A STUDY ON SCIENCE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE AND CONTENT KNOWLEDGE REGARDING CELL DIVISION

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Prof. Dr. Meliha ALTUNIŞIK
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Master of Science.

Prof. Dr. Ceren ÖZTEKİN
Head of Department

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

Prof. Dr. Ceren ÖZTEKİN
Supervisor

Examining Committee Members

Prof. Dr. Jale ÇAKIROĞLU	(METU, ELE)	
Prof. Dr. Ceren ÖZTEKİN	(METU, ELE)	
Assoc. Prof. Dr. Özgül YILMAZ TÜZÜN	(METU, ELE)	
Assoc. Prof. Dr. Semra SUNGUR	(METU, ELE)	
Assist. Prof. Dr. Betül DEMİRDÖĞEN	(B. Ecevit Ünv., ELE)	

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Name, Last name: Mehmet ŞEN

Signature :

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Şen, Mehmet

M. S., Department of Elementary Science and Mathematics Education

Supervisor: Prof. Dr. Ceren Öztekin

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This study attempted to investigate in-service science teachers' content knowledge including substantive and syntactic structures and pedagogical content knowledge regarding cell division. Data were collected from three experienced science teachers (two males and one female) teaching cell division in 8th grade level in private middle schools through pre-interviews, observations, post-interviews and teacher documents in this multiple case study.

Participants were found to have lack of knowledge in nature of science referring syntactic structures and they had lack of substantive knowledge in association between cell division and genetics as substantive structures. Moreover, participants could not pass to the process category in cell division terms showing that teachers might have problems in teaching cell division topics. Participants' findings about PCK revealed that science teachers' orientation towards science was based on the transmission of curricular objectives referring subject matter goals. Regarding knowledge of curriculum; although science teachers was aware the curricular objectives and could link vertical and horizontal relations, they presented advance level knowledge violating curriculum. Furthermore, science teachers could recognize students' misconceptions; however, they had insufficient knowledge to eliminate misconceptions. This is because science teachers' lack of knowledge about instructional strategies. Moreover, science teachers had lack of knowledge about alternative assessment technics regarding knowledge of assessments.

It is suggested to prepare and conduct professional development programs for in-service teachers including NOS integration for cell division teaching, substantive content knowledge connecting cell division and genetics. Suggested professional development programs should also focus on changing teacher orientation from transmission of knowledge to the student centered orientations. It is also recommended to focus on constructivist teaching approaches and alternative assessment techniques in professional development programs.

Keywords: Pedagogical Content Knowledge, Science Teacher, Science Education, Cell Division

ÖZ

FEN BİLGİSİ ÖĞRETMENLERİNİN HÜCRE BÖLÜNMESİ KONUSUNDAKİ PEDAGOJİK ALAN BİLGİSİ VE KONU ALAN BİLGİSİ ÜZERİNE BİR ÇALIŞMA

Şen, Mehmet

Yüksek Lisans, İlk Öğretim Fen ve Matematik Alanları Eğitimi
Tez Yöneticisi: Prof. Dr. Ceren Öztekin

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Bu çalışmada, fen bilgisi öğretmenlerinin hücre bölünmesi konusunda sürece yönelik ve içeriğe yönelik konu alan bilgileri ile pedagojik alan bilgileri araştırılmıştır. Çalışmaya özel okullarda çalışan ve 8.sınıflarda görev yapan üç fen bilgisi öğretmeni (ikisi erkek, biri kadın) katılmıştır. Bu çoklu durum çalışmasında, veriler ön görüşme, gözlem, son görüşme ve öğretmen dökümanları aracılığıyla elde edilmiştir.

Sonuçlar göz önüne alındığında; öğretmenlerin sürece yönelik alan bilgilerini gösteren bilimin doğası bilgileri bakımından ve içerik alan bilgisi ile ilgili hücre bölünmesi ve genetik konularının ilişkisini göstermekte yetersiz kalmışlardır. Öğretmenler ayrıca hücre bölünmesi ile ilgili kavramlarda süreç kategorisine geçememişlerdir ve bu durum öğetmenlerin hücre bölünmesi konularını öğretmeleri sırasında sorun yaratabilir. Öğretmenlerin hücre bölünmesi ile ilgili PAB'ları göz önüne alındığında ise öğretmenlerin fene karşı yönelimlerinin kazanımları aktarmak üzerine kurulu olduğu görülmüştür. Müfredat bilgisi ile ilgili olarak; fen bilgisi

öğretmenleri öğretim programındaki kazanımları bilmelerine ve hücre bölünmesi konularını diğer konularla ilişkilendirmelerine rağmen, öğretmenlerin kazanımları aşan bilgiler verdikleri gözlemlenmiştir. Ayrıca, fen bilgisi öğretmenleri konu ile ilgili kavram yanılgılarını bilmelerine rağmen bu kavramları nasıl giderecekleri ile ilgili yeterli bilgiye sahip değildirler. Bu durumun nedeni öğretmenlerin yetersiz olan öğretim stratejileri bilgisi olabilir. Benzer şekilde fen bilgisi öğretmenleri alternatif değerlendirme yaklaşımlarını da bilmemektedirler.

Bu çalışmanın sonuçlarına bağlı olarak öğretmenlerin hücre bölünmesi derslerine entegre edebileceği bilimin doğası eğitimi içeren ve hücre bölünmesi ve genetik konularını birlikte ele alan seminerlerin verilmesi tavsiye edilmektedir. Ayrıca bu seminerlerin öğretmenlere öğrenci merkezli yaklaşımları benimsetmeleri onların fene karşı yönelimlerinin değişimi açısından önem arz etmektedir. Son olarak ise bu seminerlerde yapılandırmacı öğretim yaklaşımlarının ve alternatif değerlendirme tekniklerinin üzerinde durulması önerilmektedir.

Anahtar Kelimeler: Pedagojik Alan Bilgisi, Fen Bilgisi Öğretmeni, Fen Bilgisi Eğitimi, Hücre Bölünmesi

To My Grandfather

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LIST OF ABBREVIATIONS

PCK	Pedagogical Content Knowledge
PCKg	Pedagogical Content Knowing
CK	Content Knowledge
PK	Pedagogical Knowledge
KoC	Knowledge of Context
PST	Pre-service Science Teachers

CHAPTER 1

INTRODUCTION

The most important thing is students' understanding of phenomena in science teaching. Teacher ability of teaching science concepts follows students' understandings as second important thing in science education (Kind, 2009). Thus, teachers have enormous impact on science teaching. When, Shulman (1986) who is the eponym of PCK analyzed the studies conducted with teachers, he concluded that researchers focused on teachers' content knowledge as an indication of being a good teacher in the first half of 20th century. However, these researches turned into teacher's pedagogical knowledge such as evaluation, instructional plans and classroom management in the second half of the 20th century (Shulman, 1986).

Thus, Shulman (1986) thought content knowledge as missing paradigm in teacher knowledge research since teacher content knowledge was ignored in the second half of the century. Moreover, Shulman (1986) interrogated that why research in teacher knowledge focused on content knowledge and pedagogical knowledge separately and ignored one of these knowledge types in different times. According to Shulman (1986, 1987) views, there should not have been a sharp distinction between pedagogical knowledge and content knowledge. Thus, Shulman firstly defined the term pedagogical content knowledge in 1986 to link pedagogical knowledge and content knowledge. According to Shulman (1986), pedagogical content knowledge was special combination of content and pedagogy. Moreover, Shulman (1986) claimed that although pedagogical content knowledge includes content knowledge, this knowledge exceeds content knowledge by its teach ability aspect. Then, Shulman (1987, p.8) defined PCK as: "That is special amalgam of content knowledge and pedagogical knowledge in particular topics which is organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" . Another definition proposed by Shulman was (1986, p.9) as “the ways of representing and formulating the subject that make it comprehensible to others.”

According to Shulman (1986) Pedagogical Content Knowledge (PCK) makes a subject to be comprehensible for learners with the use of representations of ideas, powerful analogies, illustrations, examples, explanations and demonstrations. Awareness of students’ preconceptions, knowing the strategies to reorganize students’ knowledge and curricular knowledge are essential for teachers’ pedagogical content knowledge (Shulman, 1986). However, Shulman views were found lack of theoretical background. His ideas had no empirical evidence. Moreover, Shulman’s views included vague terms and they were too simplistic (Kind, 2009).

Until this point, arise of PCK theory was explained, and development of PCK is explained anymore. According to Shulman (1986, 1987) views, PCK includes knowledge of representations that corresponds to knowledge of instructional strategies and knowledge of students’ subject matter and learning difficulties that corresponds to knowledge of learner. Similar to Shulman, Grossman (1990) suggested a model for PCK that is transformation of other knowledge domains which are subject matter knowledge, general pedagogical knowledge and knowledge of context. Grossman (1990, p.5) proposed the figure below to explain her ideas.

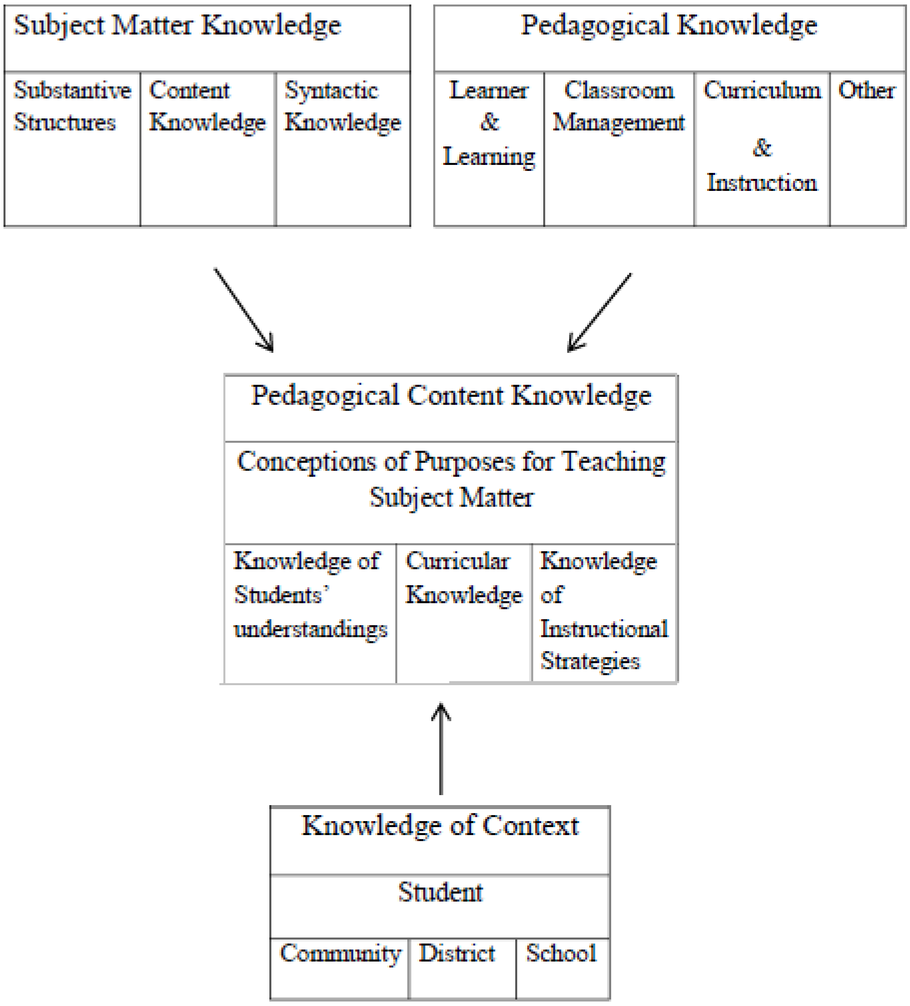

Figure 1.1 Grossman's Model of PCK (1990, p.5)

According to Grossman (1990)'s ideas teacher's PCK includes four dimensions which are conceptions for purposes for teaching subject matter, knowledge of students' understandings, curricular knowledge and knowledge of instructional strategies. According to this model, conceptions for purposes for teaching subject matter are hierarchically more important than other PCK components.

Although Grossman (1990) explained that PCK is transformed knowledge of other knowledge domains, her explanation of PCK included lack of knowledge whether this knowledge is active or passive process. Cochran, DeRuiter and King

(1993) developed a theory that was based on constructivist views to emphasize that PCK is active process that increases over time. Because of Cochran et al. (1993) claimed that PCK is active process, researchers named PCK as PCKing. According to Cochran et al. (1993), knowledge is created by the learner. This knowledge created by learner is different from the knowledge that exists in outer world. This knowledge is also subjective because human beings organize their knowledge by themselves. Cochran et al. (1993) also stressed the importance of experience in their perspective because the more teachers experienced, the more they get new understandings which let them to construct their new knowledge. In this view, teacher's knowledge is whole and new understandings of teacher's knowledge accompanied by experience affect teacher's whole knowledge and develop the existing knowledge increasing teacher PCK. Cochran et al. (1993) claimed that development of PCK depends on the simultaneous integration and development of four components in terms of teacher understanding of students, specific teaching context where social interaction occurs, pedagogical knowledge and subject matter content. Cochran et al. (1993, p.268)'s pedagogical content knowing model is presented below.

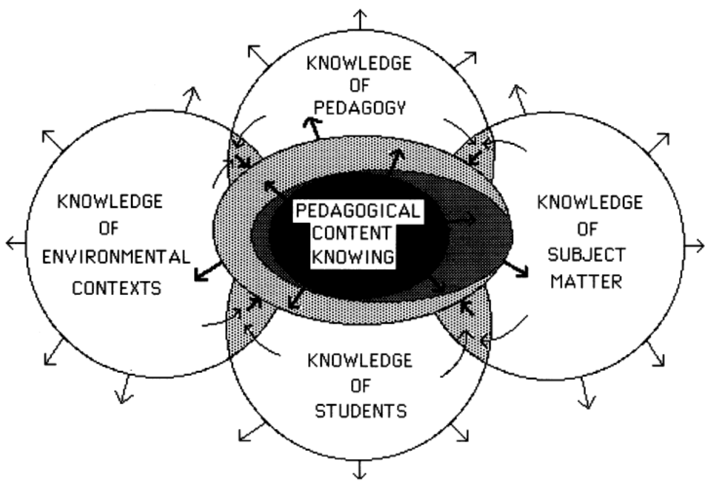

Figure 1.2 Cochran et al.'s PCKg model (1993, p.268)

In their model, PCKg of a teacher is limited at first; however simultaneous development of other four components as shown with arrows causes PCKg development. In addition, there is an integration and interrelation between four components while they are resulting PCKg.

Although Shulman (1986, 1987) claimed that PCK is a bridge between pedagogical knowledge and subject matter knowledge, he did not provide a model for the connection of subject matter knowledge and pedagogical knowledge. Hence, Veal and MaKinster (1998) released their own model to connect pedagogical knowledge and subject matter knowledge. Veal and MaKinster's PCK model included hierarchical relationship. Hierarchical taxonomy offered by Veal and MaKinster (19998, p.7) is presented below.

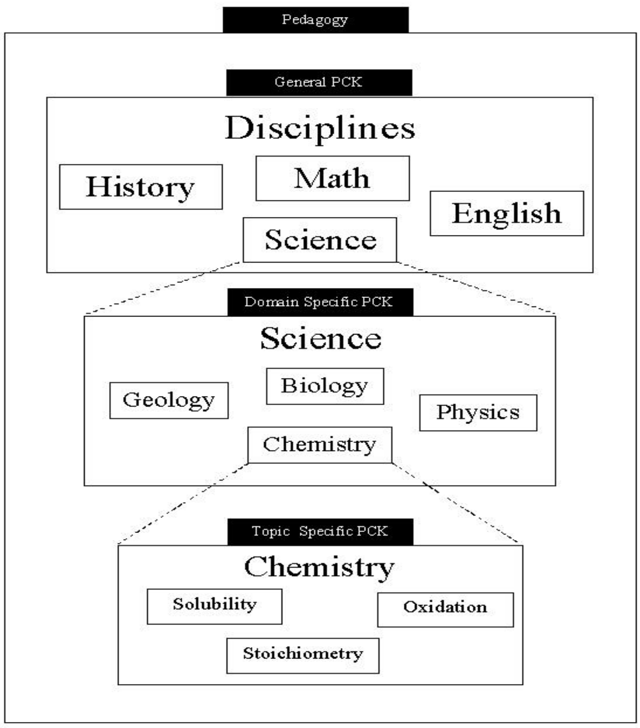

Figure 1.3 Hierarchical Taxonomy of Veal and MaKinster (1998, p.7)

Taxonomy offered by Veal and MaKinster (1998) showed that each teacher should have general pedagogical skills such as planning, teaching methods, evaluation etc. This knowledge base is not related with specific content area. After having pedagogical skills, teachers gain General PCK. General PCK is more specific than pedagogical knowledge because it is specific to disciplines such as science, math etc. Expert teachers are supposed to have this knowledge base. Domain specific PCK is more specific than General PCK. Domain specific PCK focuses on one domain of a discipline such as chemistry in science. Topic specific PCK is the most specific one. If a teacher wants to have well topic specific PCK, this teacher should have all the skills found in previous levels. Each topic found in a domain has its own different teaching style, method and approach, therefore PCK is topic specific (Veal & MaKinster, 1998). Moreover, Veal and MaKinster (1998) attempted to explain how PCK develops. Figure 4 represents' Veal and MaKinster's second taxonomy for PCK regarding how PCK develops.

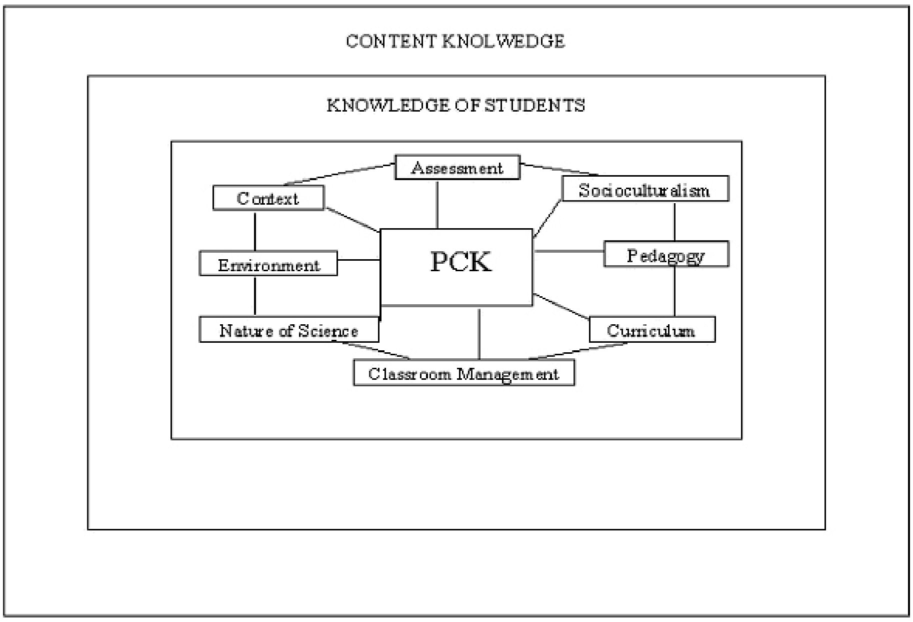

Figure 1.4 Veal and MaKinster's second taxonomy for PCK (1998, p.11)

According to Veal and MaKinster (1998)'s second model, PCK is at the center and there is a relationship between PCK and other attributes. In order to have robust PCK, teachers should have well content knowledge that is prerequisite. Second prerequisite for well PCK is the knowledge of student. Model showed that content knowledge and knowledge of learner interlock because teacher having robust content knowledge could easily understand and elicit students' errors and misconceptions. Other attributes that assist in development of PCK such as assessment, context and curriculum are not in hierarchical relationship but they are inter-related according to Veal and MaKinster (1998). If all these attributes including content knowledge and knowledge of learner are integrated, PCK of a teacher develops. This model showed that PCK is a continuum and it can increase with all of its components.

Veal and MaKinster (1998) used an analogy to better identify their PCK views. According to their explanation, there are two different languages in teaching process. First language is content knowledge that students are unfamiliar. Teacher is the translator who knows the both of the languages. Second language is the translated content knowledge that is understood by students. Teaching is the process of translation. In this analogy, teacher ability to translate content knowledge increases students understanding.

Similar to Grossman (1990), Magnusson et al. (1999) suggested modified version of Grossman (1990) model. According to this model, PCK has five components in terms of orientations toward science teaching, knowledge and beliefs about science curriculum, knowledge and curriculum about students' understanding of specific science topics, knowledge and beliefs about assessment in science, and knowledge and beliefs about instructional strategies for teaching science. Magnusson et al. (1999)'s PCK model was adopted in current study as. Components of Magnusson et al. PCK model are presented in definitions of important terms part. Figure 5 presents Magnusson et al. (1999, p.4)'s PCK model.

