to phases of the moon via these nodes during the interview process. On the other hand, four of pre-service science teachers immediately responded initial interview question without any confusion. Their also responses had confident tone.

According to Sherin et al., (2012), individuals may have more constrained mental construct by some specific nodes regarding an issue. Their experience regarding the issue or recalling all or some part of the issue may cause this situation. Therefore, these four pre-service science teachers have more constrained mental construct regarding phases of the moon comparing other participants. They may consider phases of the moon in depth or considerable experience.

Pre-service science teachers explained phases of the moon via dynamic mental constructs including "shadow", "location", "angle" nodes besides "orbit", "illumination", "half" nodes. In other words, they activated both related and unrelated nodes for explaining phases of the moon. In the current research, pre-service science teachers' responses which is not consistent with scientifically supported idea were not entitled as misconception. In consistent with the knowledge in pieces perspective, these ideas were perceived as a contributor for sophisticated understanding (disessa, 2017; Parnafes, 2007). As aforementioned, since structure of unitive knowledge is perceived among different conceptual change perspectives, their role of learning is also different. According to knowledge of theory and ontological perspective, students' unitive knowledge is obstacle for their learning. Therefore, initial knowledge of individuals should be replaced or confronted (Larkin, 2012). However, according to knowledge of pieces perspective, intuitive knowledge was perceived as positive resources for learning (disessa, 2017; diSessa, 2014b). Knowledge pieces that students possess before teaching contributes construction of new conceptions. Following footstep of this idea, it was concluded that difficulties pre-service science teachers encounter was related to organization of nodes. In other words, pre-service science teachers should reorganize their existing knowledge elements to have more sophisticated conceptual understanding. However, reorganization may not be easy to apply since it is dependent on context, characteristics of intuitive knowledge and connection among knowledge elements (Ozdemir, 2013). Thus, pre-services science teachers should aware of their existing problems regarding their own conceptual structure and they attempt to solve these problems.

Previous research studies regarding phases of the moon have attempted to develop conceptual understandings of pre-service science teachers by engaging them in constructive activities (Bell & Trundle, 2008; Ogan-Bekiroglu, 2007; Trumper, 2006a; Trundle, Atwood, & Christopher, 2006; Trundle & Bell, 2010). These studies attempt to change pre-service science teachers' conceptual understandings via series of activities which require long time period. In addition, some teaching activities required using technological materials which are generally not easily accessible or affordable. As it was shown in the current study, sophistication of pre-service science teachers' explanation pertaining phases of the moon was related to reorganization of existing knowledge elements. More specifically, the barrier to construct more sophisticated understandings on phases of the moon does not depend on knowledge elements' presence or absence. Therefore, pre-service science teachers should be motived to consider their understanding regarding phases of the moon. They should explore lack points and inconsistencies of their explanations in different context. All the activities and teaching modules designed for them should aim to encourage them to ask question regarding their own ideas and observations.

Many studies (Hobson, Trundle, & Saçkes, 2010; Öztürk & Ucar, 2012; Trundle et al., 2002, 2007a) exploring individuals' understanding on phases of the moon generally includes a couple of steps. Initially, Researchers analyzed responses of the individual considering a coding schema. Then, type of codes examined. Finally, individuals' understandings on phases of the moon categorized as scientific, unscientific or some other categories between these two categories. Learning corresponded to change of categories from unscientific to scientific. Possible change of pre-service science teachers' mental construct during the interview and their attempts to enhance their initial explanations during the interview were ignored in these studies. However, the current study showed that pre-service science teachers' conceptual understanding was dynamic and has potential for change during the interview. As shown in findings section, pre-service science teachers may suggest ideas regarding phases of the moon in different time points of the interview. For instance, pre-service science teachers explaining full and new moon with blocking node, activated "angle" node while explaining gibbous and crescent moons. In a

similar vein, although some pre-service science teachers explained first and last quarter moon activating “orbit”, “half” and “illumination” nodes, they integrated “blocking” node to this conceptual system while explaining new and full moon. The current study showed that categorizing of pre-service science teachers’ understanding regarding phases of the moon is not meaningful since their mental construct may be dynamic. Therefore, according to perspective of the current study, determining activated nodes and linkage among the nodes in their context may be more appropriate for tracking pre-service science teachers’ understandings.

The current study was conducted in order to portray the mental construct of pre-service science teachers in short time scale without any learning support. However, it was revealed that pre-service science teachers also changed their initial explanation during the interview process without any explicit manipulation. This situation showed that the context of a clinical interview holds a potential for pre-service science teachers to reorganize their own knowledge elements. Therefore, design of the present study has instructional implication for teaching phases of the moon. It plausible to consider that interview questions contributed to improve pre-service science teachers’ awareness towards phases of the moon. In the current research pre-service science teachers were asked to explain why we observe different phases of the moon. Then, they were asked to explain each of the moon phases separately. While explaining, inconsistencies were appeared. For instance, pre-service science teachers may explain new moon phases via shadow dominated modes while first and last crescent moons explained by reflection, angle dominated modes. Some of these conflicts were detected by pre-service science teachers during the interview. Interviewer also attracted attention to inconsistencies of pre-service science teachers’ explanations and provide opportunity for pre-service science teachers to reconsider their explanations. They tried to modify their initial explanation in order to eliminate deficiencies they detected. However, pre-service science teachers could not suggest more sophisticated explanation regarding phases of the moon although they aware of deficiency of their explanations. This is most probably because pre-service science teachers do not possess additional sources which help them reorganize their knowledge elements.

There were also pre-service science teachers who did not change of their explanation on different appearance of phases of the moon. Four of them had explained mechanism of lunar phases consisted with scientific view. They only encountered difficulties which may stem from their spatial abilities. For instance, they generally confused waxing and winning crescent moon while drawing diagrams. In addition, all these pre-service science teachers were senior and, high or medium engagement. Aysu and Ayşin had high level teaching engagement. Aybilge had high level and Ayfer had medium level astronomy engagement. Therefore, it was plausible to consider that pre-service science teachers' engagement on astronomy or astronomy engagement may positively contribute to organization of their conceptual structures. However, astronomy engagement and astronomy teaching engagement are not guarantee appropriate understanding of pre-service science teachers. To illustrate, although Aygün and Aydan had medium level astronomy engagement like Ayfer, their conceptual understanding on phases of the moon was not consistent with scientific explanation. On the other hand, two pre-service science teachers did not change their initial explanation although their explanation was not sophisticated. Both pre-service science teachers had different characteristics. Aytaç acknowledged that he was not have enough information after his initial responses. He underlined that he was unsure whether or not his responses are correct. Therefore, he could not concentrate on modifying his initial responses. On the other hand, Aybüke confidently responded initial interview questions. Her confidence prevented her from considering lack points of her responses. In conclusion, pre-service science teachers' confidence on their response have potential to influence on their dynamic mental construct. Pre-service science teachers who change their initial responses was not confident or unconfident.

Some speculation can be made how science teachers should teach phases of the moon to middle school students taking into account findings of the current study. It was revealed that quality of pre-service science teachers' explanations was related to organization of their knowledge pieces obtaining from formal and informal learning experiences regarding phases of the moon. Unsurprisingly, studies sampling middle school students (Parnafes, 2012; Sherin et al., 2012) also showed that these

students have daily life experience and engaged in informal science learning activities on astronomy issues. Therefore, middle school students easily constitute dynamic mental construct via knowledge elements obtained from their experience. For instance, Parnafes, (2012) showed that middle school students improve quality of their initial explanations by realizing details and limits of their explanations. Specifically, it is stressed that middle school students also attain more sophisticated level of understanding by reorganized their initial explanations by their own attempt. Science teacher should also provide opportunities to students to examine their own explanation regarding phases of the moon. Teachers should be aware of that presenting or offering better explanation concerning students' problem would not be helpful in order to have sophisticated understanding regarding phases of the moon. In the current study, it was observed that pre-service science teachers' awareness towards phases of the moon increased as a consequence of interview questions. Pre-service science teachers focused on interview question that they could not responded appropriately. Therefore, science teachers can utilize questioning technique as a way to improve their students' awareness. Group discussion can be an effective way for students learning. Students may activate and organize their knowledge pieces by the help of interaction among students.

Context is important component for knowledge in pieces perspective. Activation of knowledge elements were highly influenced by context. It was suggested that students should activated knowledge pieces in different context in order to have more sophisticated and stable understanding (diSessa, 1993). Therefore, different context should be provided for students while instructing on phases of the moon. In addition, pre-service science teachers should be equipped with skills in order to present the same phenomena with different context. For instance, Ucar, (2008) presented phases of the earth context for pre-service teachers. In that study, pre-service teachers attempt to explain how the earth appears while looking from the moon. It may be effective practice since the same knowledge elements should be activated for explaining both phases of the earth and phases of the moon. Moreover, examining phases of the Venus and Mercury may be another effective way to have sophisticated understanding. Both pre-service students or middle school students can

forecast appearance of the Venus and Mercury taking into account mechanism of phases of the moon.

Having fragmented knowledge structure is most probably related to pre-service science teachers' experiences. Firstly, phases of the moon and associated topics have potential to present rich daily life experience and informal learning opportunities. As noted previously, pre-service science teachers participated to current research had daily life experience such as unsystematic observations of the moon and solar/lunar eclipses. In addition, they stated that they are interested in news regarding astronomy issues in social and visual media, visited science museums and observatory, and watched documentaries. In brief, pre-service science teachers may obtain different knowledge elements through daily life experiences and informal learning environment. Secondly, pre-service science teachers also attended lectures which corresponds to formal education. They stressed that they pursued astronomy course when they were in middle school. Furthermore, they enrolled in undergraduate astronomy course. All these courses contain phases of the moon and topics related to the moon. However, it was revealed that these courses did not support pre-service science teachers to design constrained mental structure regarding phases of the moon. It is plausible to consider that pre-service science teachers were not aware of their own conceptual structures and they could not establish a linkage among the related nodes that they gained as a consequence of these courses.

Considering the variety of nodes that was detected by data analysis process of the current research, pre-service science teachers mental construct was shaped by not only astronomy courses but also physics courses they participated in. Accordingly, pre-service science teachers activated nodes such as "shadow", "sweeping", "scattering" and "refraction" in their explanation on phases of the moon, although there is no direct linkage between these knowledge elements and phases of the moon. Such a finding might be associated with that these pre-service science teachers may not have constrained mental structure regarding some physics topics, too. To be more specific, pre-service science teachers may not possess sophisticated understanding on Kepler laws, and nature and structure of waves. To conclude, one of the reasons

behind pre-service teachers' unorganized mental structure regarding phases of the moon was that their unorganized mental structure on other content areas. Since they were not constrained and organized, pre-service science teachers easily try to activate unrelated knowledge elements while explaining phases of the moon.

As stressed previously, data of the current study were constituted by pre-service science teachers' verbal explanation, drawings and model demonstration. Drawings and three-dimensional models were generally preferred in order to elicit participants' conceptual understanding on phases of the moon (Atwood & Atwood, 1995; Stahly et al., 1999; Trundle et al., 2002) . However, it was questionable whether or not utilizing three-dimensional models influence participants' understanding on phases of the moon (Atwood & Atwood, 1995, 1996; Trundle et al., 2002). The current study was not designed to reveal potential role of three-dimensional models and drawings on participants understanding. There was no specific attempt to show effect of type of data collection instruments on participants' understandings. However, some speculations also can be made comparing pre-service science teachers' verbal, drawing and model demonstration responses. First, pre-service science teachers' verbal and drawing responses were overlapping each other. During the interview, pre-service science teachers simultaneously responded question via verbal and drawing. Therefore, explicit role of drawing on pre-service science teachers' mental structure could not be examined independently. On the other hand, it was revealed that utilizing three dimensional models had potential to shaped pre-service science teachers' dynamic mental constructs. Pre-service science teachers activated new knowledge elements and disactivated previously activated knowledge elements after exposed to three dimensional models. That is to say, three dimensional models influenced pre-service science teachers' dynamic mental construct. However, it was detected that quality of their explanation did not change after three-dimensional model. Their responses still could not reflect sophisticated understanding on phases of the moon. This situation indicated that three-dimensional models have potential to influence dynamic mental construct of pre-service science teachers although they could not help pre-service science teachers to enhance sophistication of their explanations on phases of the moon.

It was showed that pre-service science teachers' spatial reasoning abilities highly influence their consideration on phases of the moon. This finding was compatible with researches which shows potential role of spatial ability on individuals' understandings on astronomy topics (e.g., Plummer, 2014; Wilhelm, 2009b; Wilhelm et al., 2013). Explanation of pre-service science teachers who participated in the current research showed that they could not explained phases of the moon due to lack of their domain specific spatial ability. More specifically, lack of geometrical spatial visualization, changing frame of reference, spatial transformation and spatial projection abilities were among the culprit of their inappropriate explanation on phases of the moon. Pre-service science teachers attempted to adapt some nodes to the irreverent situations due to their low-level domain specific spatial abilities. Furthermore, they could not activate necessary nodes to suitable situations. These findings support the idea that low level spatial ability causes problem on understanding of astronomy issues (e.g., Cole et al., 2015; Plummer, 2014). Therefore, students should be equipped sophisticated spatial reasoning abilities in order to have sophisticated understanding on phases of the moon.

The present study also examined pre-service science teachers' responses in terms of naming the phases of the moon. It has been pointed out that scientific name of lunar phases may cause confusion for individuals (Dove, 2002). Accordingly, many pre-service science teachers participated in current study encountered with the same confusion. Some pre-service teachers considered that new moon is not a moon phase since it cannot be observed from the earth. In addition, "half-moon" terminology was also utilized in many circumstances instead of first and last quarter moon phases by pre-service science teachers. Surprisingly, two of pre-service science teachers entitled crescent moons as quarter moons, although crescent moon features in national flag of Turkey and it is historic symbol of power of Turkish politics. However, no problems detected considering response of pre-service science teachers regarding full moon. It is plausible to consider that pre-service science teachers were also influenced by their observable knowledge while entitling phases of the moon. To put it differently, they considered appearance of the moon while considering

names of each phases. However, their responses did not fit with scientifically accepted explanation, since the phase of new, crescent and quarter moon reflects illuminated part of the whole moon instead of illuminated part that is seen from the earth.

5.2 Implications and Recommendations

Pre-service science teachers' mental structure regarding phases of the moon was consisted of a complicated system. Although there are many different types of knowledge elements such as propositions, general scheme, p-prims and mental images, analysis conducted regardless of type of knowledge elements. All type of knowledge elements entitled as node in the current research. This situation facilitated examination of complex interview process with respect to phases of the moon which is a broad content. However, relationship among different type of knowledge elements is intriguing issue. Therefore, examination of interaction among different type of knowledge elements in a narrow content are offered for further research.

It was revealed that pre-service science teachers were equipped with appropriate knowledge elements in order to explain phases of the moon. However, they do not have sophisticated understanding since they could not activate appropriate knowledge elements and establish linkage among them. Therefore, undergraduate astronomy courses should provide opportunities in order to improve awareness of pre-service science teachers towards their own mental structure. They should ask question regarding their own experiences and opinions regarding phases of the moon.

Findings of the current study indicated that change of pre-service science teachers mental construct take place in short time scale. These findings were consistent with the previous research (diSessa, 2014b; Parnafes, 2012; Sherin et al., 2012; Wagner, 2006; Welzel & Roth, 1998) indicating that conceptual change may occur at a short time scale. Individuals may reframe their explanation through organized their knowledge elements depending on contextual factors. Therefore, teachers should constitute appropriate environment which support students conceptual change at a short time scale. For instance, teachers may ask questions to

students regarding phases of the moon at the beginning of a lesson. Since students' responses reflect students mental construct, teachers should analyze them and design suitable environment for students' learning.

The present study provides an empirical evidence supporting that spatial ability has significant role in developing sophisticated understandings on phases of the moon. Although number of the objective regarding astronomy topics increased by recent revision of middle school science curriculum, there were no explicit explanation regarding spatial abilities. Spatial ability was perceived as mathematical competencies in order to solve the problems that students encounter in daily life (MoNE, 2018). To put it another, potential role and importance of spatial ability for astronomy and science learning were ignored. Since spatial ability is one of the important factors for both astronomy and science learning, middle school science curriculum should explicitly underline importance of spatial ability. Furthermore, spatial ability also has topic specific characteristics. For instance, changing frame of reference which is a type of spatial ability can be introduced by science contents. Therefore, considering spatial ability as a mathematical competency may not be effective to develop students' spatial abilities. In addition, Science curriculum should present guideline to enhance students' spatial ability for science teachers.

As stressed previously, spatial ability is requirement of sophisticated understanding of phases of the moon. Low spatial abilities limits students understanding of lunar eclipses. However, it was showed that spatial abilities are not stable and they can be enhanced via appropriate strategies (Harle & Towns, 2010). Therefore, science teachers should also consider students' spatial abilities and present opportunity for students to have sophisticated spatial ability. More specifically, they should prefer three-dimensional model which potentially contribute to visualization of celestial bodies. In addition, presenting computerized model, simulations, animations to students may other options to improve their spatial abilities.

Participant of the current study was pre-service science teachers have different level of astronomy and astronomy teaching engagement. Their level of engagement

was also considered while examining response of pre-service science teachers. However, any findings that shows linkage between pre-service science teachers' responses on phases of the moon and their engagement on astronomy and teaching astronomy were detected. To put it differently, their level of engagement may not be an indicator of accuracy of their explanation on phases of the moon. This may be related to the fact that quality of an engagement rather than its quantity is more influential while organizing knowledge system. However, some speculations still can be made about potential role of engagement categories on pre-service science teachers' response. Accordingly, pre-service science teachers referred to their sky observations, assisting and instruction more frequently with comparing other engagement categories during the interview process. Namely, pre-service science teachers tried to visualize their sky observation, assisting or instruction while explaining phases of the moon. Therefore, future research can turn their attention to reveal linkage between quality and type of engagement, and understanding on phases of the moon.

5.3 Limitation of the Study

The current study has a couple of limitations. Initially, researcher's experience on clinical interview is one of the limitations of the current study. Researcher did not have any experience regarding clinical interview. Researcher did not conduct any clinical interview in order to reveal conceptual understanding. In order to overcome this issue, pilot interviews were conducted with four pre-service science teachers before main research.

This study was designed with qualitative research paradigm and included fourteen pre-service science teachers as participants. This situation limits generalizability of the findings. These fourteen pre-service science teachers pursue their undergraduate education in a public university. Findings of the current study cannot generalize all the pre-service science teachers. In addition, phases of the moon which is a specific astronomy topic was focus of the present study. Pre-service science teachers' knowledge structure revealed was peculiar to phases of the moon.

They may have different characteristics regarding other astronomy and science topics.

There was only one available video-recorder during the interview. Clinical interviews were recording using this recorder with wide-angle. Therefore, all the critical component of the interview such as participants, their gestures, their demonstration, drawing and interviewer were tried to record by the same device. However, this situation limited obtaining detailed data from participants. For instance, pre-service science teachers drawing process sometimes could not examined because of low resolution of available data.