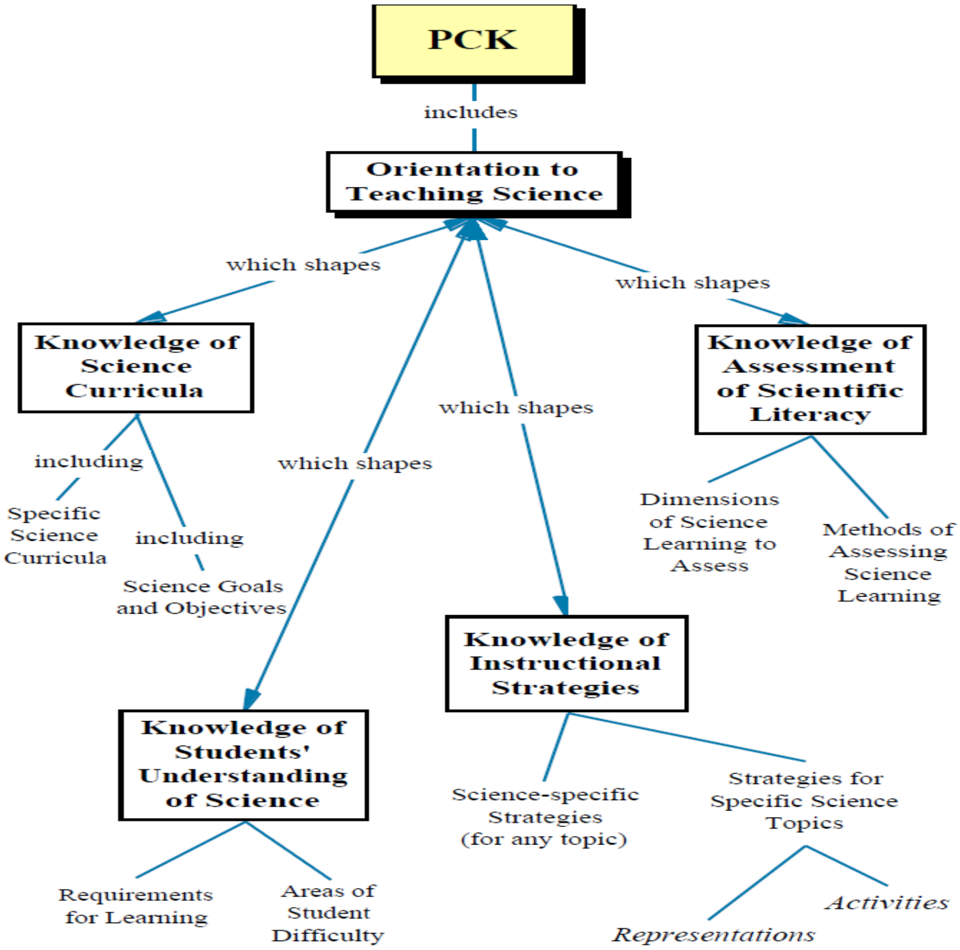

Figure 1.5 Magnusson et al. PCK model (1999, p.4)

After that, Gess and Newsome (1999) summarized the PCK models which are integrative models and transformative models. Figure 6 represents integrative models.

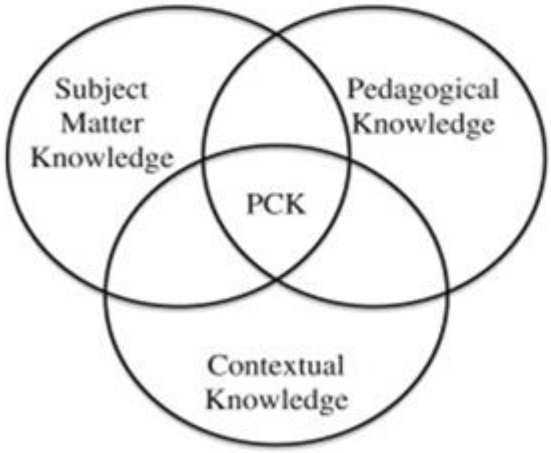

Figure 1.6 Gess Newsome's Integrative Models for PCK (1999, p.12)

In integrated models, PCK itself summarizes a teacher's knowledge base. Gess-Newsome (1999) suggested that integrative model of PCK can be likened to mixtures. In mixtures, components don't lose their characteristics and product is combination of all substances, so PCK cannot be seen as separate domain in integrative models. Integrative models also had lack of explanatory power and there is no interaction among SMK, PK and knowledge of educational context (Kind, 2009). Cochran et al. (1993) and Veal and MaKinster (1999) adopted integrative models which were mentioned above.

PCK includes subject matter knowledge in integrative models on the other hand transformative models claim that PCK is a new type of knowledge derived from content knowledge and pedagogical knowledge (Gess-Newsome, 1999). According to Gess-Newsome (1999), transformative models for PCK can be seen as a compound in which reactants (CK, PK, and KoC) lose their characteristics when they form the product (PCK). In this type of models; CK, PK and KoC can be meaningful only when they are transformed in PCK. In addition; transformative models include a mechanism which SMK of a teacher is translated into the PCK in selected topics (Kind, 2009). It is assumed that content knowledge is transformed into PCK as mechanism and there is no simultaneous development of PCK unlikely integrative models. Examples of transformative models are Shulman (1986, 1987), Grossman

(1990) and Magnusson et al. (1999)'s models (Gess-Newsome, 1999). Figure 7 represents transformative models for PCK.

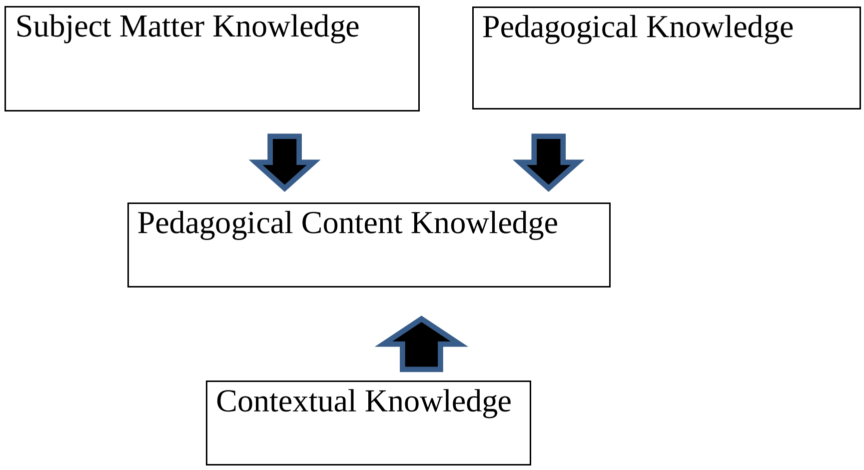

Figure 1.7 Transformative Models for PCK (Gess-Newsome, 1999, p.12)

Up to the present, arise of the PCK and different models on PCK related with the development of theory were presented. In this point, the function of PCK is presented. Teaching is both complex and difficult process (Geddis, 1993; Gess-Newsome, 1999). Hence, researchers needed to propose different solutions to reduce complex teaching process. For example some researchers focused on observing teacher behavior or some others focused on students' achievement or some others focused on teacher content knowledge as PCK researchers did. PCK is the one of the approach to understand difficult teaching process (Abell, 2008). Stated differently, Kuhn (1962) suggested that scientists release different solutions to common problem based on their different paradigm or worldview. In this case, PCK is the reflection of science educator's paradigm to understand teaching process, to increase quality of teaching, and to increase quality of science education programs (Abell, 2008; Magnusson et al., 1999). PCK is a good model to understand teaching because it organizes the knowledge, provide explanations, and release new relations. Hence, teaching could be less problematic (Gess- Newsome, 1999).

PCK connects science education programs and actual classroom practice each other. In-service and experience science teachers' teaching ability is better than novice or pre-service teachers (Abell, 2008). In this point, PCK acts as a bridge between pre-service teachers and in-service teachers. By this way, science teachers share their experiences with pre-service teachers. Therefore, pre-service teachers do not have to re-invent the wheel (Bucat, 2004). For example; In-service teachers' practice could be recorded and this records could be presented in teacher education programs and workshops to develop other teachers' PCK or vignettes can be produced by science educators to increase pre-service teachers' understanding of teaching process. However, this situation is not as easy as Bucat (2004) claimed because PCK is topic; person and situation specific construct what makes PCK's nature complex (Park & Oliver, 2008; Van Driel & Berry, 2012). For example; Van Driel and Berry (2012) claimed that same teachers' PCK in selected topic may change with different students, different hours in the day, different days of the week. In another word, a science teacher's PCK can be different for selected topic depending on the learner, time and context. Hence Van Driel and Berry suggested noticing contextual factors in teacher programs. In conclusion, in-service teachers' teaching practice can be transferred to in-service professional development programs and pre-service education programs caring local context. By this way, high quality science teachers grow what makes PCK useful paradigm. (Abell, 2008; Gess-Newsome, 1999; Kind, 2009).

1.1 Topic Specific PCK

As Veal and MaKinster (1998) mentioned, each topic found in a domain has its own different teaching style, method and approach, therefore PCK is topic specific. In this study, topic-specific PCK was selected as theoretical framework of the study. Cell division topics were selected as specific science topics in this study. Why cell division topics were selected in this study is explained in this section.

Cell division topics are one of the most difficult topics in science education for both teaching and learning (Atılboz, 2004; Brown, 1990; Clark, 2000; Lewis-Wood Robinson, 2000; Mickle, 1990; Öztaş et al., 2003; Sarıkaya et al., 2004;

Williams et al., 2012). Previous researchers explained the sources of difficulties about teaching and learning with respect to process aspect of cell division (Brown, 1990; Mickle, 1990), micro level nature of cell division (Atılboz, 2004), and abstract and complex structure of these topics (Sarıkaya et al., 2004). Researchers claimed that science topics including procedural knowledge should take careful attention. Although students could learn static knowledge easily, they cannot learn the process knowledge in traditional ways. Hence, there is a need in science education research about how process based topics such as cell division topics are taught in classrooms (Brown, 1990; Mickle, 1990). Similarly; abstract, complex and micro level issues requires more attention in science education because students who do not reach formal operational stage cannot understand abstract issues (Aydemir, 2014). Because of these reasons, it is meaningful to study about how experienced in-service teachers' teach PCK.

Biology topics are interrelated with each other and some biology topics are pre-requisite for others such as cell, cell division, and genetics (Brown, 1990; Clark, 2000; Kazancı et al., 2003; Kindfield, 1994). Students, who cannot learn cell division topics, cannot understand growth, reproduction, development and genetics too (Clark, 2000). Therefore, it is valuable to study on cell division topics as unifying themes on biology.

Another reason why cell division topics were selected in this study is these topics' relationship with genetic literacy and scientific literacy (Freidenreich, Duncan, Shea, 2011; Lewis & Wood-Robinson, 2000). MoNE (2006) aims to prepare scientific literate public and genetic literacy is part of scientific literacy. Although genetics related technology increases, public and students' awareness about genetic issues is insufficient (Lewis & Wood-Robinson, 2000). In order to increase scientific literacy and genetic literacy in public, students should understand the genetics related topics such as cell division. Moreover, students as citizens of the future cannot be decision maker people about controversial issues related with genetics such as cloning (Lewis & Wood-Robinson, 2000). Another component of scientific literacy is science process skills. According to Colvill and Pattie (2002), science process skills are the building blocks of scientific literacy. Cordero and Szewcak (1994) claimed that cell division studies increase students' science process skills by using microscope and observing cell division process. Therefore, PCK study on cell division increases the attention to science process skills that is part of scientific literacy.

1.2 Significance of the Study

Abell (2008) reported that PCK is a tacit construct hidden in teacher minds. Therefore, there is a need in use of multiple data sources about PCK studies to better understand nature of PCK. Current study used multiple data sources to get science teachers' PCK which are pre-interviews, observations, post-interviews and teacher documents. By this way, detailed data were collected and analyzed regarding science teachers' PCK on cell division to get evidence for nature of PCK.

Most of the previous PCK studies held with pre-service teachers and number of PCK studies held with in-service teachers are limited (Abell, 2008; Aydın & Boz, 2012; Kind, 2009). On the other hand, pre-service teachers' PCK includes lack of knowledge or it is non-existent because pre-service teachers have no experience that is essential for PCK (Cochran et al., 1993). Because of this reason, current study was conducted with in-service teachers who had at least five year experience in their career assuming that science teachers had robust PCK. By this way, in-service teachers' PCK was gathered and results were presented in current study.

Previous studies mostly used some components of the PCK and ignored some others. Overarching component of PCK, orientation towards science, was the most ignored component. Therefore, still there is little known about science teachers' orientation towards science components (Abell, 2008; Friedrichsen & Dana, 2005; Friedrichsen et al., 2010). In this point researchers call more study on all components of PCK. This study included all the components of Magnusson et al. (1999) model.

Another significance of current study is regarded with the focus of discipline. Previous studies were conducted in chemistry topics. Hence, there is a need to understand science teachers' PCK about biology and physics topics (Aydın & Boz, 2012). Because of cell division topics were chosen as specific topic in current study, this study has contributions on PCK literature about biology topics. Moreover, previous researches on PCK were held in secondary science education teachers and there are few studies held with elementary education departments. Findings of current study have also contributions on PCK literature held with elementary teachers. Findings gathered from elementary science teachers provide evidence for the nature of PCK too.

Analogies, models, examples, and materials which were used by participants in current study can be used in pre-service teachers' training programs and in-service teacher development programs. By this way, science teachers' might develop their PCK regarding cell division as Not only science teachers' develop their PCK, but also they improve their content knowledge regarding cell division. Furthermore, findings about misconceptions and difficulties of students provide information for the literature about cell division misconceptions and difficulties.

PCK is the transformation of content knowledge (Magnusson et al., 1999). Therefore, science educators should consider content knowledge and PCK together. Content knowledge includes both substantive and syntactic structures (Grossman, 1990). However, previous PCK studies usually focused on substantive content knowledge (Abell, 2008). In this study, researcher focused on both substantive structure and syntactic structure to better understand science teachers' nature of PCK.

Finally, Aydemir (2014) suggested that there is a need for PCK studies held in private schools because PCK studies were mostly held in public schools. This study was held with in-service teachers working in private schools, hence findings of the current study set light to PCK studies held in private school context.

1.3 Statement of the Problem

This study aims to investigate science teachers' content knowledge and PCK on cell division. Content knowledge was investigated with respect to syntactic knowledge and substantive knowledge. PCK was investigated with respect to orientation towards science, knowledge of curriculum, knowledge of students, knowledge of assessments, and knowledge of instructional strategies. Based on the aim of the study, the following research questions and sub-research questions were formed.

1. What is science teachers' content knowledge regarding cell division topics?
   1.1. What is science teachers' syntactic content knowledge with respect to nature of science knowledge?
   1.2. What is science teachers' substantive content knowledge regarding cell division?
2. What is science teachers' PCK regarding cell division?
   2.1. What is science teachers' orientation towards science with respect to beliefs about goals of science teaching?
   2.2. What is science teachers' knowledge of science curriculum regarding cell division?
   2.3. What is science teachers' knowledge of students' understanding of science regarding cell division?
   2.4. What is science teachers' knowledge of assessment in science regarding cell division?
   2.5. What is science teachers' knowledge of instructional strategies regarding cell division?

1.4 Definition of Important Terms

Important terms which are frequently used in this study are defined below:

Content Knowledge (CK): According to Schwab (1964) content knowledge includes two structures which are substantive content knowledge and syntactic content knowledge. **"**The substantive structure of a discipline is the organization of concepts, facts, principles, and theories, whereas syntactic structures are the rules of evidence and proof used to generate and justify knowledge claims in the discipline." (Abell, 2007, p.1107). Khalick and BouJaoude (1997) claimed that nature of science knowledge refers to syntactic structure of content knowledge. Hence, science teachers' nature of science knowledge was obtained to understand their syntactic knowledge.

Pedagogical Content Knowledge (PCK): Shulman (1986, p.9) defines PCK as "the ways of representing and formulating the subject that make it comprehensible to others." or Shulman (1986) define that Pedagogical Content Knowledge (PCK) makes a subject to be comprehensible for learners with the use of representations of ideas, powerful analogies, illustrations, examples, explanations and demonstrations. Awareness of students' preconceptions, knowing the strategies to reorganize students' knowledge and curricular knowledge are essential for teachers' pedagogical content knowledge.

Orientation toward Science: Orientation of teaching science seeks answers the question of "what is the purpose of science at a particular grade level?" This component of pedagogical content knowledge represents teacher general view toward science teaching. However, a teacher doesn't need to have only one orientation towards science; they may represent multiple orientations towards science. In fact, different orientations may be incompatible with each other like discovery and didactic orientation towards science (Magnusson et al., 1999).

Knowledge of Science Curriculum: Knowledge of science curriculum consists of two different categories in terms of mandated goals and objectives, and specific curricular programs and materials. Knowledge of goals and objectives shows a teacher's knowledge of objectives about selected topic for students placed in curriculum. In addition, teachers are supposed to know previous years related objectives and goals about selected topic and following years' objectives for particular grade. This curricular knowledge is vertical dimension of knowledge of goals and orientation. Next, knowledge of specific curricular programs consists of different kinds of curricular programs and materials that are compatible for teaching selected topic like textbooks, articles, lab materials, internet etc. (Magnusson et al., 1999).

Knowledge of Students' Understanding of Science: This dimension shows that teachers must be aware of students understanding about subject. This dimension has two sub dimensions in terms of knowledge of requirements for learning and knowledge of areas of student difficulty. Firstly, teacher's knowledge of requirements for learning needs awareness of students' prior knowledge whether their knowledge is sufficient to new learning. For example, if course objective is to learn temperature change, students should already know to read thermometer and teacher should be aware of that. Teacher should also concern students' age and grade level and capable of understanding their different learning styles. Secondly, knowledge of areas of student difficulty represents the knowledge of teacher about which concepts students find difficult and what the reasons underlie for these difficulties. Usually abstract topics and topics that can't be connected with prior knowledge are difficult for students learning (Magnusson et al., 1999).

Knowledge of Assessment in Science: Knowledge of assessment in science has two sub dimensions in terms of knowledge of dimensions of science learning and knowledge of the methods. Knowledge of dimensions of science learning to assess refers the teacher knowledge to assess what is important in particular topic. This knowledge of assessment dimension includes assessment of conceptual understanding, interdisciplinary themes, nature of science, scientific investigations and practical reasoning. Knowledge of methods of assessment mentions teacher knowledge about different ways to assess specific science topics. Some assessment methods are more useful than others depending on some aspects of students learning. For example, if students' cognitive development in a topic is assessed, it is suitable to choose written texts; however, if students' scientific investigation in a topic is assessed, it is better to assess with laboratory practical examination. Currently, students generated products such as journal entries, written laboratory reports, drawings, working models provide opportunities for the performance based assessments and portfolios which are contemporary assessment methods (Magnusson et al., 1999).

Knowledge of Instructional Strategies: Knowledge of instructional strategies includes two dimensions in terms of knowledge of subject specific strategies and knowledge of topic specific strategies. Knowledge of subject specific strategies is broader than knowledge of topic specific strategies. Knowledge of subject specific strategies are suitable for science teaching generally; however, knowledge of topic specific strategies represents particular topics in science teaching. Knowledge of subject specific strategies is parallel with “orientations to teaching science”. These general instructions serve to realize goals of particular orientations. Best known subject specific strategies are “learning cycle” that is used for discovery, inquiry and conceptual change oriented instruction. Knowledge of topic specific strategies is another sub-dimension of knowledge of instructional strategies. Knowledge of topic specific strategies also comprehends two subunits with respect to topic specific representations and topic specific activities. Topic specific representations are used to facilitate students’ learning on specific concepts or principles. Some of these representations are illustrations, examples, models and analogies. Teachers need to know each representations strengths and limitations during the instruction of topic. Teachers can answer students’ questions and use different representation in specific topic with the help of their improved SMK. However, improved SMK doesn’t guarantee to develop teacher PCK. Topic specific activities are used for students’ better understanding of specific concepts or relationships. Some of these activities are problems, demonstrations, simulations, investigations, and experiments (Magnusson et al., 1999).

CHAPTER 2

REVIEW OF LITERATURE

This study aims to examine in-service teachers' content knowledgeand pedagogical content knowledge about cell division. In the current study, content knowledge was explored as syntactic content knowledge in terms of nature of science, and substantive regarding cell division topics. To this end, previous studies regarding in-service teachers' nature of science knowledge and cell division studies in literature were presented at first. After studies regarding content knowledge were presented, PCK studies which were conducted with both in-service and pre-service teachers were reported.

2.1 Studies regarding Science Teachers' Content Knowledge

First research question of this study examines science teachers' content knowledge which are syntactic and substantive knowledge. Hence, previous studies regarding syntactic knowledge and substantive knowledge were reported in this section.

2.1.1 Nature of Science Studies held with In-Service Teachers

One of the aims of this study is to understand experience in-service teachers' NOS views as syntactic knowledge component of content knowledge. Therefore, previous studies related with NOS views of in-service teachers were reported in this section. However, NOS studies which held with pre-service teachers and NOS studies held with students are not reported in this study because these studies exceeds the scope of this study. NOS studies held with in-service teachers can be divided into two categories in terms of NOS studies examining in-service teachers NOS views, and NOS studies aiming to increase science teachers' NOS views based on the literature.

In this section, studies examining in-service teachers' NOS views were reported at first. Iqbal, Azam and Rana (2009) searched secondary science teachers' nature of science knowledge in Pakistan. In this study, 200 secondary science teachers (biology, physics and chemistry) were selected from Lahore that is metropolitan in Pakistan for this study. A NOS questionnaire prepared by Haidar (1999) including demographic information and nature of science information was applied to participants. Results of this study showed that participants were mostly in traditional category for Nature of science knowledge (60 %). In detail, their views on scientific theories were traditional however they thought that invalid theories are useful for scientific development. Nearly half of the participants thought that scientific models are copies of realities and the others thought that scientific models are the product of scientists' ideas. The participants' views about scientists were traditional also. In addition, participants thought that scientific knowledge is cumulative and generated by observation as traditional view; however they had contemporary views in tentative nature of scientific knowledge. Furthermore, participants thought that scientists discover what exists in nature about scientific laws. The reasons why teachers had low contemporary views on nature of science were found as emphasize in content knowledge, existing curriculum, teaching methods and assessment systems which leading traditional views on NOS. In addition, teachers tend to develop views on teaching and NOS depending on how they were taught in their school years.