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APPENDICES

A. INTERVIEW QUESTIONS / MÜLAKAT SORULARI

1. İkinci Bölüm (Ayın farklı şekillerde görülmesinin nedenleri)
    a. Dünya'dan baktığın zaman Ay'ı hangi şekillerde görüyorsun? Eğer her gece aynı saatte Ay'a baksaydın Ay'ı sırasıyla hangi şekillerde görürdünüz?
    b. Ay'ın farklı görünmesinin nedenleri ne olabilir? Bunu her bir farklı görünüm için nasıl açıklarsınız?
    c. Yukarıda da belirtmiş olduğun görünümlerin her birinde Ay, Dünya ve Güneş'in konumlarını üç boyutlu modelleri kullanarak nasıl gösterirsiniz?
    d. Ay dolunay evresinde ve en tepede ise, saatin yaklaşık kaç olduğunu tahmin edebilir misiniz?

2. Üçüncü Bölüm (Güneş ve Ay tutulması)
    a. Daha önce Güneş ve Ay tutulması gözlemledin mi? Bu tutulmalarda ne olduğunu açıklar mısınız?
        i. Eğer gözlemlediyseniz, hangi yıl ve nerede gözlemlediniz?
    b. Güneş ve Ay tutulmalarının nasıl olduğunu çizerek açıklayabilir misiniz?
    c. Ay, Dünya ve Güneş modeli kullanarak tutulmaların nasıl olduğunu açıklayabilir misiniz?
    d. Ayın evreleri ile Güneş ve Ay tutulmasının arasında bir bağlantı var mı?
        i. Hangi evrelerde Ay tutulması/Güneş tutulması gerçekleşebilir?

3. Birinci Bölüm (Güneş ve Ayın görünür hareketleri)
    a. Dünyadan bakıldığında Güneş nasıl hareket eder?
    b. Dünyadan bakıldığında Ay nasıl hareket eder?
        i. Ay ne zaman ortaya çıkar ne zaman kaybolur?
        ii. Gündüzleri Ay görülür mü? Neden?
        iii. Görünen yüzü değişir mi?
    c. Dünyadan bakıldığında gözlemlenen Ay ve Güneş hareketleri arasında ne ölçüde benzerlik ve farklılıklar vardır?
    d. Ayda bulunan bir gözlemci Dünyayı görebilir mi? Bu gözlemcinin nasıl bir gözlemi olur?

4. Dördüncü Bölüm (Farklı enlem ve boylamlardan ayın görünümü)

a. Aynı enlem üzerinde bulunan Trabzon ve İstanbul'daki iki gözlemcinin aynı anda yaptıkları Ay gözlemleri arasında ne ölçüde benzerlik ve farklılıklar vardır? Neden?
b. Aynı boylam üzerinde bulunan, kuzey yarımkürede yer alan New York ve güney yarımkürede yer alan Uruguay'da iki gözlemcinin aynı anda yaptıkları Ay gözlemleri arasında ne ölçüde benzerlik veya farklılıklar vardır

B. APPROVAL OF METU ETHICS COMMITEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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02 OCAK 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Doç.Dr. Elvan ŞAHİN;

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Bilgilerinize saygılarımla sunarım.

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EDUCATION

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PhD	Middle East Technical University Elementary Education	2019
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WORK EXPERIENCE

- March 2018– Present: Research Assistant, Department of Science and Mathematics Education, Kafkas University.
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AFFILIATIONS

Turkish Science Education and Research Association (SERA)

PUBLICATIONS

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D. TURKISH SUMMARY / TÜRKÇE ÖZET

Astronomi insanların kendilerini çevreleyen gök yüzünü anlama yollarından biridir. İlk astronomların kim oldukları bilinmese de astronomi insanlık tarihi kadar eskidir. Bundan 30,000 yıl öncesine ait mağara duvarı çizileri astronominin ne kadar eski olduğunu gösteren güzel bir örnektir (Karttunen ve diğ., 2007). Eski insanların astronomiye olan ilgileri, kendi yaşam standartlarını da geliştirmelerini sağlamıştır. İnsanlar mevsimlerin değişimi, yıldızların konumları, gök cisimlerinin hareketleri gibi birçok olayı gözlemlemişlerdir. Bu gözlemlerinin sonucunda kendi hayat standartlarını geliştirecek yeni sistemler bulmuşlardır.

İnsanların astronomiye olan ilgisi günümüzde de devam etmektedir. Sosyal medya ve görsel basında paylaşılan; tutulmalar, yeni yıldız ve gezegenlerin keşfi, dünya dışında yaşam olasılığı haberleri bu ilginin göstergesidir. İnsanların astronomiye verdiği önem ve gösterdikleri ilgi, astronomi konularının eğitim programlarında yer almasını beraberinde getirmiştir (Bailey & Slater, 2004). Astronomi konularının eğitim programlarında yer alması birçok faydayı da beraberinde getirmektedir. Astronomi konuları ilköğretim ve ortaöğretim kademelerinde öğretilen başka konulara kolayca uyarlanabilmektedir.

İnsanlar için astronomini önemi düşünüldüğünde astronominin programında yer alması kaçınılmazdır (Bailey & Slater, 2004). Astronominin eğitim programlarına entegre etmenin birçok faydası vardır. Astronomi konuları ilk ve orta kademedeki birçok derse entegre edilebilir. Örneğin astronomi fizikte bulunan kütle çekimi ve ışık gibi kavramların öğretimi için bir araç olarak görülmüştür. Plotnick, Varelas ve Fan (2009) yapmış oldukları çalışmada; Kepler yasası, gelgitler, kütle çekimi kavramını öğretmek için astronomiden faydalanmışlardır. İlaveten, dünyanın manyetik alanı, elektrik ve manyetizma konularını öğretmek için de astronomiden yararlanmışlardır. Diğer taraftan trigonometri, logaritma ve diğer matematik konularının öğretiminde astronomi kullanılabilir. Öğretmenler bu matematik kavramlarını öğretirken astronomi içeriğinden faydalanabilir. Astronomi gerçek dünya ile matematik arasında bir bağ kurarken aynı zamanda öğrencilerin matematiğe karşı olan motivasyonunu yükseltir (Ros, 2009).

Tüm bu faydalara rağmen, astronomi eğitimi etkili öğrenme ve öğretme açısından birçok sorunla karşı karşıya kalmaktadır. Bazı sorunlar astronomi disiplininin doğası ile ilgiliyken, bazı sorunlar ise öğretmenlerin bilgisi ve öğrencilerin uzamsal yeterlilikleri ile ilgili olabilmektedir. Bazı araştırmacılar (örn., Kasturirangan, 1997; Pasachoff & Percy, 2009) tarafından belirtildiği gibi astronomi öğretiminde karşılaşılan zorlukların kaynağı astronomi disiplininin doğasından kaynaklanabilmektedir. Örnek vermek gerekirse, birçok astronomi aktivitesi gece gerçekleştirilmektedir. Yıldızları, gezegenleri ve ayı gözlemleyebilmek için öğrencilerin gece dışarda olması gerekmektedir. Fakat gece öğrencileri için güvenli ve uygun bir ortam oluşturmak zordur. Bundan dolayı öğrenciler sınıflarda öğrendikleri bilgileri, gözlemleri ile birleştirememektedirler. Buna ilaveten, astronomi öğretimi teleskop, çeşitli optik araçları ve simülasyon programlarına ihtiyaç duymaktadır. Birçok okul ve aile bu tür araç ve gereçleri temin edecek ekonomik düzeyde değildir.

Etkili astronomi eğitimin öğretmenlerden kaynaklı sorunları genellikle öğretmenlerin astronomi konularındaki uygun olmayan anlayışları ve yetersiz pedagojik alan bilgilerinden kaynaklanmaktadır. Öğretmenler ve ilk ve orta öğretim seviyesindeki öğrenciler ile yapılan çalışmalar hem öğretmen hem de öğrencilerin benzer kavramsal yanlışlara sahip olduklarını göstermektedir (Cinzia & Perucchini, 2013; Schoon, 1995). Bununla birlikte, öğretmenlerin yetersiz kavramsal anlayışlarının, öğrencilerin öğrenmelerini kısıtladığını gösteren çalışmalarda mevcuttur (Ahn & Choi, 2004; Monk, 1994).

Öğrencilerin uzamsal yetenekleri, onların astronomi öğretimini etkileyen faktörlerden biridir. Birçok farklı tanımlaması olmasına rağmen, uzamsal yetenek döndürme ve çevirme faaliyetlerini de içeren, bir nesneyi zihinde oluşturma yeteneği olarak tanımlanabilir (Linn & Petersen, 1985; Lohman, 1988; Michael ve diğ., 1957). Uzamsal yetenek birçok konunun öğrenmesini kolaylaştırırken, yetersizliği de öğrenme açısından zorluklara neden olmaktadır. Bundan dolayı öğrenciler yeterli düzeyde uzamsal yeteneğe sahip olmalıdırlar.

Ayın evreleri konusu öğretimi esnasında bahsedilen bu zorluklarla karşılaşılan temel astronomi konularından biridir. Ayın evrelerinin açıklanması ay güneş ve dünya sisteminin göz önünde bulundurulması gerekmektedir. Buna göre öğrenciler ayın

dünyanın etrafında dönerken güneş tarafından yarısının aydınlatıldığını görebilmeleri gerekmektedir. Bununla birlikte ayın göreceli pozisyonunun dünyadan ayın aydınlanan kısmının ne kadarını gördüğümüzü belirlediği ve görülen kısmın da ayın evresi olduğunun farkında olunması gerekmektedir (Parnafes, 2012; Trundle ve diğ., 2002).

Treagust ve Duit, (2008) kavramı, öğretmenler, kitaplar ve diğer insanlar tarafından sunulan dışsal sembollerin, insanların içinde yapılandırılması olarak tanımlamaktadır. Öğrencilerin hangi kavramlara sahip olduklarının bilinmesi, öğrenmenin mevcut kavramlar ile öğretimin etkileşimi sonucu olduğu için önemlidir (Posner ve diğ., 1982). Öğrencilerin bilimsel açıklamalar ile uyuşmayan anlayışları kavram yanılgısı olarak isimlendirilir. Bu kavram yanılgılarının öğrencilerin öğrenmesini zorlaştırdığı düşünülmektedir (Hawkins, 1979). Güneş, dünya ve ay sisteminin karmaşık mekanizmasından kaynaklı olarak, ayın evreleri konusunda bireyler birçok kavram yanılgısına sahiptirler. Ayın evreleri konusunda kavramsal anlayışı belirlemek üzere ilkokul öğrencilerinden yetişkinlere kadar birçok grup üzerinde çalışmalar yapılmıştır. Bu çalışmalar dair bulgular katılımcıların sahip oldukları kavramsal anlayışın kabul edilen bilimsel görü ile uyumu olmadığını göstermektedir.

Bireyler ayın evreleri konusunda da birçok astronomi konusunda olduğu gibi uzamsal zekalarını kullanmaları gerekir. Reynold (1990) ve Wellner (1995) çalışmaları yüksek seviyede uzamsal zekaya sahip olan bireylerin ayın evreleri konusunu açıklamada daha başarılı olduklarını göstermiştir. Bununla birlikte çeşitli uzamsal zekâ türlerinin yeterli düzeyde olmamadan ayın evreleri konusunun yeterli düzeyde anlaşılamayacağı vurgulanmaktadır. Uzamsal zekadan kaynaklanan sorunların yanında, bireylerin temel fizik konularındaki eksiklikleri de ayın evreleri konusunun anlaşılmasını güçlendirmektedir. Parker ve Heywood (1998) kırılma yansıma yayılma gibi konuları içeren ışığın yapısı ayın evrelerini anlamak için önemli konular arasında yer aldığını belirtmişlerdir.

Ayın evreleri konusu ay ile ilgili olan birçok konu ile de yakından ilgilidir. Lindell ve Olsen (2002) ayın evrelerine yönelik olarak oldukları ayın evreleri kavram alanını belirlemişlerdir. Buna göre, ayın evreleri kavram alanı sadece ayın evreleri

değil, bununla birlikte gözlemcinin konumu, tutulmalar, ayın görünür hareketleri ve ayın yörüngesel hareketleri kavramlarını da içermektedir. Güneş ve ay tutulması birçok insan tarafından iyi bilinen gök yüzünde gerçekleşen göz alıcı bir olaydır. Ay tutulması ayın dünyanın gölge konisinden geçmesiyle olurken, güneş tutulması ise ayın güneş tarafından örtülmesi ile oluşmaktadır (Moore, 2000). Güneş tutulmasında ay dünya ile güneş arasında ve yeni ay evresinde bulunmaktadır. Buna karşın, ay tutulmasında ise dünya ay ile güneş arasında bulunur. Ay tutulmasında ise ay dolunay evresinde bulunmaktadır. Yeni ay ve dolunay evreleri ay da bir kere görülmesine rağmen güneş ve ay tutulmaları yörüngedeki 5.2 derecelik eğiklikten sonra her ay gözlemlenmezler.

Ayın görünümü aynı zamanda dünya üzerindeki konumumuz ile de bağlantılıdır. Schoon (1995) çalışmasında öğretmen adaylarının dünya üzerindeki farklı noktalardan ayın görünümünün nasıl olacağını tasavvur etmekte zorluk yaşadıklarını göstermişlerdir. Çalışmaya katılan öğretmen adaylarından yarıdan fazlası Amerika'da dolunay gözlemlenirken, Avustralya'da farklı bir evrenin gözlemleneceğini söylemişlerdir. Bu durum öğretmen adaylarının boylamın ayın evrelerine nasıl etki edeceği noktasında yetersiz olduklarını göstermektedir.

Kavramsal değişim üzerine yapılan çalışmalarda bireylerin öğretim öncesi bilgilerinin öğrenmeleri üzerine olan etkisi vurgulanmaktadır. Fakat araştırmacılar arasında öğretim öncesi bilginin nasıl bir yapıda olduğuna yönelik bir fikir birliği bulunmamaktadır. Öğretim öncesi bilginin yapısını açıklayan bilgi parçacıkları ve teori şeklinde bilgi olmak üzere iki yaklaşım bulunmaktadır. Bir taraftan bazı araştırmacılar bilginin birbiri ile uyumlu ve teori benzeri bir yapıda olduğunu öne sürmektedirler (Vosniadou & Brewer, 1992). Diğer taraftan, bilginin parçalı ve birbirinden bağımsız parçacıklar tarafından oluşturulduğunun altını çizmektedirler (diSessa, 1993).

Sherin et al., (2012) bilginin yapısına dair çalışmalardaki buğuların katılımcılar, çalışılan konu ve veri toplama yöntemi ile yakından ilgili olduğunu vurgulamışlardır. Klinik mülakatlar öğrencilerin kavramsal anlayışını ortaya çıkarmak için kullanılan önemli yöntemlerden biridir. Kavramsal değimi inceleyen birçok yöntem klinik mülakatı veri toplama yöntemi olarak tercih etmiştir. Klinik mülakatlar

dinamik bir süreç olup, katılımcılar mülakat esnasında cevaplarını hızlı bir şekilde değiştirebilmektedirler. Bu değişim bir tür kavramsal değişim olarak kabul edilip farklı araştırmacılar tarafından farklı isimler ile adlandırılmaktadır.

Klinik mülakatlar katılımcıların kavramsal anlarını ortaya çıkartmada en etkili yöntem olarak kabul edilmiştir. Birçok çalışma kavramsal değişimi göstermek ve mevcut kavramları belirleye bilmek için klinik mülakatı veri toplama yöntemi olarak kullanmıştır. Ancak klinik mülakatlar dinamik bir süreci içermektedir. Bu süreçte katılımcı bir olayı açıklarken farklı yöntemler kullanabilmekte ve açıklamasını hızlı bir şekilde değiştirebilmektedir. Sorular, ayarlamalar, çevre ve araştırmacı bağlam açısından hassas olan bilgi parçacıklarını etkileyebilmektedir. Klinik mülakatın bu özelliği göz önünde bulundurularak mülakat sürecinin detaylı bir şekilde incelenmesi tavsiye edilmiştir.

Katılımcıların klinik mülakat süresinde cevaplarında meydana gelen değişim kısa zaman periyodunda ortaya çıkan bir kavramsal değişim türü olarak kabul edilmiştir. Klinik mülakatın dinamik ve karmaşık bir süreç olduğu düşünülerek araştırmacılara bu süreçte analiz için daha basit bir çerçeve kullanmaları tavsiye edilmiştir. Nod - mod çerçevesi katılımcıların klinik mülakattaki cevaplarını kullanılan sistemlerden biridir. Bu çerçeve nod, mod ve değişken zihinsel yapı olmak üzere üç birimden oluşmaktadır. Nodlar aktif edilmiş herhangi bir tür bilgi çeşidine karşılık gelmektedir. Bir grup aktif edilmiş nod ise mod olarak isimlendirilir. Değişken zihinsel model ise nod ve modlardan oluşan zihinsel düşünmenin bir ürünüdür. Nodlar ve modlar uzun süreli hafızanın bir parçası iken değişken zihinsel modeller saniyeler içinde değişebilme potansiyeline sahip geçici yapılardır.

Araştırma Soruları

Bu çalışma orta okul öğretmen adaylarının ayın evreleri konusunda açıklamalarını nasıl yapılandırdıklarını ortaya çıkarmak için gerçekleştirilmiştir. Bir başka ifade ile bu çalışma bilgi parçacıkları perspektifi ışığında öğreten adaylarının kavramsal anlayışları hakkında zengin ve detaylı bilgi edinmeyi amaçlamaktadır.

Bu çalışma aşağıdaki araştırma sorularını cevaplamayı amaçlamaktadır.

- Öğretmen adaylarının ayın evreleri konusundaki cevaplarının altında hangi zihinsel yapılar bulunmaktadır.

    - Ayın evreleri konusu açıklanırken hangi bilgi parçacıkları aktifleştirilmektedir.
    - Hangi faktörler öğretmen adaylarının ayın evreleri konusundaki açıklamalarına şekillendirmektedir.
- Öğretmen adayları dinamik zihinse yapılarını çoklu ortam yaklaşımı ile zenginleştirilmiş bir klinik mülakatta nasıl değiştirmektedirler.
    - Öğretmen adayları dinamik zihinsel modellerini üç boyutlu modeller ile karşılaştıktan sonra ne ölçüde değiştirirler.

Çalışmanın Önemi

Bu çalışma fen bilgisi öğretmen adaylarının ayın evreleri konusundaki anlayışları üzerine olan bilgimizi genişletecektir. Bundan önceki çalışmalarda ilkokul düzeyinden üniversite düzeyine kadar katılımcıların ayın evreleri konusunda kavram yanılgılarına sahip oldukları gösterilmiştir. Bu çalışmaların büyük çoğunluğu (örn., Bell & Trundle, 2008; Trundle & Bell, 2010) bireylerin birbiriyle tutarlı bilgi yapılarının olduğunu varsayan teori şeklinde bilgi perspektifine göre yapılandırılmıştır. Bu nedenden dolayı astronomi konusunda bilgi parçacıkları bakış açısıyla yapılan araştırma sayısı oldukça sınırlıdır. Bundan dolayı bu çalışma ayın evreleri konusunda bilgi parçacıklarına yönelik olan eksikliği doldurmayı amaçlamaktadır.