Aslan, Yalçın and Taşar (2009) also examined 48 elementary science teachers' nature of science knowledge. Data were collected by use of Views on Science Technology and Society (VOSTS) Questionnaire and semi-structured interviews. Semi-structured interviews were applied to 3 of the participants. Results showed that only 8 % of the participants had contemporary views on what science is. Half of the participants thought that observations of different scientists can be different from each other. The others had traditional views about the observations. On the other hand, most of the participants thought that scientific knowledge is tentative (77 %). Nearly, 60 % of the participants thought that there is a hierarchy between hypothesis, theory and law showing that most of the participants had misconception about the theory, law and hypothesis. 46 % of the participants thought that there should be some wrong and correct assumptions for development of scientific knowledge which shows that wrong assumptions are as important as correct assumptions for science. Similarly, only 8 % of the participants thought that there is no one scientific method because creativity and imagination can lead more than one scientific method to scientists. In conclusion, researchers claimed that most of the participants had acceptable views on nature of science that falls between traditional views and contemporary views. Only, 8 percent of the in-service science teachers had contemporary views on nature of science. Researchers thought that their study results showed science teachers had insufficient NOS knowledge in general. The only nature of science aspects that teachers had contemporary views was tentativeness aspect of science. The reason that science teachers hold traditional views on NOS was related by researchers as textbooks and wide use of traditional views in science courses.

Doğan and Abd-El Khalick (2008) examined Turkish secondary science in-service teachers' NOS views and the possible relationships between NOS and teachers' demographic variables such as geographical region, education level and socioeconomic status. In this study, a modified version of Views of Science, Technology and Society Questionnaires' 14 items were asked to teachers. Stratified sampling was used to collect data. Researchers selected three cities of each of the seven geographical regions in Turkey categorizing their socioeconomic status as high, middle and low. Total 63 schools participated in this study and 6 teachers from each of the schools participated in this school. Total number of the teachers that participated in this study was 378. Results of this study suggested that participants had naive ideas about most of the NOS items in general. On the other hand, 27 % of the participants hold informed views about the theory- driven nature of observation that is subjectivity. Only, 34% of the participants could know that scientific models are not copy of reality. Although all of the participants hold naive ideas about the relationship between hypothesis, theories and laws, 23% of participants hold informed views about the assumptions of theories and laws. In addition, 23% of participants could know that some good theories are simple and some good theories are complex. Moreover, 10 % of the participants thought that there is more than one universal scientific method in science because scientific method that is used in a research is determined based on its research question. Furthermore, 23 % of the participants answered that errors are inevitable in science and they could be minimized by the discussions among scientists. Similarly, 46% of the participants could know that scientific knowledge is never certain. Participants' views were also found as naive about epistemological status of theories (38% informed answer). Participants who held naive ideas about theories thought that scientists discover facts like a miner discovers gold. On the other hand, participants who held informed ideas about theories thought that scientist invent theories like an artist invent a sculpture because theories are the interpretation of observed phenomena. On the other hand, participant teachers held informed views about tentative nature of science (%71) and relationship between classification scheme and reality (%73). Participants could understand that there can be more than one classification scheme in nature because there is no certain knowledge about how really nature is and science is tentative. As a result, researchers found that in-service science teachers answered most NOS questions in modified version of VOSTS questionnaire as naive category. Researchers suggested that there should be more emphasize in pre-service teacher education programs about NOS, and professional development programs about NOS should be supported to develop in-service teachers' understandings of NOS. In education faculties, science method courses should include NOS, learning as conceptual change, history and philosophy of science to develop pre-service teachers' NOS views who will be in-service science teachers in future.

As Doğan and Abd El Khalick (2008) suggested, some researchers conducted some workshops and professional development programs in order to develop in-service teachers' naïve ideas about NOS. For example, Posnanski (2010) developed and conducted "NEST" Nature of Elementary Science Teaching professional development program about NOS where 22 K-8 in-service science teachers participated. This study both aimed to improve science teachers NOS views and their NOS instruction in their classrooms. Researcher claimed that only pedagogical knowledge is not sufficient to develop understanding of NOS. Therefore, he focused on both PCK and content knowledge in this study. Teachers' NOS views were gathered by use of the Views of the Nature of Science Questionnaire (VNOS-C) developed by Lederman et al. (2002) before and after the program. Teachers' NOS instructions were observed in their classrooms and 8 teachers were selected to be observed. According to VNOS-C, teachers NOS views were naive at the beginning of the study and their NOS views were informed at the end of the study. On the other hand, all participants scored lower both before the study and end of the study in terms of observation/ inference aspects and theory/law aspects of NOS. In addition, participants reported that this program developed their PCK in selected topic, NOS views and content knowledge in the interviews that is conducted to reveal strength of program. Interview results also showed that teachers gained general views of NOS in this program. However, teachers did not mention specific aspects of NOS. During observations, teachers taught NOS explicitly in first observations. However, teachers showed little effort to teach NOS in their classrooms in the following observation which showed that effect of this program is short-lived. Furthermore, some teachers claimed that both standard exams and curriculum did not include NOS, therefore it was unnecessary to teach NOS in their classrooms. Researcher suggested that such kind of teacher development programs should include constructivism based activities which may change teacher orientation towards science. By this way, teacher understanding of NOS can be better and they can reflect these changes into their teaching.

Similarly, Doğan, Çakıroğlu, Çavuş, Bilican, and Arslan (2011) examined the one week in-service program for in-service science teachers to develop an understanding about nature of science. This study was conducted in Ankara and Bolu cities and 44 in-service science teachers participated in this study. *Views of Science-Technology and Society Questionnaire* was used to collect data that was prepared by Ryan and Fleming (1989). Responses of the participants were analyzed as traditional, acceptable and contemporary. The possible relationship between pre-test and post-test results was analyzed by chi square test. As result, participants developed themselves in the items in terms of scientific knowledge depends on evidences based on experiment and observation, classification of hypothesis, theory and laws, “scientific method” myth and epistemological place of hypothesis. On the other hand, teachers had contemporary views on nature of scientific models, tentativeness aspect of NOS and probability of uncertainty in science both in pre-test and post-test results. They also couldn’t develop contemporary understandings for the assumptions of theory and law both in pre-test scores and post-test scores. Researchers claimed necessary materials should be provided to teachers to teach NOS to their students. Researchers also mentioned that it was one week in-service program; therefore participants may not develop themselves in some aspects of NOS. Therefore, such kind of in-service programs and workshops should be expanded for time to get better results.

Capps and Crawford (2013) developed and conducted a professional development program with in-service science teachers called as “fossil finders” to develop in-service science teachers’ subject matter knowledge about evolution, geology and their NOS & inquiry knowledge in USA. Researchers claimed that teacher knowledge affect their classroom practice, therefore they should both improve their subject matter knowledge and NOS. Researchers in this study used quasi experimental design dividing 20 in-service teachers as participant group and comparison group. This professional development program lasted 60 hours. Natural history museum was also used to increase teachers’ knowledge. In addition, teachers had opportunity to work with archeologists to understand evolution and geology. The course also focused on the NOS and inquiry by the assistance of experts. Subject matter knowledge was measured by use of multiple choice questions and open ended questions on the other hand inquiry and NOS knowledge was gathered by use of open ended questions prepared by researchers. Pre-test and post-tests were applied to both participant group and comparison group for both subject matter knowledge, NOS and inquiry. In statistical analysis, ANCOVA was used where pre-test scores were covariate to eliminate beginning differences between two groups. According to the results, participants group developed their subject matter knowledge, NOS and inquiry more than comparison group did. At the beginning of the study, researchers found that participants views about NOS: science is experimental that ignore importance of observation, there is one scientific method which includes step by step procedure. In addition, only 30 % of the participants knew the difference between laws and theories. Rest of the participants thought that there is a hierarchy from theory to laws in pre-test scores. On the other hand, most of the teachers were aware of the difference between observation and inference (90%) and they knew that science is influenced by the social norms and socio-cultural issues (nearly 100%). At the end of the study, there was significant improvement on teachers' views on scientific method. They were aware that there are multiple ways of scientific knowledge which depends on the research questions. Teachers were also capable of understanding the difference between theory and laws explaining that laws are the statements that define observable phenomena and theories are the explanatory framework of multiple observations. In addition, participants developed their views about subjectivity and creativity aspects of NOS. On the other hand, participants who were limited knowledge of NOS couldn't develop their NOS views as much as researchers expected, but participants who had some degree of NOS developed their NOS knowledge as expected. Researchers related this situation with duration of program. Professional development program last 1 week and it was reported that this duration is not sufficient for the grasp understanding about such complex issue if teachers have limited knowledge about NOS.

Morrison, Raab and Ingram (2009) examined how elementary teachers and secondary teachers differ in NOS knowledge when they visit, observe and work with scientists. Researchers claimed that discussions with scientists and observing them can increase science teachers NOS understanding because they are not familiar to first hand scientific research. It is reasonable that this study would have more advantage for elementary teachers than for secondary teachers because secondary teachers are more familiar to scientific experience and research comparing with their elementary colleagues. In this study, scientists took role as teacher and teachers took role as students. VNOS-B (Lederman et al., 2002) was used to get data about participants' NOS views and 20 elementary and secondary science teachers participated in this study. Depending on the results, in-service teachers improved their NOS views from pre-test to post-test. Secondary science teachers NOS views were better than elementary science teachers at the beginning of the study. However, elementary teachers developed their NOS views more than secondary teachers did. Although elementary teachers developed themselves more than secondary teachers on NOS, secondary teachers still had better understanding about NOS depending on the post-tests. Observing scientists works and conversation with them about science also changed teachers' views about science teaching. After this study completed teachers tended to mention basic principles in their course, more explanation about scientific phenomena. In addition, teachers wanted to give students more freedom to investigate. They wanted their students to be independent learners. In their lessons, they wanted to use history of science to teach both content and NOS. They also wanted to benefit from scientific journals for both themselves and their students. Similarly, they said that they would support their students to use and develop their imagination. Finally, they said they would focus on cause effect relationship to solve scientific problems in their courses. Although this study is beneficial to improve both science teachers' views about NOS, scientists and science teaching; there should be same terminology between scientists and teachers to facilitate communication among them.

In conclusion, previous studies conducted with in-service teachers focused on teachers NOS views and the development programs formed in order to increase in-service teachers' NOS views. Previous studies showed that in-service teachers have naïve ideas about NOS knowledge in general and development programs are successful to improve teachers' NOS views in some degree. In this section, nature of science knowledge was used interchangeable to the syntactic knowledge.

2.1.2 Studies based on Substantive Knowledge

One of the aims of this study is to examine in-service teachers' content knowledge regarding cell division. In this section, studies based on substantive knowledge related with cell division were covered. Previous studies considered cell division can be four parts in terms of cell division studies conducted with students, cell division studies provided tools to increase students' cell division knowledge, cell division studies conducted with in-service teachers and cell division studies related to textbook analysis.

Cell division studies were mostly held with high school students in cell division literature. Brown (1990) examined 614 high school students' understanding of duplication of chromosomes in to chromatids, the separation of chromosomes in meiosis and the concept of allele. This study was based on a question about meiosis 1 metaphase stage. Question was taken from University Entrance Exam of England and Wales. In addition, different colors of pipe cleaners, plastic ties, self-adhesive labels and adhesive tape were given to pupils to make a model that represents their answers. By this way, students both procedural knowledge involving specific steps and conceptual knowledge employing certain steps and rejecting others were evaluated. Significance of this study is to relate genetics and meiosis which expects to increase students' understanding of these concepts. Results of the study showed that only 14 % of the participants answered the question correctly, 53% of the participants identified each chromosome has duplicated into identical chromatids. On the other hand, 18 % of the participants showed identical chromatids in a chromosome with different colors which is a misconception identified in this study. Similarly, 10 % of the participants showed that one chromosome consisted of 4 pipe line (chromatid) that is another misconception found in this study. Furthermore, only 16 % of the participant knew that sister chromatids carry the same allele. Also, 8 % of the participants left some chromatids blank which was misconception. In addition, 2 % of the participants put different alleles on sister chromatids which was another misconception and 9 % of the participants placed different alleles on sister chromatids for both of the homolog chromosomes. Moreover, 23 % of the participants didn't try to answer the heterozygous aspect of homolog chromosomes. Some of the students put related alleles in the wrong position on chromatids which show us students have difficulty in concept of "locus". Finally, students were well in putting chromosome in equatorial plate of cell in metaphase. However, researcher claim that teaching and learning description of named stages of cell division is not necessary because static knowledge on cell division will not be helpful for students to understand process of meiosis.

Lewis and Wood-Robinson (2000) conducted three study regarding high school students' knowledge on genetics related concepts rather than focusing on their misconception about these issues. Totally, 482 students whose ages are between 14-16 participated in this study from England and Wales high schools. Data were collected by written questions and interviews. Content of the questions were based on size sequence of cell, chromosome, gene, DNA, organism and nucleus at first part. Next, living things and their relationship with their genetic information was focused on. Then, biological terms such as DNA, chromosome, allele were asked to students. After that transfer of genetic information within individual cell was asked to responders. Later on, process of cell divisions and purposes of them were asked. Finally, researchers focused on reproduction related concepts such as fertilization and genetic information transfer to new generation were asked to students. According to results, 73 % of the students think that genes determine people characteristics, 14 % of them think that it is important because of the transfer of genetic information. Only half of the students think that genes are found in cells. 25 % of them think that genes are found in some organs such male reproductive system. In addition, 3 % of the students stresses that alleles are the different forms of genes. 11 % of them think that genes are found in chromosomes and 25 % of them reported that genes are bigger that chromosomes. 11 % of students think that there is no relation between genetic information and chromosomes. About the living things and their relationship with genetic information, only half of the participants could know that genetic information is found in all livings. Researchers related this situation with their misconceptions about the living criteria about the cellular structure. Researchers also reported that majority of the students didn’t know the differences between mitosis and meiosis and only minority of them know the difference between somatic cells and gametes. Similarly, majority didn’t know the processes and purposes of cell division. Most of the students think that genetic information found in cells are used for only that cell needs and functions and these students are lack of the knowledge that this genetic information is used for the production of new cells and new individuals. 10 % of the students thought that each cell in an organism carry different genetic information. On the other hand, 20 % of the students thought that an individual’s all cells contain same genetic information. 26% of the students thought that all cells in an organism contain same number of chromosomes. 22 % of the students thought that different cell types such as cheek cells and nerve cells carry different genetic information. 12% of the participants thought that number of chromosomes reduced during all cell divisions because they think that cells share their chromosomes with new ones so number of chromosomes decreases. Specifically about their view on mitosis and meiosis, 33 % of the students thought that mitosis is important for plants' growth, repairment and replacement of cells. 15 % of them thought that meiosis is the preparation for reproduction, 15% of them thought that meiosis increases the genetic variation and only 8 % of the students pointed out that number of chromosomes decreases during meiotic division. 45 % of the students knew that gametes have same number of chromosomes. Researchers pointed out that some of the participants knew that same type of cells include same number of chromosomes although they didn't understand the purposes of meiosis. Students also had some difficulties for the understanding of sexual reproduction in plants because of their lack of knowledge on the mechanism of pollination and they thought that seeds are evidence for asexual reproduction for plants. In conclusion, researchers showed that secondary school students have lack of knowledge on genetic related issues and they held many misconceptions. Findings of this study are important as serving curriculum makers who were supposed to make science for all curriculums leading scientifically literate public.

In another study, Atılboz (2004) examined 139 9th grade students' knowledge and misconceptions about the mitosis and meiosis division. Data were collected by use of 25 open ended questions. Researcher claimed that because of cell division is at the microbiological level, it is very difficult for students to make it concrete in their mind. Results of the study showed that 44% of the students didn't know that DNA replication must occur to make number of chromosomes constant after mitosis. None of the students could know that condensing of DNA and protein shape the chromosome. On the other hand, more than half of the students knew the number of chromosomes after mitotic and meiotic cell division. 8% of the students could draw the daughter cell structure correctly after a given cell picture exposed to mitosis and 10% of the students could draw gametes correctly after a given cell picture exposed to meiosis. 53% of the participants could give example of diploid cells found in human body and 43% of them could give example of haploid cells. 40% of the students could answer that firstly homolog chromosomes separate from each other and then sister chromatids separate from each other. Half of the participants could know that crossing over occurs after tetrad formation. Researcher concluded that high school students have difficulty and misconceptions in understanding about chromosome-DNA relationship, structure of daughter cells and gametes that formed after mitosis and meiosis, diploid and haploid cell definitions, number of cells formed after cell divisions, concepts of homolog chromosomes and sister chromatids, and the events occurred in meiosis and mitosis. Researcher claimed that students couldn't know this basic terms and their relationship, it is reasonable that they weren't able to understand events occurred in cell divisions and processes of cell divisions. Researcher suggested teachers to focus on why and how these events occur rather than expect their students to memorize stages of cell divisions. Researcher also advised teachers to use concrete activities which eliminate the possible misconceptions and increase students' understandings in cell division.

In conclusion, previous studies showed that students have many difficulties and misconceptions related with cell division topics. In addition, these topics are abstract in nature and it is difficult to learn which makes studying on cell division topics valuable. Cell division studies were not limited to identify high school students' cell division knowledge. Moreover, science educators developed some models, tools and concept maps to develop students' understandings of cell division because cell division topics are abstract and difficult for students to be learnt. Some of the examples of studies that developed tools, models and concept maps to facilitate students' understandings were presented below.

Some students better learn by physical activity and some others learn reflectively. Some learn with sequential steps on the other hand some learns by large jump. Hand models are useful to understand some topics for both students who learn with physical activity and reflective students who use these models by thinking. Mickle (1990) provided a hand model that represents to mitosis and meiosis for students understanding of the dynamic process of cell division. The lack point of this model is that it doesn't show nuclear membrane, cytoplasm and spindle during cell division. This model emphasizes the duplication of chromosomes into sister chromatids, split of sister chromatids, duplication of DNA during interphase. Middle and index fingers for each hand were used as chromosomes in this model. In addition, each stage of the meiosis and mitosis were represented by this model. For example, model shows only index fingers of two hands as the representation of cell before interphase of mitosis. This model may lead us the compare meiosis and mitosis during teaching. Chromosomal segregation can be successfully shown by this model. However, it is not suitable to show crossing over, and there is a lack point for the clear representations of the prophase and telophase stages. In addition independent assortment can't be represented in this model because we can use only a pair of chromosomes. Here, researchers suggested students to make cooperation for this model to explain independent assortment as four different chromosomes. Final advantage of this model is that it requires little time for preparation and it has no cost.

Kindfield (1994) developed a tool to assess students understanding of the meiosis. Researcher prepared a meiosis question to see undergraduate students' model for meiosis and interviewed with the participants related with their models. Kindfield saw this reasoning problem as a tool for assessing students' understanding of meiosis. In their answers, students drew their diagrams for their explanation of the events that are expected to occur during meiosis showing meiosis 1 and meiosis 2, sister chromatids, homolog chromosomes, alleles, centromeres, separation of homolog chromosomes, separation of sister chromatids, and gametes. Alternative diagram drawn by students showed that students thought sister chromatids have different alleles. Although origin of chromosomes comes from replication of DNA in interphase, students thought that origin of the chromosomes is the joining of homolog chromosomes found in gametes during fertilization. In addition, interview results showed that students didn't mention the crossing over or its impact on variation. This study as a reasoning problem can show students their lack points and misconceptions. This situation makes them confronted and dissatisfied, so they can motivate themselves to learn the scientific explanation of phenomena. This study also lets students to solve meiosis problem more than one way making the issue more flexible. Kindfield suggested students to draw diagrams for better understanding of meiosis because diagrams explain the gamete production at the easiest and the best way. They are more useful than verbal explanation of meiosis. By the use of such kind of reasoning problem, students develop robust understanding on the process of meiosis. Researcher also claimed that robust understanding of the meiosis will facilitate the students' understanding of genetics concepts.

Clark (2000) developed a model kit to represent cell division models better. Researcher claimed that their kit model is useful for solution of meiosis and mitosis problems. Researcher offered instructors to guide their students during the application of kit models. Teachers can also easily identify students' misconceptions related with cell divisions. Researcher kit model includes chenille stems colored yarn, plastic straws, petri dishes, clothesline, miscellaneous containers, and a little glue. This kit model was useful for students review at home and a pair of students can benefit from each of this kits. Chromosomal structures, chromosomal replication synapsis, genetic segregation, independent assortment of alleles, reduction division, and stages of cell divisions can be shown by this model. This model is also useful for chromosomal nondisjunction which is resulted by genetic disorders such as Down syndrome. In Clark's study, undergraduate students had some misconceptions and these misconceptions were apparently released by the use of kit model. Undergraduate students were not aware of the fact that sister chromatids are identical because they showed sister chromatids using with different colors. This kit was also used in a workshop that secondary school teachers joined. 98% of the teachers (n=74) reported that this kit model is very useful to explain cell division. In addition to workshop, this kit model was presented to the genetics majors. Similarly, genetics majors (n=28) found this kit model purposeful, creative and worthwhile depending on a 7 point Likert type scale. If there can be some modifications, researcher claimed that this kit model can be used in elementary science classrooms.

Concept maps are used for both assessment and teaching tool. Concept maps make abstract and difficult topics more concrete and visual. Concept maps lead meaningful learning. Kazancı, Atılboz., Bora and Altın (2003) advised teachers to use concept maps in genetics related topics. By the use of concept maps, teachers could understand possible misconceptions that students hold. In addition, concept maps increase students' motivation and attitude towards biology courses. Researchers also advised that concept maps can be useless when it is used solely in science courses. Concept maps should be integrated other class activities during lecture. Researchers suggested that the use of concept map as a teaching tool should be taught to teachers in professional development programs.

In an experimental study, Sarıkaya, Selvi and Bora (2004) examined 56 9th grade students' science achievement based on the use of models in cell division. Pre-test post-test controlled group experimental design was conducted in this study. Experiment group included 32 students who took traditional teaching before they created their own models about cell division. Control group included 24 students who took only traditional teaching. An achievement test was developed by the researchers to assess students' cell division understandings. This test was applied to each group before and after the course. While students in experiment group created their own models, they used play dough to construct chromosomes and stages of mitosis and meiosis. Researchers emphasized the important terms such as homolog chromosomes, heterozygote, homozygote, tetrad, synapses, crossing over and gene while students forming their models. Independent sample t-test results showed that there was no statistical difference between groups in pre-test scores, however, experimental grouped statistically performed better than control group. Results showed that modeling was useful for the learning of abstract and complex topics such as cell division topics. Researchers suggest that hands on activities such as modeling help students to improve their science success, their attitudes towards science courses and their motivation. When students actively engage in an activity, they can listen, see, touch and analyze which facilitate the learning and decrease the forgetting of a concept. In conclusion, models are useful which make the science topics easier. Researchers also advised that cheap and readily available materials are better to be used in modelling.