Bireylerin kavramsal anlayışına ve bu anlayışın değişimine yönelik yapılan çalışmalar genellikler klinik mülakatın doğasını göz ardı etmektedirler. Buna göre bu tür çalışmalarda bireylerin mülakattaki son cevapları değerlendirilecek, süreç içinde öne sürdükleri cevaplar değerlendirilmemektedir. Fakat, mülakat esnasındaki öğrencilerin vermiş oldukları her cevap, onların bilgiyi yapılandırmasını bir parçasıdır. Bundan dolayı bu çalışmada mülakat süreci bir bütün olarak incelenmiştir. Bununla birlikte bireylerin cevaplarını nasıl yapılandırdıkları ortaya konulmuştur.

Bilgi parçacıkları perspektifi bağlamında astronomi konularında yapılan çalışmalarda katılımcı olarak okul öncesi ve ilkokul çağındaki öğrencilerin kullanıldığı görülmektedir. Bu yaklaşımın ötesinde bu çalışmada katılımcı olarak fen bilgisi öğretmen adayları yer almıştır. Diğer çalışmalardaki öğrenci guruplarıyla

karşılaştırıldığında fen bilgisi öğretmen adaylarının ayın evreleriyle alakalı daha fazla tecrübeye sahiptirler. Bundan dolayı bu çalışmanın bulguları farklı gruplar arasında karşılaştırma yapma şansı sunmaktadır. İlaveten fen bilgisi öğretmen adaylarının hareketli zihinsel yapılarının diğer yaş gruplarındaki öğrencilerle ne ölçüde benzerlik taşıdığı görülecektir.

Hem bilgi parçacıkları hem de teori şeklinde bilgi perspektifi yaklaşımları kavramsal değişime yönelik olarak farklı mekanizmalara sahip olmasına rağmen her iki yaklaşımda etkili bir fen öğretimini amaçlamaktadır. Ancak bu perspektiflerin öğretim sürecine bakış açıları birbirinden farklıdır. Teori şeklinde bilgi perspektifine göre yeni ve eski kavramların birbiri ile ilişkilendirilmesi zordur. Bundan dolayı öğretim kavram yanılgılarını değiştirmeye yönelik olarak kurgulanır. Diğer taraftan bilgi parçacıklarının aktif edilmesi bilgi parçacıkları perspektiflerinin en önemli özelliğidir. Öğretim esnasında öğretmen bilgi parçacıklarına odaklanmalı ve öğrencinin bu parçacıkları farklı bağlamlarda kullanmasını sağlamalıdır. Bunun sonucunda bireyler bilgi parçacıklarını doğru bir şekilde organize ederler ve zihinsel yapılarını oluştururlar. Bundan dolayı fen bilgisi öğretmen adaylarının kavramsal anlayışlarını anlamak onların sahip oldukları mevcut anlayışları geliştirmek açısından çok önemlidir. Öğretmen yetiştirme programlarına konulan astronomi dersleri öğretmen adaylarının kavramsal yapıları göz önüne alınarak düzenlene bilir.

ALANYAZIN TARAMASI

1960'lı yıllar boyunca fen bilgisi eğitimi öğrencilerin sahip olamadıkları fen içeriğine odaklandılar. Öğrencilerin fen konularındaki kısıtlı anlayışları zihinsel yeterliliklerine bağlandı ancak bu düşünce bilişsel Alandaki çalışmaların sonucunda hızlı bir şekilde değişti. Öğrencilerin sahip olmadıkları yerine öğrencilerin sahip oldukları bilgileri temel alan bir fen öğrenimi düşüncesi ortaya çıktı bundan dolayı fen eğitimi mevcut kavramlar bilimsel olarak kabul edilmiş düşüncelerle yer değiştirmesi olarak kabul edildi

Kavramsal değişim Thomas Kuhnun bilim tarihi ve teorilerin yapısına olan düşünceleri ve Jean Piagetin çocukların anlayışları üzerine yaptığı deneylerden kaynaklanır. Bir taraftan Piaget'in çalışmaları kavramsal değişimin mekanizmasını

belirler. Diğer taraftan Kuhn'nün paradigma değişimi fikri teorilerin radikal olarak değiştiğini gösterir. Bu düşüncelerden yararlanarak Posner (1982) kavramsal değişim mekanizması önermiştir. Bu mekanizma öğrencilerin fen bilimlerini nasıl öğrendiklerini göstermektedir. Posner tarafından önerilen bu mekanizma süreç boyunca birçok eleştiriye uğramıştır. Bazı araştırmacılar öğrencilerdeki kavramsal değişimin yüzeysel olduğunu belirtirken bazı araştırmacılarda öğrencilerin eski ve yeni kavramları bir arada tuttuklarını belirtmişlerdir.

Daha güncel olarak Vosniadou (2012) kavramsal değişimin klasik bakış açısını revize etmiş ve çerçeve teori yaklaşımını öne sürmüştür. Bu yaklaşıma göre kavramsal değişim ani bir değişim yerine yavaş ve kademeli bir değişimin sonucunda ortaya çıkmaktadır. Tutarlı bilgi yapısını oluşturan birçok element mevcuttur. Yeni fikirler mevcut çerçeve kavrama eklenir. Bundan dolayı eski ve yeni kavramlar arasında bir yer değiştirme olmaz. Çerçeve teori perspektifine göre kavramsal değişim ontolojik ve bilgisel açıdan öğrencinin ön bilgilerinin değişimini ifade eder. Bu bakış açısına göre kavram yanılgıları ön kavramlar sentetik modeller olmak üzere ikiye ayrılmıştır. Bir taraftan öğrencilerin günlük yaşam tecrübeleri sonucunda elde ettikleri kavramlar ön kavramlar olarak isimlendirilmişlerdir. Diğer taraftansa formal eğitim sonucunda tutarlılığın kaybolmasıyla sentetik modeller ortaya çıkmaktadır. Bir başka ifadeyle öğrenciler bilimsel düşünceleri kendi ön kavramlarının içine entegre ederler.

Önceki paragraflarda gösterildiği üzere kavramsal değişime yönelik farklı mekanizmalar sunulmuştur. Buna ilaveten araştırmacılar arasında kavramaların yapısına yönelik bir fikir birliği bulunmamaktadır. Öğrencilerin bilgilerinin tutarlımı yoksa parçalı bir yapıda mı olduğu tartışmalıdır. Bilginin yapısını açıklayan iki farklı düşünce vardır. Bunlar bilgi parçacıkları ve teori şeklinde bilgi olmak üzere iki başlığa ayrılmaktadır. Bir tarafta bazı araştırmacılar öğrencileri sahip oldukları bilginin teorilerle benzer özelliklere sahip olduğunu ileri sürmektedir. Kabaca belirtmek gerekirse teori farklı bağlamlarda tutarlı olan bilgi yapılarına karşılık gelmektedir. Diğer taraftan parçacıklı bilgi perspektifini savunan bilginin bireylerin sahip olduğu bilgi yapılarının düzensiz bilgi parçacıklarından oluştuğunu ve bunların yarı bağımsız olduklarını ileri sürerler. Tutarlılık, bu perspektife göre geçici ve yerel bir nitelik taşır

bir başka ifadeyle tutarlılık belli bilgi yapılarının belirli bağlamlarda aktif edilmesine karşılık gelir.

YÖNTEM

Araştırma Deseni

Bu çalışmada fen bilgisi öğretmen adaylarının ayın evreleri konusundaki kavramsal yapılarının derin ve detaylı bilgi edinebilmek amacıyla nitel araştırma yaklaşımı benimsenmiştir. Bununla birlikte bu çalışma durum çalışması olarak kurgulanmıştır. Durum çalışması bir veya birkaç durumdan ortaya çıkan bir konu hakkında inceleme olarak tanımlanabilmektedir (Creswell ,2007). Merriam (2009) açısından durum çalışmalarında en önemli noktanın durum veya analiz biriminin ne olduğunun belirlenmesi olduğunu belirtmektedir. Analiz birimi bir olay, konu, süreç veya farklı bir özelliğe sahip bir insan olabilir. Bu çalışmaya katılan öğretmen adaylarının ayın evrelerine yönelik olarak kavramsal anlayışları karmaşık bir sistem oluşturmaktadır. Bundan dolayı çalışmaya katılan her bir fen bilgisi öğretmen adayı bu çalışmadaki durumları teslim etmektedir.

Katılımcılar

Bu çalışmanın amacı fen bilgisi öğretmen adaylarının ayın evreleri konusundaki kavramsal yapıları hakkında derin bilgi sahibi olmaktır. Bundan dolayı amaçlı örneklem yöntemi ile katılımcılar seçilmiştir. Katılımcıların seçimi belirli kriterler tarafından şekillendirilmiştir. Buna göre, bu çalışmanın katılımcıları üçüncü ve dördüncü sınıf öğrencileri arasından seçilmiştir. Bu öğrenciler öğretmen eğitimi, fizik ve astronomi konusundaki temel dersleri almıştır. Bununla birlikte çalışmaya katılan öğretmen adayları araştırmacının gözlemleri sonucunda seçilmiştir. Çalışmaya katılan öğrenciler, açık fikirli, düşüncelerini rahatlıkla dile getirebilen öğrenciler arasından seçilmiştir. Bu kriterlere uygun olan on altı öğretmen adayı çalışmaya davet edilmiştir. Bu öğretmen adaylarından on dördü çalışmaya katılmıştır. Bu öğretmen adaylarına mülakat esnasında astronomi ile ilgili ilişkilerini belirleyebilmek için sorular sorulmuştur. Buna göre, katılımcılardan yedisi astronomi ile ilgili öğretim materyali hazırladığını beyan etmiştir. Bununla birlikte dört öğretmen adayı gözlem

evi ve uzay kampı ziyareti yapmış, üç öğrenci ise astronomi ile ilgili kitaplar okumuştur.

Veri Toplama

Bu çalışmada veri toplama aracı olarak çoklu ortam yaklaşımı ile zenginleştirilmiş klinik mülakat kullanılmıştır. Çoklu ortam katılımcıların cevaplarını vermek için kullandıkları araçları ifade etmektedir. Bir başka ifade ile katılımcıların cevaplarını farklı şekilde ifade edebilme olanağı çoklu ortam yaklaşımı ile mümkün olabilmektedir. Bu çalışmada çoklu ortam olarak öğrencilerin sözlü açıklamaları, çizimleri ve üç boyutlu model üzerinde gösterimleri kullanılmıştır. İlk olarak kendilerine sorulan soruyu öğretmen adayları sözlü olarak cevaplamışlarıdır. Daha sonra çizim ile göstermeleri istenmiştir. Son olarak aynı soruyu kendilerine verilen üç boyutlu modelleri kullanarak göstermeleri istenmiştir.

Mülakat Soruları

Bu çalışmada kullanılan veri toplama aracı on dört sorudan oluşmaktadır. Bu sorular ayın evreleri konusunda öncü çalışmalarda kullanılan sorular dikkate alınarak geliştirilmiştir. Çalışmanın amacı göz önüne alınarak mülakat soruları dört bölüme ayrılmıştır. Bunlar, ayın evreleri ve ayın evrelerinin sebepleri, güneş ve ay tutulması, farklı enlem ve boylamlardan ayın görünümü ve ayın görünü hareketleridir.

Birinci bölümde sorulan sorular mülakatın temel sorularını oluşturmaktadırlar bu bölümde öğretmen adayları ayın farklı evrelerini göstermiş ve bu farklı görüntülerin nasıl oluştuğunu ayrı ayrı açıklamaya çalışmıştır. İkinci bölüm ise güneş ve ay tutulmalarıyla alakalı soruları içermektedir. Ayın evreleriyle alakalı geçmiş çalışmalarda gösterildiği üzere farklı yaş gruplarından birçok insan dünyanın gölgesinin farklı ay evrelerinin oluşumuna neden olduğunu düşünmektedir. Bu durum ayın evreleri konusuyla tutulmalar konusunun birbiriyle örtüşen konular olduğunu göstermektedir. Buna ilaveten birçok çalışma ayın evreleri ve tutulmalar kavramını birlikte incelemiştir. Bu yaklaşım temel alınarak güneş ve ay tutulmasıyla ilgili sorular bu çalışmada kullanılan mülakat sorularına eklenmiştir.

Lindell ve Olsenin (2002) çalışmaları ise mülakat sorularının üçüncü ve dördüncü bölümünün belirlenmesine ışık tutmuştur ilgili çalışmada sekiz farklı ay evresi kavram alanı belirlenmiştir. Bunlar konumun ayın evreleri üzerine olan etkisi ayın hareketi gök yüzündeki ayın konumu ve ayın periyotları şeklindedir bundan dolayı ayın evreleri kavramının sadece tutulmalar ve her bir ay evresinin açıklanması ile sınırlı olmadığı düşünülmüştür. Mülakat sorularına farklı konumlardan ayın görünümü ve ayın günlük hareketleri ile ilgili sorular mülakat sorularında üçüncü ve dördüncü bölümlere eklenmişti. Bir başka ifadeyle bu çalışmada yer alan mülakat sorularının üçüncü bölümü gözlemcinin koordinatlarının değişimi ile ayın evrelerinin ilişkisini içermektedir. Diğer taraftan gök yüzündeki, ayın ve güneşin hareketi ayın gündüz görülmesi dördüncü bölümde yer alan soruların konusunu göstermektedir.

Çalışmadan bir yıl önce görüşme sorularına yönelik olarak dört öğretmen adayı ile ön çalışma gerçekleştirilmiştir. Öğretmen adaylarının cevapları göz önüne alınarak bazı sorularda değişiklik yapılmıştır. Bazı sorular ise öğretmen adaylarının verdikleri cevaplardaki paralellik dikkate alınarak birleştirilmiştir. Buna ilaveten mülakat sırasında kullanılan üç boyutlu modelde de değişiklik yapılmıştır. Daha öncesinde sunulan güneş sistemi modeli sadece dünya, güneş ve ayı içeren bir model ile yer değiştirmiştir.

Çalışma kapsamında görüşme sorularına yönelik uzman görüşleri de alınmıştır. Astronomi eğitimi alanında çalışmaları olan beş akademisyenden mülakat sorularının açıklığı, uyumu, uygun terminolojinin kullanımı ve çalışma amacına uygunluğu noktasında görüş istenmiştir. İlgili uzmanlardan gelen görüşler doğrultusunda mülakat sorularında değişiklikler yapılmıştır.

Araçlar

Fen bilgisi öğretmen adaylarına mülakat esnasında çeşitli araçlar sağlanmıştır. Öğretmen adaylarının sözlü cevaplarının ardından, çizim yapmaları için kalem ve kâğıt verilmiştir. Çalışma kapsamında kullanılan diğer bir araç ise üç boyutlu modellerdir. Farklı boyutlardaki üç adet top, güneş, ay ve dünyayı temsil edecek şekilde öğretmen adaylarına sunulmuştur. Bu toplar kullanışlılığı artırmak için tahta bir destek ile sabitlenmiştir.

Araştırmacının Rolü

Bu çalışmada araştırmacının temel amacı fen bilgisi öğretmen adaylarının ayın evreleri konusundaki kavramsal yapılarını ortaya çıkarmaktır. Bu amaca ulaşmak için araştırmacı sözlü olarak sorular sormuş, bu soruları öğretmen adaylarından sözlü, çizim ve üç boyutlu modelleri kullanarak açıklamalarını istemiştir. Bununla birlikte araştırmacı öğretmen adaylarının cevaplarını netleştirmek için mülakat sorularının arasında olmayan ilave sorularda sormuştur.

Araştırmacının bu çalışmadaki ikinci rolü ise herhangi bir öğretim ve manipülasyon amacı olmaksızın, öğretmen adaylarının kavram yapılarını oluşturan parçacıklarını harekete geçirmektir. Bu amaçla araştırmacı, farklı bölümlere ayrılmış mülakat soruları sormuştur. Öğretmen adaylarının bu sorulara verdikleri cevaplar arasındaki tutarsızlıklar, araştırmacı tarafından vurgulanmış ve öğretmen adaylarının dikkatine sunulmuştur.

Veri Analizi

Bu çalışmada araştırmacı öğretmen adaylarının klinik mülakat esnasında kullandıkları ayın evreleri konusundaki bilgi parçacıklarını ortaya çıkarmak ve bu bilgi parçacıklarının birbiri ile nasıl bir etkileşim içinde olduklarını göstermektir.

Bilgi parçacıkları bakış açısına sahip araştırmalarda analizin temelini oluşturan bilgi parçacığı farklı terimlerle ifade edilebilmektedir. Bu çalışmada Sherin ve diğ., (2012) tarafından kullanılan nod/mod sisteminden faydalanılmıştır. Bu sistemin en önemli özelliklerinden biri birçok zihinsel yapıyı (genel şemalar, zihinsel resimleri, zihinsel şemalar, zihinsel modeller) nod başlığı altında gruplandırılmıştır. Bu sayede karmaşık olan mülakat sürecinin analizi kolaylaşmaktadır.

Analizin ilk aşamasında çalışmanın verileri bilgi parçacıkları bakış açısıyla uyumlu olarak kodlanmıştır. Araştırmacı öğretmen adaylarının açıklamalarını yönlendiren nodları bulmaya çalışmıştır. İkini aşamada ise bu nodların değişken zihinsel yapıları nasıl oluşturduğu incelenmiştir.

SONUÇLAR VE TARTIŞMA

Bu çalışma bilgi parçacıkları yaklaşımı göz önüne alınarak gerçekleştirilmiştir. Bu yaklaşım bilginin birbirinden bağımsız bilgi parçacıkları tarafından oluşturulmasını temel alır. Bu açıdan bakıldığında bilgi parçacıkları yaklaşımı kavramsal değişim üzerine olan ontolojik perspektif Chi, 2005; Chi & Slotta, 1993) ve teori şeklinde bilgi yaklaşımından (Carey, 1985) tamamen farklıdır. Teori şeklinde bilgi yaklaşımına göre bilgi teori benzeri birbiri ile uyumlu bir yapıdadır. Diğer taraftan ontolojik perspektif ise kavramların doğru ontolojik kategorileri yerleştirilmesi ile ilgilenir. Bundan dolayı kavramsal değişim kavramların yerleştikleri ontolojik kategorilerin yer değiştirmesine karşılık gelir. Bu çalışma bilgi parçacıkları bakış açısına dayandığı için ontolojik kategorilerin belirlenmesi veya birbiri ile uyumlu zihinsel modellerin belirlenmesi gibi bir amaca sahip değildir.