In an another experimental study, Kılınç (2008) examined the effectiveness of "divided fingers" activity as a teaching activity for cell division topics among 9th grade high school students in Ankara. Total 58 students participated in the study (30 for control group, 28 for experiment group). Control group got traditional teaching method and experimental group got "divided fingers "activity. Data were collected by cell division content knowledge test. Pretest-posttest controlled group design was used in this study. At the end of the study researcher found that there is a statistically significant increase for both control group and experiment group. However, results showed that experiment group performed better than controlled group depending post-test scores that was measured by independent sample t-test. This study showed that alternative models are useful for the effective teaching and learning of cell division topics. Kılıç also mentioned that students had difficulty on cell division content knowledge test's some items. The most difficult items was related with diploid-haploid number of chromosome concepts, difference between somatic cells and gametes, reason for cell division, change of number of chromosome after cell division, characteristics of stages and their sequence, difference between mitosis and meiosis, and some concepts as zygote, gametes, tetrad and homolog chromosomes. Researcher also mentioned that learning cell division concepts are important because reproduction and development topics can be understood better if students learn the cell division successfully. In addition, some important biological terms such as DNA, gene, crossing over will facilitate the learning of other biology topics such as genetics, evolution and protein synthesis.

Cell division studies were also conducted with science teachers. However, these studies are less than other studies which were held with highschool students. Studies held with science teachers to understand their cell division knowledge are presented. Students have many misconceptions in biology and they are sourced from their everyday life experiences, incomplete views during instruction, textbooks and teachers. Although everyday experiences and their incomplete views as source of their misconceptions have been investigated by science educator in so many studies, teachers as a source of students' misconception in biology are not focused in science education, so Yip (1998) focused on secondary level biology teachers misconceptions' in biology topics. According to results, Yip claimed that teachers have misconception that pollen grains are equal to male gametes (sperms). Another misconception found in this study is "Genetic variation makes the individuals better adapted to the environment." According to this misconception, one may think Lamarckian misconception that genetic variation cause progressive development. On the other hand, genetic variation makes the individuals better adapted thanks to the natural selection. In addition, Yip claimed that lack of centralizing evolution in biology topics in curriculum and lack of teacher knowledge about natural selection cause some misconception about reproduction and genetics related issues in teacher mind.

Öztaş, Özay and Öztaş (2003) examined difficulties that secondary school biology teachers encountered at cell division topics. 36 secondary school in-service teachers participated in this study. Data were collected by open ended questions regarding cell division. Researchers found that 40% of the participants viewed cell division topics as the most difficult biology topic for teaching. 45% of the teachers used diagrams, pictorials, materials and slide for teaching cell division, 16% of them used video films, 27% used models explaining cell division, and 25% used laboratory activities such as observing onion cell division. Participants had most difficulty in teaching meiosis' prophase-1 stage. In addition, 13% of them had difficulty in explaining the relationship between DNA and chromosome. In addition, researchers examined teachers' answers about where students had problems in cell division. 26% of teachers claimed that terminology of cell division compelled students' understandings. 42% of teachers thought that detailed structure of cell division makes this topic difficult for comprehension. Researchers suggested teachers to use different types of teaching aids such as photos of chromosomes in different stages of cell division, film-video and models about chromosomes for effective teaching of cell division.

Students' prior knowledge and view that they hold are very important for their learning. So, their prior knowledge and misconceptions should be identified before new knowledge is constructed. In this study, three different American high school biology textbook were analyzed by Cho, Kahle, and Nordland (1985) for meiosis and genetics. Researchers firstly analyzed the conceptual organization of the meiosis and genetics. Textbooks covered the genetics and meiosis in separate chapters and meiosis chapter was isolated from genetics. However, genetics and cell division topics should be integrated with each other. These high school textbooks also didn’t mention how and when chromosomes doubled and how chromosomes are formed by two chromatids. Also, textbooks didn’t mention the origin of homolog chromosomes. In addition, chromosomal division was covered in meiosis chapter and alleleic segregation was covered in Mendelian genetics and textbooks didn’t attempt to any relation between chromosomal division and alleleic segregation. Textbooks had also different definitions about the terms about genetics. These different definitions may cause some cognitive dissonance for learners. Authors recall the Novak (1977)’s suggestion to eliminate cognitive dissonance claiming that there should be a hierarchical relationship between concepts and topic should be clarified to learner. Authors also claimed that explanation of mitosis before meiosis may increase learners’ understanding of cellular reproduction, but separate explanation of cell division and genetics may impede students to connect these two topics. Researchers suggest that a diagrammatic representation can be helpful for the explanation of gamete formation, allele segregation, zygote formation, and homozygous & heterozygous forms, dominant and recessive traits.

In conclusion, cell division studies as substantive knowledge was covered in this section. Cell division studies were conducted with students and teachers. These topics are difficult for both learning and teaching. Therefore, researchers developed some models and teaching tools in order to increase science courses efficacy in cell division topics. In addition, researchers analyzed textbooks and offered some curricular changes in order to increase students’ understandings in cell division topics.

2.2 Studies regarding Science Teachers' PCK

Second research question of this study aims to understand science teachers' PCK about cell division topics. Hence, PCK studies held with in-service teachers and pre-service teachers were reported in this section.

2.2.1 PCK Studies Conducted with In-service Teachers

One of the aims of this study is to examine in-service teachers' PCK regarding cell division. Therefore, previous studies that examine in-service teachers' PCK were covered in this section in order to understand and to be informed about previous studiesabout in-service teachers' PCK.

PCK studies were held with chemistry teachers in general and Van Driel, Verloop and De Vos (1998)' study is one of the examples of these studies. Van Driel et al. (1998) conducted their PCK study about in-service teachers that is related with chemical equilibrium in terms of student understanding of selected topics and representation of subject matter knowledge which Shulman (1986) pointed out. Researchers designed a workshop to develop experienced in-service teachers PCK in chemical equilibrium unit. In this study, 12 experienced chemistry teachers participated in workshop. First of all, participants became together and discussed about how their students' response would be to selected curricular activities about chemical equilibrium. Secondly, teachers transferred their classroom lessons to the workshop. Teachers classrooms was adjusted fostering conceptual change approach. Students were let to make small group discussion. By this way, teachers could understand what their student think and in what concepts their students had difficulties about chemical equilibrium. Teachers reported that students had some problems in dynamic nature of chemical equilibrium. In addition, teachers had some difficulties in this unit. Teachers accepted that they could make little arguments to convince their students, however they could make some analogies to explain forward and backward movement of the molecules. During the argumentation among students in class and discussions among teachers in workshop develop teachers' understanding of what their students think in chemical equilibrium. By the help of this workshop, teachers could develop an understanding about what their students' difficulties in chemical equilibrium. Similarly, teachers used small group discussions, argumentations and made some analogies to facilitate students' learning after participation to the workshop. Researchers concluded that application of programs like workshops are beneficial for changing teachers' knowledge and beliefs which have crucial effect on teacher practice. In addition, researchers suggested that programs that aim to increase teacher knowledge and beliefs should be based on constructivist epistemology because teacher knowledge and beliefs are affected by their background and context where they live. Constructivist epistemology can provide a bridge between their previous knowledge and the knowledge that is aimed to be gained with the help of the workshops.

Science educators held their studies not only with experienced science teachers, but also with beginning in-service teachers. One of the examples of PCK studies held with beginning science teachers is Appleton and Kindt's example. Appleton and Kindt (1999) examined beginning teachers PCK in terms of their use and understanding of activities. Researchers studied with 20 in-service teachers in this study. Data were gathered by observations and interviews. Researchers thought that beginning science teachers didn't have sufficient content knowledge. In this study, researchers examined the question that "If beginning teachers have limited PCK, how do they teach in class?" Interview results showed that some beginning science teachers don't teach science in their class and some of them shared the science topics with the teacher of next class and they teach some of the topics and don't teach the rest of the content. Some beginning teachers delay the starting of the lesson and sometimes when beginning teachers face with unexpected events in class, they gave up the teaching. Findings of this study also showed that beginning science teachers used activities as a substitute for their limited PCK. Some of them used the activities which are not consistent with science teaching borrowed from other lessons such as reading book. On the other hand, some others used hands on activities or experiments. Researchers' observation results showed that after teachers get familiar to hands on activities, their confidence increases and the use of such kind of activities become a part of teacher's PCK. This situation shows that beginning teachers' PCK develops over time and they become experienced science teachers. Researchers claimed that science activities will be useful under a curriculum that relates different topics each other. By this way, researchers established a relationship between beginning teachers' knowledge of instructional strategies and knowledge of curriculum. If curriculum is fragmented, activities in that curriculum would be isolated from each other which let the students think that activities perform best and science can answer all the questions that positivist paradigm suggests. Finally, these isolated activities will make the students distant from inquiry. Researchers suggested curriculum makers to develop a curriculum that includes less content and more meaningful understanding. Researchers advised that importance of science should be emphasized in schools and beginning teachers should be fostered by mentor teachers to develop beginning teachers' PCK.

PCK studies were not limited with chemistiry topics. Researchers also focused on PCK studies which were conducted with expereinced biology teachers. Yarden and Cohen (2009) wanted to examine 6 experinced in-service junior highschool teachers' PCK regarding cell topic under the last curriculum suggestions for teaching cell with other contents in Israel. Biology topics such as cell can be taught to the learner mainly by three levels in terms of macro (organismal level) that is useful for learning, micro (cellular) level that make some constraints for the learner due to visual problems and molecular structures what is not seen even indirectly. Researchers explained that the current curriculum in Israel expects teachers to connect these three different levels each other when teachers integrate cell and other science contents. Data were gathered by teachers' responses to authentic students' explanations of biological phenomena, semi-structured interviews, visual illustrations, teachers' tests, questionnaire and unfamiliar test questions which tests knowledge of cell found in curriculum. Result of this study showed that teachers had duality in their orientation towards science. They thought that cell topic should be obligatory in curriculum and it is very important in biology education. However, teachers thought that teaching cell topics is difficult, so they may postpone teaching or give little time to teach it. Results about teachers' knowledge of curriculum showed that teachers had little knowledge of curriculum about cell. Although teachers knew that there was a change in curriculum about cell topic, they couldn't detail it. The integration between cell and other topics wasn't provided by teachers in biology. Teachers could sorted the objectives and goals for cell topics depending on their importance. However, they couldn't relate macro level and cellular level which showed that they had not fully understanding of curricular objectives. Similarly, although Israel curriculum provided teachers 5 books as learning materials, most of the teachers were familiar and used only 2 of them which is another proof for their lacked PCK. On the other hand, researchers found that teachers had robust understanding about knowledge of learner. For example, teachers identified that students can't imagine the size of a cell and ignore the three dimensional structure of cells. Teachers reported that their understanding of students difficulties let them to adjust their teaching for students achievement. This situation showed that knowledge of learner has an impact on teachers' knowledge of instructional strategies. The teachers' knowledge of assessment was also found little. Teachers asked multiple choice questions, simple factual questions that recall information and they were affected in their assessment by the questions that were examined in national evaluation exam applied in Israel. Yarden and Cohen pointed out that national exam can be external factor in shaping teachers' knowledge of assessments. Furthermore, it was reported that written explanations were not asked by the teachers which requires higher cognitive level knowledge. In addition, researchers claimed teachers gave minimal attention for assessing integration of cell and other topics which shows the interaction between knowledge of assessment and knowledge of curriculum. Similarly, the assessment was based on the materials that were used in classroom, so knowledge of assesment and knowledge of curriculum can be closely related. When they taught cell in micro level, they used several teaching methods such as models, films and illustrations. However, when teachers taught the relationship between macro and micro level they didn't use several teaching methods. Researchers suggested science educators close to PCK as a hole because of the intaraction between different components of PCK. In conclusion, Yarden and Cohen examined experience science teachers PCK regarding cell under the suggestions based on curricular changes. Participants PCK components were found little apart from knowledge of learner and there is a strong interaction among PCK components which make the researchers to think that PCK as a whole.

Another PCK study held with experienced science teachers in the context of biology topics is Lankford's' case study. Lankford (2010) examined 6 experienced in-service teachers' PCK regarding diffusion and osmosis in her doctoral dissertation. Data were collected by observations, semi-structured interviews, lesson plans and student handouts. Five teachers out of six were found as constructivist in terms of their orientation towards science. One teacher believed that students can't explore and become knowledge transmitter as orientation. Teachers used demonstrations and laboratory investigations and five of them preferred to use implicit 5e as knowledge of instructional strategies. Teachers also could identify students' difficulties which are terminology in diffusion such as hypertonic and hypotonic, direction of osmosis and random molecular motion as driving force for diffusion as knowledge of learner. Teachers cope with these difficulties by defining the terminology before teaching, making demonstration for direction of osmosis, and using computer animations for random molecular motion. The way of eliminating students difficulties showed that teachers' knowledge of learner affect their knowledge of instructional strategies. Teachers also used formative assessment. Before teaching teachers checked their students prior knowledge and identify possible misconceptions. During lesson, teachers assess their students' content knowledge. Simple observations of teachers also let them to understand whether their students learn or not. Teachers' knowledge of assessment assists them to understand students' potential difficulties. However, all the teachers exceeded curriculum because they taught random molecular motion. In conclusion, this study showed that experienced teachers had well PCK regarding diffusion and osmosis in terms of PCK components. Researcher claimed that these components are integrated with each other. Because of teachers had constructivist orientation, other components are shaped by teacher' knowledge of learner where teaching is centralized on students.

Pre-service science teachers had limited PCK knowledge in science concepts. On the other hand, in-service experienced teachers had grasp understanding of PCK comparing with pre-service science teachers. Early career teachers who have two or three years of teaching experiences in their class can be thought as novice teachers. Williams, Eames, Hume and Lockley (2012) examined the potential benefits of using CoRes in early career science teachers PCK development in organic chemistry and technology units. Researchers thought that if PCK of a teacher has a dynamic structure that is open to change, these novice teachers' PCK in selected topic can be developed through the use of CoRes. Both subject matter experts and pedagogical experts participated in this study to assist novice teachers to construct their CoRes. This study was conducted in New Zealand and 4 novice teachers participated in this study. Research questions were based on how novice teachers and experts work together, how construction of CoRes affect novice teachers' planning of their lesson and how construction of CoRes affect novice teachers PCK and their classroom practice teaching in actual classroom. Qualitative research methods and case study approach were followed in this study. Field notes, observations and interviews were used to collect data to answer how novice teachers and experts work together. Results of this study showed that both novice teachers and experts benefit from this collaboration. Novice teachers claimed that they developed their knowledge of curriculum and knowledge of instructional strategies by the assistance of subject matter and pedagogical experts. Novice teachers acknowledged that they learnt new pedagogical techniques to teach organic chemistry and learnt the key concepts that are related in curriculum. CoRes were also helpful for novice teachers' planning their lectures. For example; one of novice teachers used time more efficient when he changed the place of nomenclature from middle of the lesson to the beginning of the study which is a proof as gaining on knowledge of curriculum (making adjustments on curricular schedule). In addition, novice teachers reported that they could give more daily life examples when they use CoRes which shows that novice teachers had some changes on their orientation to teaching. Similarly, novice teachers reported that they felt themselves more confident in organic chemistry courses and their beliefs toward science changed after preparing CoRes with expert teachers (orientation towards science). As a result, this study showed that Content Representation Tools (CoRes) can be helpful for novice teachers to develop their

PCK in specific science topics. However, expert teachers and subject specialists should help the novice teachers during the preparation of CoRes until novice teachers become familiar to using this tool for their teaching.

Peripheral orientation is subcomponent of orientation towards science aspect of PCK. Feierabend, Jokmin and Eilks (2011) examined 20 experienced German chemistry teachers' views on teaching climate change as peripheral orientation. Data were collected by semi-structured interviews. Results of the study showed that experienced German chemistry teachers ignored teaching of climate change and they didn't give enough time to teach climate change in chemistry classes. In addition, teachers preferred to teach traditional chemistry contents instead of teaching climate change. Some teachers viewed climate change as new topics and some others thought that climate change doesn't belong to chemistry subject. However, participants mostly thought that climate change is related with chemistry. The chemistry topics which are related with climate change were reported as topics which are environmental issues, CO_2 in the atmosphere and emission of CO_2 due to combustion. Participants thought that teaching climate change is important because it lead students to learn scientific knowledge, change behavior, evaluate topics socio-scientific issue, judge media and relate chemistry with daily life. In conclusion, chemistry teachers' views on teaching climate change showed that they ignored the required time to teach climate change in their class. On the other hand, teachers were aware of the importance of climate change teaching and they thought that teaching of climate change would facilitate to meet educational goals as socio-scientific issue. This situation showed that experience science teachers may have duality in their peripheral orientation to the specific science content.

Science educators' PCK studies held with in-service teachers aimed not only to reveal science teachers' PCK in specific topics but also to show impact of content knowledge on teachers' PCK. By this aim, Akerson (2005) claimed that elementary science teachers may have lack of content knowledge due to insufficient courses that they took in their undergraduate. Therefore, Akerson examined how two experienced in-service teachers whose teaching experience is more than 5 years and one pre-service primary school teachers' ways of compensation for their incomplete content knowledge in this study. Data were gathered by use of observations and videotapes. The selected unit was astronomy in this study. Akerson found that there are some triggering factors that make experienced teachers to compensate their lack of content knowledge. These triggering factors were students' questions and comments. These experienced teachers planned to make activities about the topics before the lesson; however, when they saw they didn't have sufficient content knowledge, they gave up the activities and selected to read non-fictional trade book and current news to the class. This shows that little content knowledge affect teachers' choice for instructional strategy. Reading nonfictional trade books and current news in class increased both experienced teachers' content knowledge and their students' content knowledge. These experienced teachers not only changed their lesson plans, they also elicited students' misconceptions and used correct scientific explanations to increase students' understandings. This situation proved that increase on content knowledge also increased teachers' knowledge of learner. On the other hand, Akerson found that triggering factor which let pre-service teacher to compensate her lack of content knowledge was her personal concerns rather than the need for increase on students' understanding. Pre-service teacher selected an activity which extended the students' grade level. The teacher also couldn't perform the activity and students remarked that they couldn't understand the topic. This situation showed that pre-service teacher's little content knowledge may cause insufficient knowledge of instructional strategies and knowledge of learner. This study suggests that teachers who have little content knowledge may change their knowledge of instructional strategies and knowledge of learner after increasing their content knowledge.

Nature of science knowledge was another dimension of content knowledge; hence researchers explored the impact of NOS knowledge on science teachers' PCK for NOS. The following studies examined the impact of syntactic knowledge on PCK. Khalick and BouJaoude (1997) examined 20 in-service female science teachers' knowledge base. Teacher knowledge base was evaluated in terms of their function knowledge, structural knowledge, development knowledge, and nature of science knowledge. Teachers' NOS was evaluated by VOSTS questionnaire and teachers were classified as naïve or informed in NOS knowledge depending on their answers. Researchers also planned teachers to draw concept maps to release their knowledge base. In the interview part, researchers asked teachers what changes they would do if these concept maps were used to teach content to different grade level students depending on teachers concept map. By this way researchers would learn in-service teachers' knowledge of learners and knowledge of curriculum. In addition, researchers claimed that knowledge of learners would lead teachers to choose strategy (knowledge of instructional strategy). Results of the study showed that most of the in-service teachers were naïve for nature of science knowledge (%67). 94 % of the teacher viewed there is only one single scientific method and they ignored the creativity and imagination' importance in science. Similarly, 47 % of the participants thought that scientific models were copy of life such as atom models ignoring the humanistic aspect of science. 82 % of them didn't appreciate the role of theories and finally, 71 % of them didn't accept subjectivity aspect of science. After they drew their concept maps, they couldn't make enough change on their concept maps to make them understandable for students. Teachers were also unaware from students' misconceptions and they were lack of activities and instructions to teach concepts. This situation showed that teachers were weak on knowledge of learner, knowledge of curriculum and knowledge of instructional strategies. In conclusion, this study showed that in-service teachers held both naïve views on NOS and their PCK were found insufficient in terms of knowledge of learner, knowledge of instructional strategies and knowledge of curriculum showing that there is a positive relation between syntactic content knowledge and PCK.

Lederman and Lederman (2004) conducted a study called as ICAN (Inquiry, Context, and Nature of Science). The aim of the study was to develop in-service science teacher's understanding of NOS and scientific inquiry and teacher's ability to teach these concepts in their classrooms. The study included three stages in terms of summer orientation where background knowledge was presented to teachers and basic NOS, scientific inquiry explicit instruction were taught to teachers, monthly academic year workshop where teachers videotaped their lessons and discuss their lessons covered in their actual classrooms with their colleagues, and a three week summer institute. Although 58 teachers participated in this project, researchers shared one grade 1-2 level teacher's understanding of NOS and scientific inquiry and her development in these concepts. In addition, teachers practiced with scientists to see how scientists work and to understand how nature of science is. Furthermore, teachers participated in informal education programs such as visiting zoos and museums in this project. Data were collected by VNOS-D. Results of this study showed that the participant teacher's NOS views were naive at the beginning; however, she developed her NOS views significantly about tentativeness, creativity, subjectivity, empirical aspects and distinction between observation and inference. In addition, teacher developed her views about scientific methodology. At the beginning she thought that there is a step by step process, and then she thought that research question guides the scientific procedure. This study also changed teacher's instructional practices. Before project started, teacher used discovery centered instruction. However, she added explicit NOS instruction to discover centered instruction in her class after she participated in project. Small group discussions and inquiry based investigations were applied in her classroom too. This study showed that a long term project can be helpful to teach NOS to in-service teachers. Researcher suggests that teaching NOS and scientific inquiry is related with content and grade level. Such kind of projects also support teachers' knowledge, instructional skills and values which develop both teacher's PCK and NOS views. Researchers mention that PCK and NOS knowledge grow together implying direct relationship.

Hanuscin, Lee and Akerson (2010) reported that although recent efforts increased teachers understanding of NOS, teachers still can't teach NOS effectively in their classrooms. In order to assist science teachers' practice teaching about NOS, researchers conducted a three year last professional development program for these in-service people. After this study completed, Hanuscin et al. (2010) decided to make secondary analysis using the same data. In their second study, researchers deal nature of science as specific topic and examined these in-service teachers PCK for NOS. 3 in-service teachers who have well Nature of Science knowledge were selected in this study by purposive sampling. Data sources were questionnaire, interviews, field notes taken from classroom observations, videos, lesson plans, and focus group session conducted with participants at the end of the study. Results of the study showed that in-service teachers transform their NOS knowledge into the way that students can understand in terms of three different ways which are translating the scientific language into kid friendly terms, making operational definition about NOS in the context of inquiry, and creating analogies for NOS aspects with related children literature. Firstly, teachers used appropriate words when they teach NOS. For example, they used scientific knowledge can be changed instead of saying NOS is tentative. They also prepared posters which include age appropriate terms for students' better understanding of NOS while they translating scientific knowledge into kid friendly terms. Secondly, teachers used operational definition in the context of inquiry when they teach NOS. For example, students made some investigations in class and teachers resembled their activities with scientists' works and emphasized the related NOS aspects. However, Hanuscin et al. (2010) claimed that a curriculum emphasized on teaching NOS should be developed to conduct NOS activities in class where students' work can be compared to scientists' work. Thirdly, teachers used the stories which students are familiar. By the help of these stories, teachers made analogies to explain NOS aspects. For example; teachers benefit "blind mice story" when they teach subjectivity. Although teachers successfully used these strategies when they transform SMK of NOS, some meanings of the NOS aspects lost and students might not understand related aspects well. Apart from how teachers transform their NOS knowledge for students learning, researchers analyzed the results in Magnusson et al. (1999) PCK model using all of its components. This study's PCK results showed that teachers have little curricular knowledge because there was no available curricular material to teach NOS and teachers had no knowledge about the materials to teach NOS. Also, teachers needed addition lessons and activities to teach NOS which showed teachers had problems in timing and conducting activities about NOS. Teachers had robust knowledge of instructional strategies thanks to the development program that researchers conducted. The analogies and inquiry based activities made NOS lessons powerful for student comprehension. Assessment of NOS is blurred and teachers' knowledge of assessment was naive. For example; teachers didn't apply formal assessment techniques for NOS. Hanuscin et al. (2010) thought that there can be two reasons for this naive knowledge. First reason was teachers' views about the ignorance of NOS to teach it, and second reason was their lack of assessment knowledge for NOS. Authors pointed out that teachers' knowledge of learner was problematic. Although they used a grade-appropriate terminology to teach NOS, the lack of knowledge of assessment caused teachers to have weak understanding about what their students learnt and what their students' difficulties about NOS. When researchers pointed out the components of PCK, they also stressed the interaction among different components of PCK. Knowledge of assessment provides teachers to decide whether their instructional strategy is effective or not. In addition, knowledge of assessment provides data for the understanding students' weakness and strengths in specific topics which may increase the knowledge of learner. This study also showed the importance of knowledge of assessment on teachers' knowledge of learners and knowledge of instructional strategy. In addition, knowledge of assessment links teaching and learning each other. Curriculum materials are also helpful to understand common students' misconceptions. Similarly, curriculum materials such as textbooks can be helpful for teachers to use specific analogies and representations which increase teachers' knowledge of instructional strategy in selected topics. Therefore, knowledge of curriculum has significant impact on teachers' knowledge of learners and knowledge of instructional strategies. In conclusion, results of this study showed that teachers who had robust syntactic knowledge also had well orientation towards science and knowledge of instructional strategies. On the other hand, teachers had deficiency on their knowledge of learner, knowledge of curriculum and knowledge of assessment regarding NOS supporting that there may be partial relationship between syntactic knowledge and teachers' PCK.

PCK studies which are held with in-service science teachers are not limited with abroad. These studies also have been conducted in Turkish context. The following studies are PCK studies which aim to examine Turkish in-service teachers PCK. For example; science educators have been studied on novice science teachers' PCK regarding biology units in Turkish context. Karakulak and Tekkaya (2010) examined two novice teachers' PCK in the context of ecology topics. Components of the PCK model suggested by Magnusson et al. (1999) were used to analyze participants PCK. Data were collected by the use of semi-structured interviews, concept maps, lesson plans, observations and field notes. Results showed that teachers had some difficulties and misconceptions on the comprehension of ecosystem, habitat, decomposers, biodiversity, food web, and energy flow through the ecosystem. Although they had general knowledge on this unit, teachers had difficulty to connect objectives each other which showed that teacher had poor knowledge of curriculum. In addition, they had insufficiency on the activities found in curriculum. In addition, teachers' knowledge of instructional strategies were lack regarding ecology and they couldn't have enough knowledge for students' difficulties and misconceptions about ecology.

Moreover, science educators has been studied with experienced science teachers in Turkish context because experience teachers are expected to provide so much information about PCK. To this end, Aydemir, Çakıroğlu and Tekkaya (2012) analyzed 5 experienced elementary science teachers' knowledge of learner of PCK components regarding genetics. This component was divided into students' requirements for learning of genetics and students difficulties in genetics topics. Data were collected by use of classroom observations and interview with teachers. Results showed that genetics topic is abstract in its nature therefore students who learn genetics needs to be in formal operational stage as requirement because students below formal operational stage can't comprehend the abstract science topics such as genetics. In addition, there are some other requirements for the understanding of genetics. Biology topics are connected to each other, and students firstly need to learn about cell, cell division and fertilization if they want to learn genetics.

Another PCK study that was held with in-service teachers is Mıhlandız and Timur's PCK study. Mıhlandız and Timur (2011) reported pre-service teachers' views about the in-service teachers' PCK who were observed by pre-service teachers in the context of school practice course. Researchers examined this study via focus group interviews and 10 senior pre-service teachers participated in this study to discuss their views. Observed in-service teachers were working in primary schools in a big city. According to focus group interviews, 5 themes formed in terms of subject matter knowledge, knowledge of instructional strategies, knowledge of curriculum, knowledge of assessment and pedagogical knowledge for in-service PCK. Focus group interview results showed in-service teacher content knowledge was very little. Pre-service teachers also claimed that in-service teachers were lack of understanding students' misconceptions. Pre-service teachers emphasized in-service teachers either didn't use teaching method or used traditional methods as instructional strategy which showed in-service teachers' lack of knowledge of instructional strategies. In-service teachers also didn't use lab facilities and technologic materials consistent with their lack knowledge of instructional strategies. In-service teachers cared High school Entrance Exam and solved related problems. Therefore, in- service teachers didn't follow curriculum. On the other hand, in-service teachers used both traditional assessment techniques such as questioning and alternative assessment techniques such as performance assessment. Finally, in-service teachers had little pedagogical knowledge. Pre-service teachers also reported that real teaching environment is a factor that affect teacher PCK.

In this section, PCK studies which were conducted with novice and experienced in-service teachers were reported. Due to fact that PCK is a dynamic, some of the researchers examined the development of in-service teachers' PCK such as in workshops programs and some of the researchers used CoRes to develop teacher PCK. On the other hand, some others examined in-service teachers' PCK in current situation. Researchers usually used similar methodology and similar frameworks such as Magnusson et al. (1999) model. In the next part, PCK studies conducted with pre-service teachers will be reported. Moreover, previous studies held with in-service teachers attempted to show impact of content knowledge on PCK because PCK is the transformation of content knowledge.

2.2.2 PCK studies held with Pre-Service Teachers

PCK studies were mostly conducted with pre-service teachers (Aydın & Boz, 2012). In this section, previous studies that examined pre-service teachers' PCK were reported.

Veal, Tripsin and Jefferson (1999) examined the development of two pre-service teachers' PCK regarding linear motion and thermodynamics concepts found in secondary science curriculum. In this study, Veal et al. (1999) used integrative models for PCK which Cochran et al. (1991) suggested. Data were collected by use of interviews, field notes taken from observation of method class and practice teaching, and reflective journals. Researchers also used vignettes to be interpreted by participants to understand the change of pre-service teachers' PCK. Results of the study showed that experience is the most important factor that develops PCK. After pre-service teachers experienced in real class, they were aware the contextual knowledge such as bureaucracy, homecoming, limited budget, discipline issues etc. It is reported that pre-service teachers' experiences increased their understanding of students' ideas. After they could understand students' ideas, they selected instructional strategies which respond to students' needs. Results also showed that pre-service teachers were teacher centered at the beginning of the study and they adopted student centered approach when they become familiar to teaching. Researchers also reported that the increase on pre-service teachers' content knowledge may increase the teacher understanding of the student views which may change the teacher selection of instructional strategies. Finally, Veal et al. (1999) claimed that development of PCK was complex and nonlinear. Both of the pre-service teachers developed their topic specific PCK. When they developed their topic specific PCK, they learnt examples from textbooks, remembered activities from their high schools as student and implemented demonstrations and activities which were suggested by cooperating teachers. Also, they could adjust the activities in their classrooms that are consistent increase on their experience. Authors suggested to bridge gap between Art and Science Faculties and Education Faculties for further studies. By this way, pre-service teachers PCK increase as the cooperation of content knowledge and pedagogical knowledge.

A study conducted by Valk vander and Broekman investigated 5 pre-service math teachers and 5 pre-service physics teachers PCK in terms of selected physics and math contents. This study was conducted in Utrecht, Netherland. Data were collected by use of lesson plans and interviews. Specific topic was selected as combustion, temperature, heat or area. Shulman's PCK model was adopted in this study which includes pupils' prior knowledge, pupil difficulties, relevant representations, strategies and student activities. This study didn't mention knowledge of assessment and orientation toward science aspects of PCK as parallel to Shulman (1986) ideas. Findings of the study showed that pre-service teachers developed some strategies for teaching selected content and they reasoned their strategies to show why they selected them. As pre-service recalled and reflect content knowledge on lesson plans and reasoned them in the interviews, their awareness to students' difficulties in selected topic increased. Their views on teaching become more student centered when they explain their lesson plans. Timetable prepared by pre-service teachers in their lesson plans help them to choose which strategy would be better. In conclusion result of this study showed that participants showed well PCK according to components of Shulman (1986) suggestions and their PCK can develop more. Knowledge of context is very important to have a robust PCK. These pre-service teachers have lack of contextual knowledge therefore it can be disadvantages for them not to have sufficient contextual knowledge to solve PCK problems caused by context.

Veal and MaKinster (1998) provided taxonomy of PCK. According to this taxonomy there are three different types of PCK that teachers have in terms of general PCK, domain specific PCK and topic specific PCK from general to more specific. In this study, Veal and Kubasko (2003) examined 12 secondary pre-service and in-service biology and geology teachers' domain specific PCK as biology versus geology. Researchers selected evolution topic that is taught both in geology and biology. Data were collected by observations, semi-structural interviews, assignments, journal entries and field notes. Findings of this study showed that both pre-service biology teachers and pre-service geology teachers preferred to traditional ways of teaching as instruction. On the other hand experienced biology teachers used discussion and idea sharing in their classrooms. Experienced geology teachers preferred to evaluate the evidences related with evolution such as fossil and rock records. The biology teachers also used more inquiry in their lessons comparing with geology teachers. Laboratory use and activities was more common in biology lessons. Pre-service geology teachers mentioned historical events and biological terms explanations and they used little activities. These findings showed that both in service biology and in service geology teachers were better than pre-service teachers in terms of knowledge of instruction. Actually, biology teachers were better than geology teachers for the use of activities, labs, analogies to teach evolution. Biology teachers felt themselves under pressure for teaching evolution more than geology teachers had. The reason why biology teachers face in difficulty more than geology teachers is that biology teachers cover the hominid evolution that is closely related with public on the other hand geology teachers focus on the evolution as historical and inanimate perspective. This situation also supports how well context affect the teacher practice and therefore knowledge of context affects teachers PCK. Biology teachers were successful in integrating different biology topics and evolution that implies good knowledge of curriculum. However, geology teachers didn’t see evolution as unifying theme. These findings supported the curricular knowledge as unifying theme in favor of biology teachers. Students had some misconceptions related with human evolution and biology teachers could identify them because they covered human evolution in their courses, similarly both geology teachers and biology teachers identified students misconceptions related with evolution occurred in short time. This study showed that although PCK is topic specific, its’ domain specific aspect shouldn’t be ignored. Different communities as domains have different perspectives. Even though these teachers taught the similar content such as evolution, they approach the topic different from each other. Similarly, their teaching will be different from each other in similar a content.

Pre-service teachers cannot gain PCK aspects immediately, and they need to improve these aspects. Hume and Berry (2011) offered pre-service teachers to use CoRes to improve their PCK. This study was conducted in New Zealand and 9 pre-service teachers participated in this study. Specific topics were selected as redox equations and atomic structure and bounding. Data were collected by the students' reflective journals, interviews and student artifacts (CoRes). Results of the study showed that knowledge of the curriculum component was obvious in pre-service teachers' CoRes. Pre-service teachers' CoRes were also detailed showing awareness of issues around students' understandings. Pre-service teachers also used instructional strategies in their CoRes relating concepts to real life and making links between abstract ideas and concrete examples like analogy. In conclusion, CoRes are helpful for pre-service teachers who are not expert in science teaching to develop their PCK. In addition, CoRes are helpful for pre-service teachers to be aware of their PCK development. These CoRes also provide pre-service teachers confidence and competence when they teach the course. Researchers also reported that sample size of this study is very little. Therefore, results of the study can't be generalized. Researchers also suggested that CoRes should be used in studies which are held with experienced teachers.

In a study conducted by Avraamidou (2012), two pre-service elementary science teachers' orientation toward science and their experiences which influenced their orientation was examined. Orientation to science was used in this study as participants view on science teaching and their views on what the purpose of science teaching. This study was conducted in a southern Eastern Europe country. Data were collected by participants' drawings, interviews, field notes on outdoor experiences, and participants' reflective journals. Related with orientation towards science, both of the participants claimed that science teaching should be guide for the development of students' critical thinking skills and inquiry. They also added that science teaching should lead students to be scientifically literate people by means of understanding how the world works. Both of the participants preferred to draw informal outdoor experiences which are related with nature and eclipse instead of drawing their formal science education courses. Avraamidou (2012) pointed out that both of the participants attitude towards science and orientation to science changed during their university years. The factors that change their attitudes and developments of orientation towards science were with respect to specific science education courses developed by science educators and female passionate instructor who was the role model for pre-service teachers. Researcher claimed that science education courses including enjoyable activities, outdoor activities triggering pre-service teachers' curiosity and facilities that let pre-service teachers to teach science to the elementary students change pre-service teachers' orientation positively. In addition, female instructors at these courses have major impacts as role model to female pre-service teachers to eliminate public bias that male dominated science ideas.

Similar to the other studies mentioned above, Brown, Friedrichsen, and Abell (2013) examined 4 pre-service biology teachers' pedagogical content knowledge in terms of orientation toward science, knowledge of instructional sequence and knowledge of learner. A teacher certification program was managed in order to seek pre-service biology teachers' knowledge development through the time and practice. Interview transcripts, field notes, lesson plans and classroom documents were used as data sources. According to results, prospective teachers' science teaching orientation was affected by their K-16 experiences and other backgrounds. These orientations were found to highly resistant to change. They thought that teaching is delivering the knowledge and learning is listening to teacher. Teacher role was active and student role was passive according to prospective teachers. Their science orientation didn't change over the program significantly. Prospective biology teachers developed their knowledge of learner in some degree through the time. For example, they were not sure about students' difficulties at the beginning of the program but they developed some understanding about the students' difficulty. The sequence of instruction started with transmitting the knowledge because they thought that students can't understand the topic without their teachers' aid. Therefore, none of the teachers achieved the 5E learning cycle and its sequence. However, over the time they used more activities and additional instructional strategies based on informing students. In conclusion, pre-service biology teachers' knowledge of instructional strategies and knowledge of learner developed partially and they were parallel to each other. Then, pre-service teachers wanted to meet students' needs and facilitate their learning, thus they needed to use more instructional strategy as developing their knowledge of instructional strategies. The findings also showed that pre-service teachers' science teaching orientation was congruent to other two components and it shaped the other components.

Kapyla, Heikkenen and Asunta (2009) examined pre-service biology teachers and pre-service primary school teachers' content knowledge and pedagogical content knowledge and their relationship with each other. The reason why researchers chose biology pre-services and primary school pre-services is that these two different groups had different degree of content knowledge on photosynthesis and plant growth. Therefore, pre-service biology teachers were labeled as content experts and pre-service primary school teachers were labeled as content novices. In this PCK study, researchers focused on conceptual problems of the students (knowledge of learner), the core content in teaching (knowledge of curriculum), knowledge of teaching methods, and orientation to teaching science. This study was conducted in Jyvaskyla, Finland where 10 primary school pre-service and 10 biology pre-service students participated in. data were gathered by lesson plan, questionnaires and interviews. Results of the study showed that biology pre-service teachers had more consistent knowledge about photosynthesis and had fewer misconceptions. On the other hand, primary school pre-service teachers had inadequate knowledge about photosynthesis and plant growth and they had more misconceptions. Secondly, biology pre-service teachers were partly aware of the students' conceptual difficulties and misconceptions and primary school pre-service teachers were not aware of the students' conceptual difficulties. In terms of the core content in photosynthesis and plant growth, biology pre-service teachers mentioned more important concepts than primary school pre-service teachers mentioned which showed that biology pre-service teachers had more knowledge of curriculum. Primary pre-service teachers teaching methods included indirect activities mostly which required more creativity and imagination; on the other hand, biology pre-service teachers preferred to direct activities to teach photosynthesis and plant growth. Both of the groups had lack of knowledge of experiments and demonstrations. Researchers claimed that although biology pre-service teachers' content knowledge was better than primary school pre-service teachers' content knowledge, both of the groups had lack of knowledge of teaching methods and therefore knowledge of teaching methods can be independent from pre-service teachers' content knowledge and PCK should be taught explicitly in teacher education programs. Researchers also examined pre-service teachers' orientations towards science, they found that content experts who were pre-service biology teachers in this study were found as conceptualists who transmits the knowledge as didactic category of Magnusson (1999) PCK model and conducts teacher centered lessons. On the other hand, primary school pre-service teachers who were content novices were found as constructivist who preferred student centered lessons. Researchers thought that pre-service orientation towards science was affected by their instructors in their undergraduate programs. In conclusion, Kapyla et al. (2009) found that teachers who have better content knowledge are also good at knowledge of learner and knowledge of curriculum. However, teachers who have better content knowledge are knowledge transmitter and use teacher centered activities showing that their orientation towards science and knowledge of instructional strategies are insufficient. So, results of the study partially support the idea that there is a positive relationship between content knowledge and PCK.

Graf, Tekkaya, Kılıç and Özcan (2011) compared 2 Turkish and 2 German pre-service science teachers' PCK regarding evolution. Data were collected by the use of concept maps, lesson plans and semi-structured interviews. Researchers analyzed pre-service teachers PCK regarding evolution in terms of PCK components which are curricular knowledge, instructional knowledge, knowledge of learner, and assessment knowledge. Results showed that Turkish pre-service teachers' curricular knowledge on evolution is not sufficient. They don't know the place of evolution and content of evolution unit in curriculum. In addition they weren't aware in which grade evolution is taught and how textbooks explain the evolution. Similarly, German pre-service science teachers are not aware of the place of evolution in curriculum; they don't know the objectives during the teaching of evolution. Furthermore, they don't know the related materials and activities used for evolution teaching. Knowledge of instructional strategies is also insufficient for Turkish pre-service science teachers. Turkish pre-service teachers reported that they don't know the evolution topic very well, and they weren't able to struggle with how to correct their students' misconceptions on evolution. They also reported that questioning can be used for instruction of evolution. On the other hand, German pre-services preferred to use station method and cooperative learning in the teaching of evolution. In addition, German pre-service teachers preferred to visualize the concepts of evolution which is abstract topic for elementary students. According to pre-service teachers' knowledge of learner, Turkish pre-service think that natural selection and variation are the easy topics which are learnt by students. The reason for students' difficulties is evolution is abstract unit and it has no relation with daily life examples according to Turkish pre-service teachers. In contrast, German pre-services thought that long process of evolution and origin of life is difficult concepts for students to learn. The sources of students' possible misconceptions are their families, non-scientific books, and their religious beliefs according to German pre-services. All of the participants claimed that students' common misconceptions were related with human descends from monkeys and evolution is purposive. Turkish pre-service teachers' assessment knowledge on evolution was based on written assessments like true false questions, filling gaps. Time of assessment was at the end of the lesson for Turkish pre-service teachers. Oppositely, German pre-service teachers chose to assess both students learning and the process during the instruction. German pre-service teachers chose the use of open ended questions, essay types questions and two tier questions for the assessment. German pre-service teachers also selected to assess students at the beginning of the course to release their misconceptions about evolution, during the course and at the end of the unit. In conclusion, both Turkish and German pre-service science teachers in this study didn't have rich PCK in the specific topic selected as evolution. Pre-service teachers couldn't satisfy enough knowledge on the place of evolution in curriculum, materials and activities used in evolution teaching. Their assessments of evolution were not specific to evolution teaching. Turkish teachers preferred to use teacher centered instruction, but German pre-services preferred to use student centered instruction.