Bu çalışma fen bilgisi öğretmen adaylarının nod olarak isimlendirilen bilgi parçacıklarını ortaya çıkarmayı amaçlar. Bulgular öğretmen adaylarının ayın evreleri konusunda bilgi parçacıklarına sahip olduğu düşüncesiyle uyumludur. Öğretmen adayları ayın evreleri, güneş ve ay tutulması, ayın görünümü ve ayın hareketleri konusunda birçok nodu aktive etmişlerdir. Öğretmen adayları bu konuları açıklayabilmek için değişken zihinsel modeller oluşturmuşlardır. Diğer taraftan çalışmaya katılan dört öğretmen adayı net bir şekilde ikileme düşmeden ve görece hızlı bir şekilde kendilerine yöneltilen soruları yanıtlamıştır. Bu durum bu öğretmen adaylarının mülakat öncesinde ayın evreleri konusunda yapılandırılmış zihinsel modellere sahip olduklarını göstermektedir.

Öğretmen adayları gölge, konum, açı, yörünge, aydınlanma ve yarım nodlarını içeren değişken zihinsel yapılar ile ayın evrelerini açıklamışlardır. Bir başka ifadeyle, ayın evreleriyle hem ilişkili hem de ilişkisiz nodları aktive etmişlerdir. Bu çalışmada öğretmen adaylarının güncel bilimsel bilgiyle uyumlu olmayan düşünceleri kavram yanılgısı olarak ifade edilmemiştir. Bilgi parçacıkları bakış açısıyla uyumlu olarak öğretmen adaylarının bu düşünceleri daha üst düzey kavramsal anlayışa ulaşmaya katkı sağlayacağı düşünülmüştür. Daha önce belirtildiği üzere öğrencilerin sahip olduğu ön bilgiler farklı kavramsal değişim perspektiflerince farklı şekilde algılanmaktadır. Teori şeklinde bilgi ve ontolojik perspektife göre öğrencilerin sahip

oldukları ön bilgiler onların öğrenmeleri için bir engeldir. Bundan dolayı öğrencilerin sahip oldukları ön bilgiler daha önceki bilgiler ile yer değiştirmelidir. Ancak bilgi parçacıkları perspektifine göre ön bilgiler öğrenme için olumlu bir kaynak olarak görülür. Öğrencilerin öğretimden önce sahip oldukları bilgi parçacıkları onların yeni kavramları öğrenmesine katkı sağlar. Bu bakış açısı düşünülerek öğretmen adaylarının ayın evrelerini açıklarken karşılaştıkları zorluğun sebebinin sahip oldukları nodların organizasyonundan kaynaklandığı düşünülmüştür. Bir başka ifadeyle öğretmen adayları daha üst düzey kavramsal anlayış için sahip oldukları nodları tekrar organize etmelidirler. Ancak tekrardan yapılan organizasyon bağlama, ön bilgini özelliğine ve bilgi parçacıkları arasındaki etkileşime bağlı olduğu için gerçekleştirmesi kolay değildir (Ozdemir, 2013). Bunun için öğretmen adayları kendi kavramsal anlayışlarına yönelik problemlerin farkında olmalı ve bunları çözmek için çalışmalıdır.

Bu çalışma öğretmen adaylarının kısa zaman süresinde herhangi bir öğretim desteği olmaksızın zihinsel yapılarını belirlemeyi amaçlar. Ancak öğretmen adaylarının doğrudan müdahale olmaksızın ön açıklamalarını değiştirdikleri görülmüştür. Bu durum klinik mülakatın öğretmen adaylarının sahip oldukları bilgi parçacıklarını tekrar organize etmelerine olanak sağladığını göstermektedir. Bundan dolayı, bu çalışma ayın evreleri konusunun öğretimine yönelik de çıkarımlar sunmaktadır. Mülakat sorularının öğretmen adaylarının ayın evrelerine yönelik olarak farkındalıklarını arttırdığı düşünülebilir. Bu çalışmada öğretmen adaylarından farklı ay evrelerinin neden gözlemlediğimizi açıklamaları istenmiştir. Daha sonra öğretmen adayları her bir ay evresini ayrı ayrı açıklamışlardır. Bunu yaparken açıklamaları arasında tutarsızlıklar ortaya çıkmıştır. Örnek vermek gerekirse öğretmen adayları yeni ay evresini gölge nodunun baskın olduğu bir değişken zihinsel modelle açıklarken aynı öğretmen adayı ilk ve son dördün evrelerini yansıma açı baskın zihinsel modeller kullanarak açıklamıştır. Bu tutarsızlıktan kimisi öğretmen adayları tarafından mülakat esnasında tespit edilmiştir. Aynı zamanda araştırmacı da bu tutarsızlıkları öğretmen adaylarının dikkatine sunmuş ve onların bu konuda düşünmeye yönlendirmiştir. Öğretmen adayları ilk açıklamalarındaki tutarsızlıkları düzeltmeye çalışmışlardır. Fakat öğretmen adayları üst düzey zihinsel açıklamalar yapamamışlardır. Bu durum büyük bir ihtimalle öğretmen adaylarının mülakat esnasında sahip oldukları nodları organize edecek kaynaklara sahip olmaması ile ilişkilidir.

Bu çalışmaların bulguları göz önüne alınarak orta okul öğrencilerine ayın evreleri konusunun öğretimine yönelik olarak birtakım açıklamalar yapılabilir. Öğretmen adaylarının ayın evresi konusundaki açıklamalarının formal ve informal öğrenme tecrübelerinden edindikleri bilgi parçacıklarının organizasyonu ile ilişkili olduğu söylenebilir. Sürpriz olmayan bir şekilde ortaokul öğrencileri ile yapılan çalışmalarda bu öğrencilerinde günlük yaşam deneyimleri ve astronomi ile ilişkili informal öğrenmelerinin olduğunu göstermiştir. Bundan dolayı ortaokul öğrencileri tecrübelerinin sonucunda elde ettikleri bilgi parçacıkları aracılığıyla kolaylıkla değişken zihinsel yapı oluşturabilmektedirler. Bundan dolayı fen bilgisi öğretmeleri öğrencilerine kendi açıklamalarını düşünecek fırsatlar sunmalıdırlar. Öğretmenler doğru düşünceyi sunmanın öğrencilerin ayın evreleri konusunda uygun bir düşünceye sahip olmalarının da yararlı olmadığının farkında olmaları gerekir. Bu çalışmada mülakat soruları sayesinde öğretmen adaylarının ayın evrelerine yönelik olarak farkındalıklarının arttığı gözlemlenmiştir. Öğretmen adayları doğru bir şekilde cevaplayamadıkları mülakat sorularına odaklanmaktadırlar. Bundan dolayı fen bilgisi öğretmenleri öğrencilerinin farkındalıklarını arttırmak için soru sorma tekniğini arttırabilirler. Grup tartışmaları da öğrencilerin öğrenmesi için etkili bir yöntem olabilir. Öğrenciler diğer öğrencilerle etkileşimin bir sonucu olarak sahip oldukları bilgi parçacıklarını aktive edip tekrardan organize edebilir.

Bağlam bilgi parçacıkları perspektifine göre önemli bir birleşendir. Bilgi parçacılarının aktivasyonu bağlamdan oldukça etkilenir. Öğrencilerin bilgi parçacıklarının farklı bağlamlarda aktive etmeleri üst düzey bir kavramsal anlayışa sahip olmaları için gerekli görülmüştür (diSessa, 1993). Bundan dolayı farklı bağlamlar ayın evreleri konusu öğretilirken öğrenciler için sunulmalıdır. İlaveten öğretmen adayları bir konuyu farklı bağlamlarda sunma konusunda yeterli becerilerle donatılmalıdır. Örneğin, Uçar (2008) öğretmen adayları için dünyanın evreleri bağlamını sunmuştur. Bu çalışmada öğretmen adayları aydan bakarken dünyanın hangi şekillerde görüldüğünü açıklamaya çalışmıştır. Bu yaklaşım hem ayın evreleri hem de dünyanın evreleri konusunda aynı bilgi parçacıkları kullanıldığı için etkili bir yöntemdir. Buna ilaveten Venüs'ün, Merkür'ün evrelerinin açıklanması öğrencilerinin üst düzey bir kavramsal anlayışa ulaşmaları için etkili bir yöntem olabilir. Hem öğretmen adayları hem de ortaokul öğrencileri ayın evrelerindeki mekanizmayı

düşünerek Merkür ve Venüs'ün evrelerini tahmin edebilir. Bu çalışmada ortaya çıkarılan bilgi parçacıkları düşünüldüğünde, öğretmen adaylarının zihinsel yapılarının sadece astronomi dersleriyle değil aynı zamanda fizik dersleri tarafından şekillendirildiği görülür. Buna göre ayın evreleriyle doğrudan bir ilişki olmamasına rağmen öğretmen adayları gölge, süpürme, yansıma, kırılma gibi nodları kullanarak ayın evrelerini açıklamışlardır. Bu bulgu öğretmen adaylarının bazı fizik konularında da yapılandırılmış bir zihinsel modele sahip olmadıklarını göstermektedir. Detaylandırmak gerekirse öğretmen adayları kepler yasası ışığın doğası ve yapısı gibi fizik konularında da uygun bir kavramsal anlayışa sahip olmadıkları söylenebilir. Sonu. Olarak öğretmen adaylarının ayın evreleri konusundaki organize olmayan zihinsel yapıların kaynağından biride onların diğer alanlardaki organize olmayan zihinsel yapılarıdır. Diğer alanlardan yapılanmamış zihinsel yapılar nedeniyle, öğretmen adayları kolaylıkla ayın evreleri konusunda ilişkisiz bilgi parçacıklarını aktive edebilmektedirler.