PCK studies were mostly held with pre-service teachers. This situation does not change in Turkish context too. PCK studies held with pre-service teachers dominate the PCK literature in Turkey. The following studies were based on the pre-service teachers PCK in Turkish context.

Pre-service teachers have no or little PCK. In order to develop pre-service teachers' PCK, Tekin (2006) examined the contribution of special method courses application on pre-service teachers PCK. This study was examined in a large public university of Turkey in 2004 and 56 pre-service teachers participated in this study. During the course, each pre-service teacher prepared and presented a science topic consistent with curriculum. Researcher observed each presentation and used an evaluation form to assess pre-service teachers' PCK. Descriptive statistics results showed that pre-service teachers had informed and acceptable PCK according to their presentations. However, pre-service teachers were lack of designing and preparing in science activities for students active engagement. Similarly, pre-service teachers couldn't ask critical questions related with the topic and they had some problems in linking science concepts to other science concepts. Researcher suggested that teacher education programs should provide more opportunity for pre-service teachers to present their lessons. Researcher also suggested that importance of method courses in science education should be emphasized and science method courses' instructors should be aware of substantive content knowledge to assist pre-service teachers.

Boz and Boz (2008) examined 22 pre-service chemistry science teachers' knowledge of instructional strategy that is one of the component of Magnusson et al. (1999) PCK model in terms of particulate structure of matter. In this study, researchers also examined the factors that affect the pre-service chemistry teachers' PCK. Data were collected by use of vignettes, lesson plans and interviews. According to analysis of vignettes, participants formed three different categories to teach particulate matter of structure in terms of concrete objects, computer animations and expository teaching. After vignette results were interpreted, two participants from concrete object category, one participant from computer animation category and one participant from expository teaching category were selected to prepare lesson plan to get deep information. According to lesson plans' analysis, participants in concrete object category prefered lecturing, questioning, demonstration and group work as instructional strategy. Participant who planned to teach the topic with the use of computer animations preferred lecturing and questioning for instructional strategy Last participant who preferred to expository teaching used only lecturing as instructional strategy. Finally, interviews were conducted after analysis of lesson plans. Interview results showed that participants were aware of the students' difficulties on topic and this awareness lead them to choose suitable instructional strategy for understandings of students. In addition, pre-service teachers' general pedagogical knowledge affected their PCK. For example, pre-service teachers thought that students in 5th grade can understand the topics if they are presented as concrete examples. Similarly, pre-service teachers' subject matter knowledge influenced their PCK. Furthermore, pre-service teachers' knowledge of students also affected their preference to use instructional strategy. For example, one of the pre-service teachers chose expository teaching and preferred lecturing as instructional strategy and reasoned that students in 5th grade have no knowledge on particulate nature of matter and pre-service teacher chose to tell topic explicitly. Pre-service teachers' beliefs also affected their PCK. Some of the pre-service teachers believed that animations are useful only for older students to learn topic and young students don't understand with animation and they see animations as game.

Uşak (2009) examined four different dimension of PCK in terms of curriculum knowledge, knowledge of learner understanding, knowledge about assessment and knowledge of instructional strategy about cell units. This study was conducted in Denizli in spring term of 2006 and 6 pre-service teachers participated in this study. Data were collected via pre-service teachers' lesson plans, lab reports, concept maps and interviews. Results of the study showed that pre-service teachers didn't reflect enough understanding about curricular objectives of cell unit. Pre-service teachers adopted teacher centered instruction and mentioned the lab applications in their knowledge of instructional strategies. Pre-service teachers used both traditional and alternative assessments like open ended questions, multiple choice questions, gap filling, matching, true-false questions, performance evaluation, structured grid, and concept mapping. Another result shows that pre-service teachers don’t have enough understanding for learner’s knowledge.

In another study, Özcan and Tekkaya (2011) explored 6 pre-service science teachers PCK in the context of evolution. Data were collected by use of semi-structured interviews, concept maps and lesson plans. Results of this study showed that participants were knowledgeable on the knowledge of learner and instructional strategies, however; they were lacked of the place of evolution and content knowledge mentioning little knowledge of curriculum. Difficult concepts in students’ mind reported by participants were population, mutation, homolog and analog organs, differentiation, adaptation and natural selection mentioning well knowledge of curriculum. Sources of these difficulties were reported as students’ religious beliefs, controversial nature of evolution, and insufficient materials. Pre-service teachers selected tests and portfolios for the assessment of evolution. Their potential instructional strategies were case studies, learning cycle and field trip.

Furthermore, Tekkaya and Kılıç (2012) examined 7 pre-service biology teachers PCK regarding evolution. In this study; semi-structured interviews, concept maps, and lesson plans were used as instruments. Knowledge of learner, knowledge of instructional strategies, knowledge of assessment and knowledge of curriculum components of PCK were examined in this study. Results of this study reported that participants thought that learning of the human evolution, differentiation, and origin of life would be difficult for the students and natural selection, mutation, adaptation would be easy to learn for students showing good knowledge of learner. In addition, pre-service teachers thought that students don’t understand the topic due to their religious beliefs. Participants thought that evolution is abstract topic, so they needed to make it more concrete with the use of visual things such as slide, videos, pictures, fossils, concept maps and analogies implying their knowledge of instructional strategies. Direct instruction, cooperative learning, questioning, field trip, role playing were selected by pre-service teachers as teaching methods. Role of teacher was reported as guide for learning in this study. Results of knowledge of assessment on evolution, all participants planned to assess students at the end of the lesson; however, their aims differed in the assessment of evolution. For example, some of the participants assess students' content knowledge on evolution, on the other hand some others focused on the elimination of students' bias towards evolution. In addition, participants thought that they would use feedback to eliminate their students' misconceptions. They also preferred to use project based learning, open-ended questions, and interpretative questions to assess their students about evolution. Results about the pre-service biology teachers' knowledge of curriculum showed that participants had insufficient knowledge of curriculum on evolution. They weren't aware of the place of evolution in curriculum, how it is expected to teach in curriculum and the degree of knowledge that is supposed to teach in class.

Taşdere and Özsevgeç (2012) examined 6 pre-service science teachers' PCK in terms of knowledge of instructional strategies and knowledge of assessment. Researchers gathered data by use of semi structured interviews and drawings of pre-service teachers. Pre-service teachers' drawings were also used to determine whether pre-service teachers are teacher centered or student centered. In their drawings, researchers want them to imagine themselves in real science class and draw the figures in their minds. Although these drawings were collected to determine pre-service teachers' knowledge of instructional strategies, their drawings also facilitate researchers to understand their orientation towards science. Results of the study showed that pre-service teachers selected to use discovery learning in their classrooms at most. Other instructional strategies selected by pre-service teachers were inquiry, problem solving, laboratory activities, brain-storming and questioning. Most of the selected strategies were consistent with constructivism approach. Pre-service teachers' drawings also showed that 2 of the drawings were student centered, 2 of the drawings were teacher centered and 2 of the drawings were between teacher centered and student centered that is conceptual model. This implied that only two of six students adopted constructivist approach which was resembled by student centered drawings. In addition, they named Vee diagrams, diagnostic tree, portfolio assessment; Project based assessment, rubric, performance assessment, concept mapping, structured grid, and poster. Although pre-service teachers could know the alternative assessment techniques, most of them couldn't give specific example of the use of alternative assessment techniques. Researchers concluded that pre-service teachers have superficial knowledge of assessment and knowledge of instructional strategies. Researchers linked their lack of knowledge with the ignorance of school experience course which is supposed to increase their PCK. In addition, pre-service teachers prepare for an exam called as KPSS (Public Personnel Selection Examination) which requires superficial knowledge, so they may not develop their PCK that is essential to be good teacher.

Although there are many studies based on pre-service teachers' PCK, the factors that shape pre-service teachers' PCK are also valuable. Therefore, Aydın, Boz and Boz (2010) examined the factors that influence teacher decision to select teaching methods in the context of "separation of mixtures". In addition, researchers focused on how these factors affect teachers' choice of teaching methods. Researchers selected 6 pre-service teachers by purposive sampling. Data were collected by semi structured interviews, field notes of observations in high schools where participants presented their teaching, lesson plans and reflection papers. Results of this study showed that there are many factors that affect the teacher selection of teaching methods in terms of mentors' effect, topic effect, participants' general pedagogical knowledge, students' requests, pre-service teachers' characteristics, time, participants' content knowledge, availability of necessary materials, participants' concern on classroom management, effect of pre-service teachers' experiences, and method courses taken in university. Researchers suggested that mentors should be good model for pre-service because of their importance in pre-service teacher development. Authors claimed that PCK of a teacher is different from content specialists' knowledge; therefore education faculties should teach content knowledge as focusing its teachibility aspects. However, education faculties in Turkey send their pre-service teachers to Science and Art faculties for the acquisition of content knowledge. Science and Art Faculties focus on delivering content knowledge that is parallel with subject specialist's content knowledge rather than focusing on its teachibility. University instructors also should be effective role model in education faculties as role model.

PCK studies in Turkish context not only examine pre-service teachers' PCK but also considered the impact of content knowledge on PCK. Özden (2008) examined the relationship between content knowledge and PCK regarding "phases of matter". Three main components of the PCK in terms of conceptual difficulties of students, knowledge of curriculum and orientation in science were selected. Totally, 28 pre-service teachers participated in this study. Data were gathered by content knowledge test, lesson plans and interviews. Researcher found that pre-service teachers had basic understanding of the content and they had few misconceptions. Pre-service teachers also had understandings for students' difficulties in this unit depending on interview. In addition, pre service teachers focused on curricular aims. They also considered on educational activities and teaching methods in their lesson plans. For example, they use experimental work, observation, drama, group working and teaching by games in their lesson plans. Finally, their interview and lesson plans show that most of the students preferred constructivist teaching which is consistent with orientation to teaching as sub dimension of PCK. In conclusion, Özden (2008) claimed that content knowledge has positive impact on teacher PCK.

Kaya (2009) examined pre-service teachers' (PST) pedagogical content knowledge (PCK), subject matter knowledge (SMK), relationship between their PCK and SMK, and relationship between intra-relationship among PCK components in the context of "ozone layer depletion". Four different components of PCK were investigated in this study where 216 pre-service teachers participated in. Data were collected by open survey questions and interviews. Pearson correlation coefficient was used to determine possible relationships and MANOVA tests were used to see impact of subject matter knowledge on PCK. Study showed that PST's subject matter knowledge was low as a success rates of 35% accordingly their answers to open survey questions related with ozone layer depletion. Researcher found that there was a strong relationship between pre-service teachers' PCK components and content knowledge. Although assessments of knowledge component and subject matter knowledge correlation was weaker than other components of PCK and subject matter knowledge, relationship between subject matter knowledge and assessment of knowledge was still found significant. The intra-relationship between components of PCK was found significantly correlated apart from assessment of knowledge and other components relation. MANOVA results supported the findings that subject matter knowledge had significant effect on pedagogical content knowledge. In addition, interview data supported these findings. Researcher proposed that if we want to increase science learning, we should develop quality of science teaching. Science teaching can increase by the development of pre-service teachers' pedagogical content knowledge. So, we need to better understand pre-service teachers' PCK nature and how it develops. Researcher claimed that PST had only one course about assessment of knowledge in Turkish context, so they had not enough opportunities to develop their assessment of knowledge component of PCK. Hence, there is no significant correlation found between this dimension and other components of PCK. PSTs take 61 course to graduate from their schools, however only 3 courses provided opportunities to develop their PCK. In this point, researcher suggested one more year as post graduate teacher education program which single goal is to develop PST's PCK before they become in-service teachers. Moreover, teaching science courses in first two years and teaching pedagogy courses in last two years in education faculties make these knowledge 2 different entities which affect negatively to their PCK, so researcher suggested that PST may take pedagogy courses and science courses simultaneously from beginning to the end of their university years to promote better PCK. Finally, Kaya (2009) advised that there should be paid attention to their internship education for practice in middle school. Reluctant and anxious school craft should be eliminated and PST should teach more in practice class to develop their PCK.

Usak, Ozden and Eilks (2011) examined Turkish freshman pre-service teachers' content knowledge and PCK in the context of chemical reaction as domain specific nature of PCK. The selected components of Magnusson et al. (1999) PCK model were knowledge of instructional strategies, knowledge of learner and knowledge of assessment. Data were collected by use of multiple choice tests combined with open-ended explanations for content knowledge. Participants' PCK was gathered by use of semi-structured interviews. Totally, thirty pre-service participated in content knowledge test and eight of them participated in interviews for PCK. Results of the study showed that pre-service teachers' content knowledge was not an appropriate level for understanding chemical reactions. Only quarter of the participants could solve the problems. Results of the study showed that only one pre-service teacher out of eight could identify students' difficulties and researchers claimed that pre-service teachers were unaware of student difficulties. In addition, pre-service teachers adopted teacher centered teaching methods such as lecturing. Only one of the pre-service teachers adopted student centered teaching strategies such as concept mapping, everyday life approaches and active learning approaches. Similar with pre-service teachers' knowledge of learner and knowledge of instructional strategies, their knowledge of assessment was also found insufficient. Pre-service teachers mentioned traditional assessment techniques such as multiple choice questions and mathematical calculations. They thought that assessing product is more important than assessing process. Because pre-service teachers wanted to make their students successful in national exam in the future and they ignored the assessment of process of their students' learning. In conclusion, researchers reported that pre-service teachers had little content knowledge and little PCK in terms of knowledge of learner, knowledge of instructional strategy and knowledge of assessment supporting the idea that there is a positive relationship between content knowledge and PCK. Researchers suggested that universities should provide a good quality of content knowledge to pre-service teachers to increase their insufficient content knowledge. In addition, researchers suggest that teachers in highschool and instructors in university should change their teaching styles from teacher centered to students centered. By this way, pre-service teachers' beliefs on teaching may change and their teaching can increase.

Canbazoğlu, Demirelli and Kavak (2010) investigated whether there is a relationship between pre-service teachers' content knowledge and PCK. As Tamir (1988) suggested, PCK components were selected as curriculum knowledge, knowledge of instructional strategies, knowledge of assessments and knowledge of learner difficulties and misconceptions in the context of "particulate nature of matter". Data were collected by observations, interviews and documents gathered by students. Result of this study showed that pre-service teachers had lack of content knowledge depending on observations and interviews. Pre-service teachers' knowledge of curriculum was affected by the schools where they go to gain teaching experience rather than their content knowledge about particulate nature of matter, and they could know the correct sequence of the topics and objectives if they met this sequence in middle schools that they experienced. Pre-service teachers didn't choose different instructional strategies and they preferred to didactic teaching and questioning, they also mentioned modeling for representation of atoms and molecules. They also didn't elaborate the topic and explain the answers superficially which is related with their limited content knowledge. Similarly, pre-service teachers couldn't use alternative assessment techniques and they preferred traditional assessment techniques such as open ended questions. However, pre-service teachers mentioned that not only product but also process is important in assessment of science course. For the knowledge of learner, pre-service teachers related students' potential difficulties and misconceptions with their own difficulties and misconceptions as parallel to their content knowledge. In conclusion, this study supported that pre-service teachers content knowledge affect their PCK components as suggested Tamir (1988) apart from knowledge of curriculum which showed that PCK and content knowledge has partial relationship with each other.

In his doctoral dissertation, Uşak (2005) examined the relationship between content knowledge and PCK among four pre-service in the context of flowering plants. In this case study, data were gathered by videotaped lessons, concept maps, lesson plans, word association tasks, written documents and interviews. Results of the study showed that pre-service teachers had some misconceptions and they have problems in visual representations of concepts in flowering plant. Researcher found that there is no relationship between content knowledge and PCK. Researcher also claimed that each participant differed in terms of different components of PCK such as knowledge of learner, knowledge of instructional strategy, knowledge of assessment and knowledge of curriculum.

Because of content knowledge includes both substantive and syntactic structures, science educators focused on the impact of syntactic knowledge on pre-service teachers' PCK too. Demirdöğen (2012) examined development of pre-service teachers' NOS views and their PCK for NOS in her doctoral dissertation in which 30 pre-service chemistry teachers participated in. Researcher claimed that pre-service teachers had naive views in NOS aspects before intervention of the study. For example, pre-service teachers thought that laws are absolute, science is objective and science is universal that is not affected by social factors. At the end of the program that last one and half semester, pre-service teachers held informed views in NOS. Researcher thought that components of PCK should be identified by pre-service teachers as integrated components in order to label pre-service teachers are good at PCK. However, results of this showed that pre-service teachers' PCK components may developed separately in this study. According to findings, knowledge of instructional strategies and orientation towards science were central in their PCK. Researcher also found that knowledge of learner informed pre-service teachers' knowledge of instructional strategies and there was an interaction between knowledge of learner and knowledge of assessment. Similarly, there is a reciprocal relationship between knowledge of instructional strategies and knowledge of assessment. Researcher claimed that although there is no clear relationship between nature of science knowledge and PCK, pre-service teachers tended to teach the NOS concepts that they informed about which may show the relationship between NOS knowledge and PCK.

Mıhlandız (2010) examined 5 pre-service teachers' nature of science knowledge and their PCK about NOS in her doctoral dissertation. Data were gathered by questionnaires and interviews. Results of the study showed that pre-service teachers held naive ideas about NOS. Pre-service teachers thought that science is interrogable and clear, they didn't mention role of experiments and observation or empirical based aspects of NOS. Similarly, participants ignored the importance of theories and they didn't think observations are affected by scientists' theories. In addition, participants had misconception that hypothesis transforms into theories and theories transform into laws. Participants were also found insufficient in terms of epistemological status of laws, hypothesis and theories. For example, they weren't aware whether theories are invention of scientists or not. In addition, they had some dilemma about epistemological status of laws. For instance, participants thought laws are both certain and changeable. On the other hand, participants had informed views about subjectivity, tentativeness and imagination aspects of NOS. Pre-service teachers had moderate level understanding of role of models in science and classification systems. In conclusion, their NOS views were found insufficient in general. Results of the study related with PCK components showed that pre-service teachers had traditional approaches in their orientation and they think that materials are useful for students which were prepared for students. In addition, pre-service teachers believed that teacher should direct students in science classes. Participants' knowledge of curriculum was also insufficient because they were not aware of the objectives found in curriculum. Similarly, they weren't aware of the objectives of science process skills, science technology society and environment, attitude and values which are related with NOS. Participants also choose traditional teaching methods such as direct instruction, questioning, demonstration and experimenting for knowledge of instructional strategies. In addition, participants taught NOS implicitly in their lesson and they mentioned history of science during NOS teaching. Furthermore, their knowledge of assessment was also found lack. Participants only tried to assess students' science process skills. Researcher claimed that pre-service teachers' knowledge of assessment and knowledge of instructional strategies are interacted with each other. Researcher also claimed that pre-service teachers' knowledge of assessment component was lower than other components. Finally, researcher claimed that there is no relationship between pre-service teachers NOS knowledge and their PCK for NOS.

In conclusion, previous studies held with pre-service teachers were presented in this section. Due to fact that pre-service teachers have little or no PCK, researchers provided certification programs and method classroom programs to develop pre-service teachers' PCK. In addition, CoRes were also used to develop pre-service teachers' PCK. Researchers also conducted PCK studies to compare in-service teachers and pre-service teachers' PCK and in-service teachers' PCK were found better than pre-service teachers as supposed. Some others examined pre-service teachers PCK who are from different disciplines in order to release their different domain specific PCK. Researchers mostly focused on some components of the PCK and they usually focused on Magnusson et al. (1999) model. Researchers not only examined pre-service teachers' PCK, but also cared the factors what affect pre-service teachers PCK and its components. Moreover, science educators also conducted studies with pre-service teachers that explore the impact of content knowledge on teachers' PCK.

2.3 Conclusion of Literature

In literature chapter, firstly nature of science studies held with in-service teachers was reported as syntactic knowledge. These studies showed that in-service teachers held naïve views in nature of science in general and there have been development programs to develop teachers' deficiency in nature of science. Next, substantive content knowledge studies regarding cell division topics were reported because mitosis and meiosis are selected based on topic specific nature of PCK. These studies showed that due to abstract and complex structure of cell division topics, it is difficult to teach and learn mitosis and meiosis. In addition, some researchers provided tools for better teaching of cell division. After presenting the literature about content knowledge, PCK studies conducted with in-service teachers were reported. Some of these studies provided professional development programs and workshops to increase teacher PCK. Some of them used tools such as Content Representation Tools (CoRes) to increase teacher PCK. Some researchers examine the current situation of teacher PCK in specific science topics. Comparing with pre-service teachers, in-service teachers had better PCK according to previous studies. Then, studies conducted with pre-service teachers were reported. Most of the PCK studies were conducted with pre-service teachers and results showed that pre-service teachers had little or no PCK because PCK is dynamic and it develops with experience. Science educators also attempted to explore relationship between content knowledge and PCK.

CHAPTER 3

METHOD

Purpose of the study is to examine in-service teachers' content knowledge regarding cell division and PCK in selected topics. In this chapter, firstly general design of the study is mentioned. Secondly, data collection procedure is covered. Next, data analysis procedure is reported. At the end of this chapter, trustworthiness, ethical considerations, limitations and assumptions of the study are reported.

3.1 General Design and Rationale

Although there are many studies conducted based on PCK, there is still vague and inconsistent results about teacher's PCK (Abell, 2008). Therefore, it is necessary to study on PCK to uncover its nature. Depending on this need, in the current study, qualitative methodology was selected. Qualitative studies focus on the phenomena in order to get detail information and thick description (Merriam, 2009). According to Denzin and Washington (2005, p.3) "Qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them".

In this qualitative study researcher aimed to get deep information for tacit and complex structure of PCK. Moreover, inductive and deductive coding was conducted consistent with qualitative paradigm. Furthermore, because of researcher is primary instrument in qualitative study, researcher collected and analyzed data himself and his colleagues. Afterwards, qualitative research focuses on words rather than numbers (Merriam, 2009). Hence photos of classroom discourse, interview reports, observation reports and teacher documents which are written exams were used in this qualitative study to get rich description. Table g presents general research design of the current study.

Table 3.1

General Research Design of Current Study

Research Paradigm	**Qualitative Research**
Aim of the study	To get deep information about science teachers' content knowledge and PCK
Data Collection Tools	Photos of classroom discourse Interview reports Observation reports Teacher documents
Data Collection Instrument	Researcher
Data Analysis	Deductive and Inductive Coding

Case study strategy was used in this qualitative study. Merriam (2009) explained that a case can be a single person, program, institution, or a community. Case studies are particularistic showing that particular situation; event or program is focused on. In addition, case studies are descriptive providing rich product (Merriam, 2009). There are different types of qualitative case studies (Merriam, 2009). Multiple case studies are suitable for the explanation of current study. Stake (2010) explained that individual cases share common characteristics and each case can be member of a phenomenon, so multiple case studies increase the variation of the study which assists on external validity as Merriam (2009) claimed.

In this study, researcher worked with three in-service teachers from different schools. Although each of the teachers meets the study's criteria and share some commonalities with each other, they differed in their characteristics, their content knowledge and their PCK. Therefore, each of the participants was separate case study in this multiple case study and each of the cases is examples of phenomena. In multiple case studies, firstly single case studies are analyzed, their similarities and differences are compared, and then results are presented in detail Merriam (2009).

Multiple case studies have their own advantages and disadvantages. Merriam (2009) claimed that multiple case studies provide greater variation increasing external validity, increase precision, validity and stability of findings. Similarly, complex and social constructs including multiple variables can be investigated. In addition, rich and holistic information helps reader to better understand research of interest. Final advantage of multiple case studies is transferability which means that results of these studies may assist the similar studies found in similar context.

On the other hand, there are some disadvantages of multiple case studies (Merriam, 2009). Firstly, multiple case studies are more demanding for understanding and interpreting the related phenomena comparing with single case study. Secondly, multiple case studies are expensive; they require time, money and detailed product. Thirdly, there is no guideline for reporting the multiple case studies. Next, training of data sources such as interview and observation can be problematic. Then, researchers need to pay additional attention to the researchers' bias, and ethical issues. Finally, they are lack of representativeness. Figure 3.1 presents procedure of the current study.

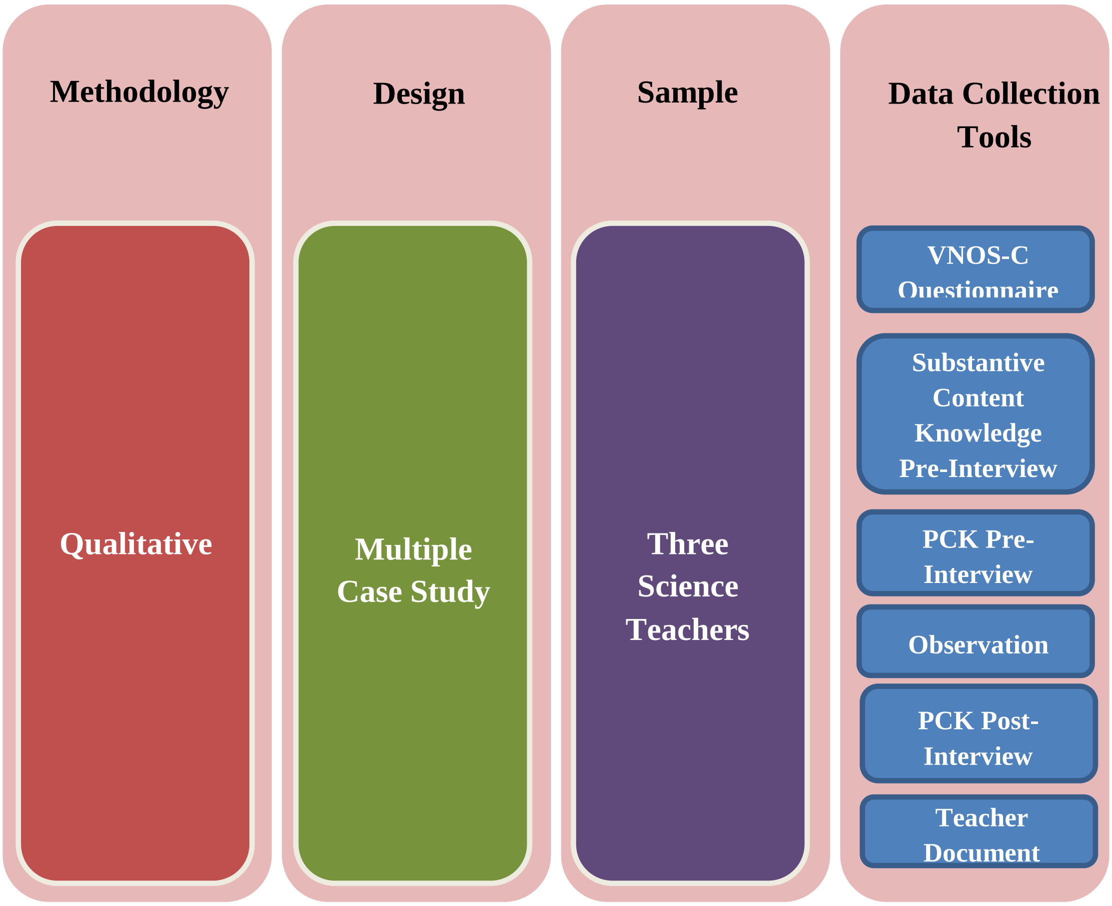

Figure 3.1 Procedure of Current Study

3.2 Participant Selection

This study aim is not to make generalization from sample to population; therefore probability sampling was not selected in this study. On the other hand, nonprobability sampling was preferred for this study. Nonprobability sampling aims to get detailed information about the participants consistent with philosophy of qualitative study (Merriam, 2009). Purposive sampling is the most used form of nonprobability sampling (Patton, 2005). Researcher's aim was to get deep information about in-service teachers' PCK and content knowledge therefore purposive sampling was selected. Purposive sampling is based on pre-determined criteria. Criteria of current study were indicated with their reasons for participant selection.

1. First of all, private schools were selected to conduct this study where public schools are eliminated. Teacher knowledge of instructional strategies are based on teaching activities and representations, so lab facilities, equipment and technological materials are highly important for teachers to realize their actual teaching. Therefore, researcher aimed to study with private schools in which facilities are better than public schools.
2. Secondly, each participants needs to graduate from elementary science education department of education faculties in this study. The reason for this criterion is that education faculties provide both content knowledge and pedagogical knowledge to pre-service teachers. These two knowledge domains are necessary to have PCK. Hence, science teachers who got these knowledge domains in their undergraduate were selected.
3. Third criterion was teachers' experience level. Because of PCK is dynamic and develops with experience (Abell, 2008), researcher aimed to conduct this study with the participants who were experienced teachers. Criteria of being experience teachers were determined as teaching experience that is more than 5 years (Creswell, 2007).
4. Fourth criterion was related with curricular place of content knowledge. Working in private school, teaching experience and graduating from elementary science education were not sufficient to be member of this study because cell division topic is taught in 8^{th} grade level. Therefore, teachers who taught 8^{th} grade level was selected in this study.

In this purposive study, convenient sampling was selected because of the availability of time, money, location and respondents (Merriam, 2009). Convenient sampling may cause poorer information comparing with other types of purposeful sampling. However, increasing number of criteria, and involuntarily attitudes of private schools participate in this study forced researcher to select convenient sampling.

3.3 Participants of the Study

There were three in-service experienced teachers in this multiple case study. Each of the teachers was different case because their content knowledge and PCK answer the research questions of the study separately. Pseudonym names were given to each of the teachers. For example, Selim represents teacher 1, Burcu represents teacher 2 and Ahmet represents teacher 3. Each of the three teacher's demographic information was given in the Table 3.2.

Table 3.2

Science Teachers' Demographic Information

Teacher	Demographic Information
Selim	Selim is male and thirty four years old. He was graduated from elementary science education department of a public university. He has been science teacher since eight years and working in private school. He has been teaching 8^{th} grade students since two years and he teaches ten hours in a week. Similar to Ahmet, Selim is assistant principal in his school.
Burcu	Burcu is female and she is thirty two years old. She is author of a test book that prepares students to High School Entrance Exam. She also wrote many questions assessing content knowledge in her earlier career. Burcu also attained nationwide science projects. Burcu was graduated from one of the public universities' education faculty's elementary science education departments. She has been science teacher since eleven years and working at private school. She worked at cram school and private schools in her career. She was responsible for 5^{th} grade students' lab applications in the past. She also taught in 6-7-8^{th} grades in the past. Mostly she taught at 8^{th} grade level. Burcu teaches 5^{th} grade and 8^{th} grade level this year. She teaches thirty hours per week in this year.

Table 3.2 (cont'd)

Science Teachers' Demographic Information

Teacher	Demographic Information
Ahmet	Ahmet is male and thirty four years old. He was graduated from one of the public universities' education faculties' elementary science education department. He has been science teacher since nine years and working in a private school. He is only teaching at 8^{th} grade level in this year. However, he taught at 4^{th} grade, 5^{th} grade, 6^{th} grade and 7^{th} grade when he worked at cram school. He taught at 4^{th} grade, 5^{th} grade, 6^{th} grade, 7^{th} grade and 8^{th} grade level in his private school career. He teaches twelve hours in a week in this year.

3.4 Data Collection

Data is a piece of information that is derived by researcher from various types of documents such as interviews, and field notes in qualitative research (Merriam, 2009). Data collection tools and the reason of use of these tools were explained in this section. Data collection tools and related content knowledge and PCK aspects were presented in Table 3.3.

Table 3.3

Data Collection Tools and Related CK and PCK Aspect

Data Collection Tools	**Related CK and PCK Aspect**
V-NOS C Questionnaire	Syntactic Content Knowledge
Substantive CK Pre-Interview	Substantive Content Knowledge
PCK Pre-Interview	Orientation towards science Knowledge of Curriculum Knowledge of Learner Knowledge of Assessment Knowledge of Instructional Strategies
Observation	Orientation towards science Knowledge of Curriculum Knowledge of Learner Knowledge of Assessment Knowledge of Instructional Strategies
PCK Post-Interview	Orientation towards science Knowledge of Curriculum Knowledge of Learner Knowledge of Assessment Knowledge of Instructional Strategies
Teacher documents (Written Exams)	Knowledge of Assessment

Data were collected from science teachers who taught cell division unit (8^{th} level) in private middle schools in Ankara. This study was conducted in fall semester of 2013-2014 education year. Data collection process started in September and ended in December. Data collection tools were explained in next section.

3.4.1 Interviews

De Marrais (2004) claimed that "interview is a process in which a researcher and participant engage in a conversation focused on questions related to a research study." Merriam (2009) claimed that interview is the best technique for the case study, so interviews are the primary data sources for this study. This studies' interview questions were semi-structured that is a mix of more or less structured questions. Semi structured interviews are flexible in use and there is no order of asking questions aiming to get specific data from participants (Merriam, 2009). In this study four different interviews were conducted which are Syntactic knowledge interview, substantive knowledge interview, Pre-PCK interview and Post-PCK interview. These different types of interviews were explained in following sections. During the interviews researcher was interviewer. Therefore, researcher was coded as "I" in at the beginning of the given excerpts and teachers were coded by their pseudonyms.

3.4.1.1 Views of Nature of Science Questionnaire (Syntactic Knowledge Interview)

Syntactic knowledge corresponds to nature of science therefore, Views of Nature of Science (V-NOS C) inventory created by Lederman et. al (2002) (Appendix A) that is adapted and translated in Turkish by Doğan et. al (2011) was used to understand teachers' syntactic knowledge (Appendix B). Teachers' NOS knowledge in V-NOS C included seven tenets, namely tentative NOS, empirical NOS, inferential NOS, imaginative and creative NOS, socio-cultural NOS, subjective NOS and functions of and differences between theory and law. V-NOS C questionnaire was asked after participants' demographic knowledge was taken. V-NOS C lasted half an hour approximately for each of the participants. During the interviews science teachers' voice recorded.

3.4.1.2 Substantive Content Knowledge Pre-interview

On the other hand, pre-interview questions that seek teachers' substantive content knowledge were prepared by researcher. Substantive content knowledge questions were prepared in the light of mitosis, cell cycle, meiosis and concepts included in cell division through analyzing science textbook approved by Ministry of National Education (2006) that is covered in science classes. Totally, twenty four questions asked to understand participants' understandings of cell division concepts and processes (see Appendix C for English and Appendix D for Turkish version). Moreover, science teachers were expected to draw mitosis process and meiosis process to get further information about their cell division knowledge. Substantive content knowledge pre-interviews were conducted in second meetings with science teachers. Pre-interview regarding substantive knowledge lasted one hour approximately for each science teacher. During the interviews science teachers' voice recorded.

3.4.1.3 PCK Pre-Interview

Pre-interview of PCK questions were prepared by researcher (see Appendix E for English and Appendix F for Turkish version). Pre-interviews explored five dimensions of Magnusson et al. (1999)'s PCK model. In detail, participants' beliefs about goals of science teaching representing orientation towards science, knowledge of curriculum including knowledge of goals and objectives and knowledge of materials, knowledge of students' understandings including requirements for learning science and knowledge of difficulties in science teaching, knowledge of assessment including knowledge of methods of assessments and dimensions of science learning in assess, knowledge of instructional strategies including knowledge of subject specific strategies and knowledge of topic specific strategies were gathered through the pre-interview PCK studies. Pre-interview PCK questions asked to participants after syntactic knowledge interviews and these interviews lasted two hours approximately for each science teachers. Science teachers' voice was also recorded.

3.4.1.4 PCK Post-Interviews

Post interview questions were asked in order to get better insight about science teachers' PCK because teachers' answers to pre-interview questions and their teaching behaviors observed in classes caused some discrepancies. Each teacher's post interview questions were different from each other because their answers to pre-interview questions and their cell division teaching differed from each other (for the post-interview questions see Appendix G, H, I). Post interviews lasted one hour in average.

During the interviews, researcher was respectful and polite towards participants. Aim of the study was told to teachers briefly, but details were not mentioned in order not to affect participant response. Researcher also interested participant answers for better communication. All the interviews were conducted in the schools where teachers worked because participants had little time to participate in interviews, therefore when they were available, researcher conducted the interviews. After pre-interviews performed, researcher transcribed tape records himself to prepare analysis of data and triangulate the results with field notes gathered by class observations.

3.4.2 Observations

Observing takes place in natural environment and observations are the first hand data (Merriam, 2009). Observations were conducted to triangulate data gathered from PCK pre-interviews. In addition, PCK is tacit construct hidden in teacher mind (Abell, 2008); therefore it needs to be observed in real classroom context. Furthermore, although teachers talked about their PCK in interviews, PCK is subject to change depending contextual factors and student needs, so it is reasonable to observe teacher PCK to triangulate the data. Observations were also useful to get detail information from participants too. For example, Selim couldn't detail his answers for the questions related with students' misconceptions related with cell division; however, he could elicit many misconceptions and tried to eliminate them. Researcher was going to think that teacher was weak in knowledge of students' misconceptions if Selim had not been observed. During the observations, researcher gathered field notes to record what was happening in the classes.

Procedure of taking field notes are as follows: researcher did not prepare a checklist for PCK because pre-determined checklist may cause to lose some points occurred in class. Therefore, researcher tried to record the events, interactions and teacher behavior as much as he could. After recording the data for each of the lesson observed, researcher prepared codes obtained from observation field notes regarding PCK. After these codes are formed and data analyzed based on field note data, codes obtained by PCK pre-interviews were matched with the codes formed from field notes. Then, most of the codes were consistent with the codes taken from interview reports. On the other hand, there were some other codes found in field notes which are not found in interview reports. The codes found only in field notes were generally related with contextual factors or contextual knowledge. These differences in codes are logical because data obtained from interviews represents teachers' planned teaching and data obtained from observations represents teachers' actual teaching and it can be affected by contextual factors similar to nature of PCK.

Observations took place in participants' real classroom environment. Observations lasted eighteen hours. Ahmet was observed four hours, Selim was observed eight hours and Burcu was observed six hours. All the observations were conducted in cell division topics. Classes were not video-taped or audio-taped because private schools did not give permission for recording. Observations were conducted in at the beginning of the 2013-2014 fall term because of curricular place of the selected topics. Observing process lasted more than two months. Sometimes, teacher courses time coincided with each other. Therefore, researcher had to go to observe one of the participants and missed some of the observations. In addition, researcher could not observe all the cell division lessons because selected topic was in the first unit and the schools did not adjust their schedule for course programs in that time. Even though schools planned their schedule, schedules were tentative and researcher missed some of the lessons.

Although researcher did not record what was happening in the class, field notes were taken. Researcher also took photos of the visuals and teacher drawings about mitosis and meiosis. Researcher added some “observer comments” to the field notes in order to connect events each other and explain the observations better. For example, class of Selim was so silent and researcher asked the reason for silence of class and Selim answered that he was the assistant principals of schools, so students were more careful and silent in his lessons in order not to suffer official problems. Researcher thought that this was important information for classroom environment and added this into field notes as observer comment.

Stance of the researcher is also important during observations (Merriam, 2009). According to Merriam (2009), there are four different position of researcher for observations in terms of complete participant, participant as observer, observer and participant and complete observer. Researcher position was “complete observer” in this study. It means that researcher did not participate in any activity, and only observed what happening in class and how teacher performed his/her was teaching about cell division topics. Researcher sat at the backmost desk and took field notes in order not to disrupt flow of lesson. Researcher sometimes sat next to the teacher table whenever taking photo was necessary.

Sometimes, it was noticed that existence of researcher in the class caused an interaction and teachers changed their behaviors. For example, Ahmet taught some cell division concepts which are not found in curriculum after researcher asked him in substantive knowledge pre-interview. When researcher asked Ahmet why he taught that concepts during his teaching, Ahmet justified that he had lack of knowledge in cell division topics released in pre-interviews and he needed to supply his weak knowledge. Ahmet reported that after compensating his weak knowledge, he needed to transfer his new understandings into students. If pre-interviews were not conducted, Ahmet would not teach the concepts that were asked him in pre-interviews.

3.4.3 Teacher Documents

Documents are the materials which are written, visual, digital, and physical that is relevant for study (Merriam, 2009). There are different types of documents such as public records, personal documents, and visual documents (Merriam, 2009). In this study; personal documents and visual documents were used.

3.4.3.1 Personal Documents

According to Bogdan and Biklen (2007), personal documents are the narratives showing a person's action, experience and beliefs. Personal documents are subjective and transfer readers to participant own perspective not researcher perspective. In this study teacher's exam questions were used as personal documents in order to get deep information about science teachers' knowledge of assessments including knowledge of methods of assessments and dimensions of science learning in assess. In addition personal documents were used for data triangulation with other data sources which are transcripts of interviews and field notes of observations. Although science teachers shared their written exams with researcher, Selim requested researcher not to share his written exam with public. Burcu's written exam is presented in Appendix J.

3.4.3.2 Visual Documents

Film, videos and photographs are visual documents (Merriam, 2009). In this study, researcher took many photos in natural settings during observations. These photos included different models such as DNA model, teacher drawings such as process of mitosis, crossing over, cell division concepts, posters drawn by students representing meiosis stages, explanations written on board by teacher, concept maps assessing student understandings, plants shown by teacher as an example of asexual reproduction.

Although documents are less important than other data collection tools, findings of observations and interviews are supported by documents. In addition, use of documents was ignored until recently, so it is remarkable to use such kind of data collection tools (Merriam, 2009). Furthermore, they are easily accessible and documents are not affected by research process that makes documents objective data sources (Merriam, 2009).

3.5 Pilot Study

After prepared pre-interview questions, researcher conducted a pilot study in order to understand whether pre-interview questions work or not. By this aim, an elementary science teacher was found and pre-interview questions asked to the teacher. Teacher participated in pilot study was working in a private school and supposed to give similar answers to main study participants' answers. This teacher also shared her views about the interviews and added teacher perspective to the study. In addition, researcher became familiar to the asking questions and learnt teacher perspective related with topic. Pilot study gained researcher anticipation about what teachers know. Depending on the pilot study, researcher made some adjustments about each of the questions. Some confusing words are explained differently for the main study such as term of misconception. Pilot study also let researcher manage the time required for each pre-interviews because pilot study spanned nearly three hours that is exhaustive for participants, so researcher decided to divide pre-interviews in two parts. Researcher planned to ask V-NOS C and PCK questions at first and substantive content knowledge questions were asked at the second part.

When researcher prepared content knowledge questions and PCK questions, a science educator professor checked the whole process of preparation. In addition, pre-interview questions were asked to a science education research assistant to get better insight about the study. Furthermore, two assistant professors studied on PCK gave feedback about pre-interview questions. By the help of their feedbacks, some PCK questions replaced from one PCK component to another. For example, questions that examined the teachers' activities related cell division were at knowledge of curriculum. However, these questions placed in knowledge of instructional strategies after expert feedbacks.

3.6 Data Analysis

3.6.1 Content Knowledge

"Shulman's view of SMK was derived from the work of Schwab (1964), who defined two types of subject matter knowledge: substantive and syntactic. The substantive structure of a discipline is the organization of concepts, facts, principles, and theories, whereas syntactic structures are the rules of evidence and proof used to generate and justify knowledge claims in the discipline." (Abell, 2007, p.1107).

Accordingly, in the first part of the present section, participants' syntactic knowledge was analyzed. In the second part, participants' substantive content knowledge regarding cell division was analyzed.

3.6.1.1 Syntactic Knowledge

Because syntactic knowledge refers to Nature of Science knowledge (Khalick & Boujaoude, 1997), Participants' nature of science knowledge gathered through pre-interviews utilizing V-NOS C and subsequently categorized as inadequate, adequate and informed based on the V-NOS C rubric (Bilican, 2014; Lederman et al., 2002). Rubric for NOS used in this study is given in Appendix K.