Daha önce açıklandığı gibi bu çalışmanın verileri öğretmen adaylarının sözlü açıklamaları, çizimleri ve model ile yaptıkları gösterimlerden oluşmaktadırlar. Çizimler ve üç boyutlu modeller genellikle ayın evreleri konusundaki kavramsal anlayışı detaylı bir şekilde ortaya çıkartmak için kullanılır (Atwood & Atwood, 1995; Stahly et al., 1999; Trundle et al., 2002). Ancak üç boyutlu modellerin katılımcıların ayın evreleri üzerine olan kavramsal anlayışlarının üzerine olan etkisi tartışmalıdır (Atwood & Atwood, 1995, 1996; Trundle et al., 2002). Bu çalışmada çizimlerin ve üç boyutlu modellerin katılımcıların kavramsal anlayışları üzerine olan etkisini ortaya çıkartmak amacına sahip değildir. Farklı veri toplama araçlarının katılımcıların anlayışlarına olan etkisini ortaya çıkartmak gibi bir amaç taşımamaktadır. Ancak çalışmaya katılan öğretmen adaylarının sözlü yanıtları çizimleri ve üç boyutlu modeller üzerindeki gösterimleri düşünülerek bazı düşünceler ortaya konulabilir. İlk olarak öğretmen adaylarının çizimleri ve sözlü açıklamaları iç içe girmişti. Mülakat süresince öğretmen adayları çizimlerini ve sözlü açıklamalarını eş zamanlı olarak yapmışlardır. Bundan dolayı çizimlerin öğretmen adaylarının kavramsal anlayışına etkisi bağımsız olarak incelenememiştir. Diğer taraftan üç boyutlu modellerinin fen bilgisi öğretmen adaylarının kavramsal anlayışları üzerine potansiyel bir etkisi olabileceği düşünülmüştür. Öğretmen adayları üç boyutlu modellerle karşılaştıktan

sonra yeni bilgi parçacıklarını aktive ederken daha önce aktive ettikleri bazı bilgi parçacıklarını ise pasivize etmektedirler. Bu durum üç boyutlu modellerinin fen bilgisi öğretmen adaylarının dinamik zihinsel yapıları üzerinde etkisinin olabileceğini göstermektedir. Ancak üç boyutlu modellerden sonra yapılan açıklamanın niteliğinin değişmediği saptanmıştır. Ayın evreleri konusundaki öğretmen adaylarının açıklamalarının niteliği değişmemiştir. Açıklamaları üç boyutlu modellerden sonra da üst düzey kavramsal bir anlayışa karşılık gelmemiştir. Bu durum üç boyutlu modellerin değişken zihinsel yapıları değiştirme potansiyeli olduğunu ancak üst düzey bir kavramsal bir anlayışa ulaştırmayı sağlayamadığını göstermektedir.

Öğretmen adaylarının uzamsal zekâları da ayın evreleri konusunda ki açıklamalarını şekillendirmektedir (Plummer, 2014; Wilhelm, 2009b; Wilhelm et al., 2013). Bu bulgu daha önce uzamsal zekanın astronomi konularındaki anlayışa etkisini gösteren çalışmaların bulgularıyla tutarlıdır. Bu çalışmaya katılan öğretmen adaylarının açıklamaları uzamsal zekadan kaynaklanan sorunları göstermektedir. Daha detaylı baktığımızda dinamik uzamsal canlandırma, referans noktası değiştirme, uzamsal değişim gibi uzamsal zeka türlerindeki eksiklikler ayın evreleri konusundaki açıklamalarında ki sorunun temelini oluşturmaktadır. Öğretmen adayları uzamsal zekalarındaki eksiklikten dolayı bazı bilgi parçacıklarını doğru olmayan bağlamlarda aktifleştirmektedirler. Bununla birlikte doğru bağlamda da doğru bilgi parçacıklarını aktif edememektedirler. Bu bulgular düşük seviyelerde ki uzamsal zekanın astronomi öğretimi açısından problemlere neden olduğu düşüncesini desteklemektedir bundan dolayı öğrenciler üst düzey uzamsal zekâ yetenekleriyle donatarak ayın evreleri konusunda üst düzey kavramsal bir anlayışa ulaşabilirler.

Bu çalışma ayın evrelerinin isimleri konusunda öğretmen adaylarının cevaplarının incelenmesini de içerir. Daha önceki çalışmalarda ay evrelerinin isimlerinin çoğu birey için karışıklığa neden olduğu belirtilmiştir (Dove, 2002). Bu çalışmada da ayın evrelerinin isimlerine yönelik olarak benzer bulgulara da ulaşılmıştır. Bazı öğretmen adayları görülmediği için yeni ayı bir ay evresi olarak düşünmemişlerdir. Buna ilaveten ilk ve son dördün ay evreleri yerine yarım ay terimi kullanılmıştır. Sürpriz bir şekilde Türk siyasi tarihinin sembolü olması ve Türk bayrağında bulunmasına rağmen iki öğretmen adayı hilal evresini dördün olarak

isimlendirmişlerdir. Ancak dolunay evresine yönelik olarak öğretmen adaylarının cevaplarında herhangi bir soruna rastlanmamıştır. Öğretmen adaylarının ayın evrelerinin isimlerini belirtirken gözlemlerine dayandıkları düşünülebilir. Bir farklı şekilde ifade etmek gerekirse ayın evrelerinin isimlerini düşünürken ayın görünümünü göz önünde bulundurmuşlardır. Ancak yeni hilal dördün ay evrelerinin isimleri uzay perspektifli bakış açısından kaynaklandığı için öğretmen adaylarının cevapları kabul edilen bilimsel bilgi ile örtüşmemektedir.

Öneriler

Öğretmen adaylarının ayın evreleri konusundaki değişken zihinsel yapıları karmaşık bir sistem olarak düşünülmüştür. Farklı türde bilgi türü olmasına rağmen bu çalışmanın analizleri farklı bilgi türlerini tek bir başlık altında toplayan bir bakış açısından faydalanarak gerçekleştirilmiştir. Bu çalışmada tüm bilgi parçacıkları nod olarak isimlendirilmiştir. Bu durum ayın evreleri konusunda ki karmaşık mülakat sürecini kolaylaştıran bir etken olmuştur. Ancak farklı bilgi türleri arasında farklı etkileşimlerin olma ihtimali vardır. Bundan dolayı farklı bilgi türlerini göz önünde bulundurarak ayın evreleri konusunda bilgi yapılarının araştırılması gelecekteki çalışmalar için önerilir.

Öğretmen adaylarının ayın evreleri konusunu açıklamada kullanacakları gerekli nodlara sahip oldukları ortaya çıkmıştır. Ancak gerekli olan bu nodları aktifleştiremedikleri ve aralarında uygun etkileşimi kuramadıkları için üst düzey kavramsal bir anlayışa sahip olmadıkları görülmüştür. Bundan dolayı lisans eğitiminde verilen astronomi dersleri öğretmen adaylarının kendi zihinsel yapıları üzerine farkındalıklarını arttıracak fırsatlar sunmalıdır. Öğretmen adayları kendi tecrübeleri ve fikirleri üzerine sorular sormalıdır.

Bu çalışmanın sonuçları fen bilgisi öğretmen adaylarının değişken zihinsel yapılarının kısa zaman aralığında değişebileceğini göstermektedir. Bu bulgu kavramsak değişimin kısa zaman aralığında gerçekleştiğini gösteren çalışmaların sonucuyla örtüşmektedir. Bireyler bağlamsal faktörlerle bağlantılı olarak bilgi parçacıklarını organize ederek açıklamalarını düzenleyebilmektedirler. Bundan dolayı öğretmenler öğrencilerinin kısa zaman aralıklarında kavramsal değişimlerine fırsat

sağlayacak uygun çevreyi oluşturmalıdırlar. Örneğin öğretmenler derin başında öğrencilerine ayın evreleriyle ilgili soru sormalıdırlar. Öğrencilerin verecekleri cevaplar onların zihinsel yapılarını yansıtacağı için, öğretmenler bunları analiz ederek uygun bir öğretim ortamı oluşturmalıdırlar.

Bu çalışma ayın evreleri konusunda üst düzey kavramsal bir anlayışa sahip olmada uzamsal zekanın önemini göstermektedir. Orta okul fen bilgisi müfredatında son yapılan değişikliklerde astronomi konusunda ki kazanımların sayısının artmasına rağmen, uzamsal zekaya yönelik olarak bir ilerleme mevcut değildir. Uzamsal zekâ öğrencilerin günlük hayatta karşılaştıkları sorunları çözmek için kullandıkları matematiksel bir yetenek olarak algılanmaktadır. Bir başka ifadeyle uzamsal zekanın astronomi ve fen öğretimindeki potansiyel rolü ihmal edilmektedir. Uzamsal zekâ astronomi ve fen öğretiminde önemli bir etken olduğu için orta öğretim fen müfredatı uzamsal zekanın önemine daha fazla vurgu yapmalıdır. Buna ilaveten uzamsal zekâ konuya özel karaktere sahiptir. Örneğin bir uzamsal zekâ türü olan referans noktası değiştirme sadece fen konularıyla birlikte sunulabilmektedir. Bundan dolayı uzamsal zekayı bir matematiksel bir yetenek olarak düşünmek öğrencilerin uzamsal zekalarını geliştirmek açısından etkili değildir. Buna ilaveten fen bilgisi müfredatı öğretmenlere öğrencilerin uzamsal zekasını geliştirmeye yönelik tavsiyeleri içermektedir.

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