3.6.1.2 Substantive Content Knowledge

Substantive content knowledge refers to basic concepts related to cell division, cell cycle knowledge, mitosis knowledge and meiosis knowledge in this study. Totally, twenty four questions asked to understand participants' understandings of cell division concepts and processes. If participants' answers consisted with scientific explanations, their answer was labeled as sound understanding. On the other hand, participants' answers including lack of knowledge were put under partial understanding category. Participants' answers were labeled as naive if they were inconsistent with scientific explanations and included misconceptions. On the other hand, if participants do not answer the question, they are not categorized in this question (see Table 3.4).

Table 3.4

The Scientific Definitions of the Cell Division Topics and Concepts

Concept	**Definition**	**Source**
Basic Cell Division Concepts:		
Write the items in order of size. Start with the largest	Organism> Cell> Nucleus> Chromosome> DNA> Gene	Lewis & Wood-Robinson, 2000
Chromosome	DNA molecule with proteins bound to it containing genetic information responsible for protein synthesis and replicates in cell division. Origin of chromosomes comes from replication of DNA in interphase	Venville & Treagust, 1998 Kindfield, 1994
Homolog chromosomes	One chromosomes of each pair comes from each of the organisms' two parents. This pair of chromosomes is homolog chromosomes They have the same genetic sequence. They are not identical. Origin of homolog chromosomes and their information come from parents	Kindfield, 1994 Sadava et al., 2012
DNA	Double stranded molecule that form chromatin. DNA takes role in protein synthesis. Its function is replicating itself during interphase	Venville & Treagust, 1998
Gene	the sets of productive sequences of instructions for protein synthesis	Tsui & Treagust, 2004

Table 3.4 (cont'd)

Concept	Definition	Source
Allele	The alternate form of genetic character found at a given locus on a chromosome. Alleles in homolog chromosomes carry different information pass the new cells in division	Lewis & Wood-Robinson, 2000 Sadava et al., 2011
Sister chromatid	Sister chromatids have same alleles. They are formed after DNA replicates itself. Sister chromatids are spouse and it is another name of duplicated chromosome	Brown, 1990 Kindfield, 1994
Centrosome	Centrosome is an organelle that doubles forming a pair of centrosomes in interphase. Centrosomes produce spindle structure during cell division	Sadava et al., 2011
Centriole	Centrioles are part of centrosome. Centrioles are two hollow tubes which are at right angles to each other. It helps organization of microtubules during cell division	Sadava et al., 2011
Centromere	Centromere is the region where sister chromatids join	Sadava et al., 2011
Kinetochore	Specialized structure on a centromere to which spindle fiber attach	Sadava et al., 2011
Asexual reproduction	In asexual reproduction, organism reproduces itself. Offsprings are clone of parent organism and offsprings are genetically identical to their parent	Sadava et al., 2011
Sexual reproduction	Sexual reproduction needs offsprings produced by meiosis. Organism is not identical to its parents. Two parents each provide one gamete to offspring. Fertilization of offsprings provides sexual reproduction	Sadava et al., 2011
Somatic cell	Body cells not differentiated for reproduction. Include two set of chromosomes (diploid) They are the cells that undergo mitosis.	Sadava et al., 2011
Gamete	Gametes that occur after cell division completed, gametes join in fertilization process. Gametes include set of chromosomes (haploid)	Kindfield, 1994

Table 3.4 (cont’d)

Concept	**Definition**	**Source**
Zygote	Two gametes (egg cells of females and sperm cell of males) fuse to produce single cell, this cell is zygote.	Sadava et al., 2011
Cell Cycle:		
Cell Cycle	A cell reproduces by g an orderly sequence of events in which it duplicates its contents and then divides in two. This cycle of duplication and division, known as the cell cycle, is the essential mechanism by which all living things reproduce Includes interphase, mitosis and cytokinesis. G1 (growing gap), S (DNA synthesis) and G2 (waiting time) are stages of interphase. Cell cycle direction is as follows: G1, S, G2, Mitosis and Cytokinesis	Koc & Turan, 2012 Sadava et al., 2011
Mitosis:		
Mitosis	The mechanism that include replication and segregation of chromosomes. After chromosomes are replicated, they are segregated in to two new nuclei that are identical to each other and their parent. Somatic cells undergo mitosis. Mitosis of somatic cells provides asexual reproduction	Williams et al., 2012
Events in Mitosis (Drawing the Mitosis)	Nucleus replicates DNA and centrosome in interphase. Chromatin becomes compact and chromosomes become visible in prophase. The nuclear envelope breaks down in prophase. Spindle develops in prophase. Chromosomes become aligned at equatorial plane in metaphase. Chromosomes are most visible at metaphase. Sister chromatids separate and move to the poles in anaphase. Nuclear envelope re-forms in telophase. Chromosomes uncoil and diffuse as chromatin in telophase	Sadava et al., 2011

Table 3.4 (cont’d)

Concept	**Definition**	**Source**
Differences of plant mitosis and animal mitosis	Spindle is produced by cytoplasm in plant cell while it is produced by centrosome in animal cell. Animal cells divide by furrowing and contractile ring cause division while plant cell divides by the occurrence of cell plate. Thick structure of cell wall in plant cell does not let it divide by furrowing	Lewis, Leach & Wood-Robinson, 2000
Meiosis:		
Meiosis	Meiosis is the process which produces gametes. Products of meiosis are not identical. Meiosis provides genetic diversity among the products. Sexual reproduction is based on fusion of gametes produced by meiosis.	Lewis, Leach & Wood-Robinson, 2000 Sadava et al., 2011
Basic terms regarding meiosis	*Synapsis:* Homolog chromosome pair adheres along their length and this process is synapsis. It is the starting point of crossing over. *Tetrade:* Four chromatids of each pair of homolog chromosomes are called a tetrad. It hap pens in propohase-1 *Chiasmata:* X shaped structure that is attachment of non-sister chromatids of homolog chromosomes. It happens in prophase-1 *Crossing over:* Exchange of genetic material between non-sister chromatids on homolog chromosomes. The function of crossing over is to provide genetic variation	Sadava et al., 2011

Table 3.4 (cont'd)

Concept	Definition	Source
Drawing of Meiosis	DNA and centrosome replicate in interphase. Chromatin condenses and chromosome becomes visible in prophase-1. Synapsis aligns homologs in prophase-1. Crossing over occurs between non-sister chromatids in prophase-1.Nuclear envelope breaks down in prophase-1. Homolog pairs line up on the equatorial plane in metaphase-1. Homolog chromosomes move to opposite poles of cell in anaphase-1. Chromosomes gather into nuclei and original cell divides in telophase-1. Nuclear envelope re-forms in telophase-1. Interkinesis follows telophase-1. Interkinesis is similar to mitotic interphase, but there is no DNA replication. Chromosomes condense again and nuclear envelope breaks down in prophase-2. Paired chromatids align in equatorial plate in metaphase-2. Chromatids are separated moving to opposite poles of the cell in anaphase-2. Chromosomes gather into nuclei forming chromatin in telophase-2. Nuclear Envelope reform in telophase-2. After division four haploid cells are produced	Sadava et al., 2011
Genetics vs. Meiosis	The law that connects meiosis and genetics is law of independent assortment. According to this law; it is matter of chance which member of a homolog pair goes to which daughter cell at anaphase-1. Each daughter cell may get paternal chromosome or maternal chromosome. Place of homolog pairs determine which chromosome moves to which daughter cell	Sadava et al., 2011

Table 3.4 (cont'd)

Concept	Definition	Source
Differences of plant meiosis and animal meiosis	Spindle is produced by cytoplasm in plant cell while it is produced by centrosome in animal cell. Animal cells divide by furrowing and contractile ring cause division while plant cell divides by the occurrence of cell plate. Thick structure of cell wall in plant cell does not let it divide by furrowing	Lewis, Leach & Wood-Robinson, 2000; Lewis & Wood-Robinson, 2000; Sadava et al., 2011
Mitosis vs. Meiosis	Synapsis and crossing over occurs only in meiosis. Number of chromosomes reduces in meiosis. Mitosis is faster than meiosis. Mitosis provides constancy and 2 daughter cells are identical with each other and their parent cell. Meiosis provides diversity and 4 daughter cells are different from each other and parent cell	Sadava et al., 2011

Teachers' substantive knowledge was further analyzed depending on ontological category of entities, which help us better understand their conceptualization of the cell division concepts. Entities in world can be grouped as matter, process and mental states. Teachers' content knowledge regarding scientific concepts should extend matter category and reach process category to help their students (Chi et al., 1994). Matter category includes the aspects which are storable, having volume, having mass, colorful. On the other hand, occurring with time and having a beginning of sequence represents the process category of ontological classification of entities. For example; identification of gene as "genes are located on chromosome" is in matter category. However, "genes are the productive sequence of genetic information" definition belongs to process category (Venville & Treagust; 1998). Teacher who cannot reach the process category for related concept is also assessed under the category of matter since understanding of a science concept requires a conceptual change from matter category to process category according to the theory of Incompatibility (Chi et al., 1994). Codes for ontological category was derived from previous research in literature (Chi et al., 1994; Tsui & Treagust, 2004; Venville & Treagust; 1998) as presented in Table 3.5.

Table 3.5

Codes for Ontological Categories of Entities about Substantive Knowledge

Matter	**Process**
Particle (Venville & Treagust; 1998)	Events (Chi et al., 1994)
Structure (Venville & Treagust; 1998)	Sequence (Venville & Treagust; 1998)
Segment (Aydemir, 2014)	Function of Concepts (Aydemir, 2014; Tsui & Treagust, 2004)
What concept is (Aydemir, 2014)	What concept does (Venville & Treagust; 1998)
What happens to concept (Venville & Treagust; 1998)	Explanatory power of concept (Tsui & Treagust, 2004)
Size (Chi et al., 1994)	How this term affects other terms (Venville & Treagust; 1998)
Shape (Chi et al., 1994)	Concept relationship with other concepts (Venville & Treagust; 1998)
Color (Chi et al., 1994)	Significance of concepts (Venville & Treagust; 1998)
Location (Chi et al., 1994)	Role of concept (Tsui & Treagust, 2004)
Molecule (Chi et al., 1994)	Explain a mechanism (Tsui & Treagust, 2004)

3.6.2 Data Analysis of PCK

In this study, science teachers' PCK was analyzed depending on Magnusson et al. (1999) PCK model. All of the five components and their corresponding subcomponents were included in this study (see Table 3.6).

Table 3.6

Components of PCK used in Current Study

Orientation Towards Science	**Knowledge of Curriculum**	**Knowledge of Students' Understanding**	**Knowledge of Assessment**	**Knowledge of Instructional Strategies**
Central Goals	Knowledge of Goals and Objectives	Knowledge of Requirements for Learning	Knowledge of Dimensions of Science Learning to Assess	Knowledge of Subject Specific Strategies
Peripheral Goals	Knowledge of Specific Programs and Materials	Knowledge of Areas of Student Difficulty	Knowledge of Methods of Assessment	Knowledge of Topic Specific Strategies Knowledge of Representations Knowledge of Activities

3.6.2.1 Data Analysis of Orientation towards Science

Researchers generally found *Orientation* component of the model as most problematic one (Avraamidou, 2012; Friedrichsen & Dana, 2004). Although, Magnusson et al. (1999) proposed nine different orientations namely academic rigor, didactic, process, activity driven, discovery, conceptual change, project based science, inquiry and guided inquiry, science educators are not sure about whether these nine orientations types are really orientations. They thought that Magnusson et al. (1999) study has lack of theoretical and empirical background (Friedrichsen & Dana, 2005, Friedrichsen et al., 2010). Friedrichsen et al. (2005) proposed different approach to teacher orientation in which science teaching orientations can be formed by teachers' beliefs about the goals or purposes of science teaching.

In line with this view, in this study, beliefs about the goals of science teaching were assessed to uncover participants' orientation towards science. To assess beliefs about the goals of science teaching representing teachers' orientation towards science; the questions which are 'What do you understand about the term "science teaching?', 'What are the goals of science teaching in your opinion?', 'As a science teacher, what is the meaning of teaching cell division topics for you?' and 'Why do you teach cell division topics as a science teacher?' was asked and then classroom observations were conducted to triangulate data obtained from interviews. Because of beliefs about goals of science teaching is more complex and broader than science educators thought; teachers' beliefs about the goals of science teaching are explored based on two dimensions which are central goals and peripheral goals in this study. Central goals directly affect teacher's practice and decision whilst peripheral goals have little impact on teacher practice.

Moreover, beliefs about goals of science teaching are not limited with subject matter goals as Magnusson et al. (1999) claimed. Thus, teachers' beliefs are categorized in this study as affective domain goals, general schooling goals and subject matter goals after participants' central goals and peripheral goals are determined (Friedrichsen & Dana, 2005). Schooling goals consider students' preparation to university and life whilst affective goals are based on attitude towards science, self-confidence, and curiosity On the other hand, subject matter goals focus on transmitting content knowledge (Friedrichsen & Dana, 2005).

3.6.2.2 Data Analysis of Knowledge of Curriculum

In this study, in accordance with Magnusson et al. (1999), two dimensions of knowledge of curriculum; knowledge of goals and objectives, and knowledge of specific curricular programs and materials, were examined. Since all schools in Turkey follow the same curriculum offered by MoNE, in this study, knowledge of specific curricular programs was not questioned. Participants' knowledge of curriculum was gathered by interview questions and observations. Interview questions were derived from the related literature and codes were produced to understand participants' knowledge of curriculum by deductive analysis. Table in the below presented the codes list regarding knowledge of goals and objectives, knowledge of materials and their corresponding examples.

Table 3.7

Codes for Knowledge of Curriculum

Codes for Knowledge of Goals and Objectives	**Source**
The reason why cell division place in curriculum	Yarden & Cohen, 2009
Place of topic in curriculum	Yarden & Cohen, 2009
Vertical Curriculum	Clark, 2000; Magnusson et al., 1999
Horizontal Curriculum	Brown, 1990; Kindfield, 1994; Lewis et al., 2000
Cell Division objectives	Canbazoğlu et al., 2010; Graf et al., 2011; Magnusson et al., 1999; Mıhlandız, 2010; Valk et al., 1999
Sorting the objectives based on their importance	Yarden & Cohen, 2009
Modification of textbook, and objectives	Cho et al., 1985; Hashweh, 1987; Lewis et al., 2000; Williams et al., 2012
Limitations in objectives	Aydemir, 2014
Misconception caution in objectives	Aydemir, 2014
Dependance on Curricular Materials	Cochran et al., 1993
The degree of knowledge that is supposed by curriculum	Graf et al.,2011; Tekkaya & Kılıç, 2012
Codes for Knowledge of Materials	**Source**
Source that teacher use	Graf et al., 2011; Magnusson et al., 1999; Shulman, 1986;Yarden & Cohen, 2009
Aim of using source	Yarden & Cohen, 2009

3.6.2.3 Data Analysis of Knowledge of Students' Understanding of Science

Knowledge of students' understanding of science in cell division topics included two components in terms of knowledge of requirements for learning and knowledge of students' difficulty.

Participants' knowledge of requirements for learning was gathered through the question of "What prior knowledge should your students have to understand cell division topics?" which was derived from the PCK literature. Obtained responses were, then analyzed in accordance with the three types of requirements (i.e., prerequisite knowledge for learning of cell division) reported by the both previous cell division and PCK studies:

First requirement is to know cell topic and be capable of connecting it other biology topics which are cell division, fertilization, genetics, evolution etc. (Cho et al., 1985; Lewis et al., 2000; Williams et al., 2012).

Second requirement is to know both chromosomal structure and movement of chromosomes to understand both processes of mitosis, meiosis and their differences (Williams et al., 2012).

Third requirement is to know basic genetic terms and their relationship which are crucial for cell division (Atılboz, 2004).

Participants' knowledge of students' difficulty, however, was gathered by both pre-interviews and observations. Knowledge of students' difficulty was also supported by post interviews following classroom observations to get more information or to eliminate possible inconsistencies may arise between pre-interviews and observations. Thus, content of questions in post interviews was unique to the participant. Specifically, under this heading, difficult points that students had in cell division and possible reasons of these difficulties, students' misconceptions and sources of these misconceptions, as well as the way of identifying and remediating misconceptions were examined deeply. Understanding and conceptualization of each aspect of knowledge of students' difficulty were analyzed in three different parts; in terms of concepts, mechanisms and processes. Difficult points that students had in cell division and the reasons of these difficulties are presented in Table 3.8.

Table 3.8

Students' Difficulties and Reasons of These difficulties regarding Cell Division

Knowledge	*Difficulties*	*Reasons*
Concept	Homolog chromosome, Allele, sister chromatids (Brown, 1990; Clark, 2000) Genetics related concepts, gamete chromosome number (Lewis et al., 2000).	Abstract nature (Williams et al., 2012) Cell division has its own terminology which students are not familiar (Lankford, 2010; Lewis et al., 2000; Öztaş et al., 2003).
Mechanism	Mechanism of pollination and mechanism of copulation to understand sexual reproduction (Lewis et al., 2000). Mechanism of genetic transferring (function of spindle fiber) (Williams et al., 2011).	Cell division is in micro level that is not visible (Atılboz, 2004; Yarden & Cohen, 2009).
Process	Duplication of chromosomes into chromatids (Brown, 1990). Separation of homolog chromosomes (Brown, 1990). Separation of sister chromatids (Brown, 1990; Clark, 2000). Origin of homolog chromosome (Kindfield, 1994). Crossing over and its impact on variation (Kindfield, 1994). Processes and purposes of cell division (Lewis, 2000; Williams et al 2012).	Students tend to assimilate the knowledge they learn recently. Therefore, they do not think that plants reproduce sexually because plants do not move (Lewis et al., 2000). Cell division is difficult because it includes detailed procedure (Lewis et al., 2000; Öztaş et al., 2003). Longer process of meiosis makes meiosis more difficult than mitosis (Williams, 2012).

Analysis of the previous misconception literature on students' misconceptions regarding cell division, sources of these misconceptions and the way of identifying and remediating misconceptions are presented in the Table 3.9.

Table 3.9

Students' Misconceptions regarding Cell Division, Sources of Misconception, Identification and Remediation of Misconception

Dimension	**Example**
Misconceptions	Genes function for only cellular needs (Lewis & Wood Robinson, 2000).
	Different cell types include different genetic information (Lewis & Wood Robinson, 2000)
	Chromosome numbers reduce in all cell division types because chromosomes are shared. (Lewis & Wood Robinson, 2000)
	Sister chromatids carry different alleles .(Brown, 1990; Clark, 2000; Kindfield, 1994)
	Homolog chromosomes carry same genetic information (Brown, 1990).
	Origin of sister chromatids is based on fertilization (Kindfield, 1994).
	Cells always divide regardless of their maturity (Yılmaz, 1998).
	Homolog chromosomes occur after chromosomes duplicate (Yılmaz, 1998).
	Homolog chromosomes attach each other from their centromeres (Yılmaz, 1998).
	Homolog chromosomes take role just in meiosis (Yılmaz, 1998).
	Original cell disappears after division (Yılmaz, 1998).
	Plants do not reproduce sexually because they do not move (Williams et al., 2012).
	Organelles of old cell pass to one of the daughter cells (Yılmaz, 1998).

Table 3.9 (cont'd)

Dimension	Example
Sources of Misconception	Use of daily life language may cause misconceptions such as the words "sharing, splitting, replicating, dividing, copying" (Atılboz, 2004; Lewis et al., 2000; Öztaş et al., 2003). Textbooks which presents biology topics separately, and presents them in wrong sequence may cause some misconceptions (Yip, 1998). Teachers can be source of misconceptions (Öztaş et al. 2003, Yip, 1998). Lack of understanding the relationship between genetics and cell division may cause misconception leading cognitive dissonance (Cho et al., 1985; Williams et al., 2012).
Identification of Misconception	Immediate feedback as formative assessment, Quizzes, Discussions, Short tests, Concept maps, Interview, Two tier diagnostic test (Mann & Treagust, 1998).
Remediation of Misconception	Conceptual change approach, Analogy, Concept map, Conceptual change text, Refutational text (Mann & Treagust, 1998).

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3.6.2.4. Data Analysis of Knowledge of Assessment

Knowledge of assessment includes two sub-domains in terms of knowledge of dimensions of science learning to assess and knowledge of methods of assessment (Magnusson et al., 1999). Participants' knowledge of assessment was gathered through interview questions, observations and teachers' written exams applied to the students at the end of cell division unit. Recalled that current study adopted deductive coding procedure, knowledge of assessment component and its sub components are coded deductively based on previous assessment studies, PCK literature and cell division studies

Knowledge of dimensions of science learning refers to what is important in particular topic. It is suggested that teachers should assess not only conceptual understandings (Lankford, 2010; Magnusson et al., 1999), and interdisciplinary themes (Magnusson et al., 1999), but also nature of science (Hanuscin et al., 2010; Magnusson et al., 1999), science process skills (Magnusson et al., 1999; Mıhlandız et al., 2010), and problem solving skills (Magnusson et al., 1999). Teachers who assess the knowledge mentioned above found to have robust understanding on knowledge of dimensions of science learning. Teachers assessing only students' conceptual understanding, on the other hand, reported having partial understanding about the knowledge of dimensions of science learning.

Other dimension of knowledge of assessment is knowledge of methods that refer to different ways to assess specific science topics (Magnusson et al., 1999). Assessment of students' can be done by two ways in terms of formative assessments and summative assessments (Earle, 2014). Formative assessments, also known as assessment for learning, are conducted at the beginning of the lesson, in the middle of the lesson, and at the end of the lesson in order to elicit students' understanding and move students learning forward. On the other hand, summative assessments, called assessment of learning, are conducted at the end of the unit. Summative assessment deals with the result and answer the question of "What did students learn in this unit?" Although most of the formative assessment techniques are verbal and interactive, summative assessments are included written tests (Earle, 2014). Teachers who use traditional techniques, such as multiple choice question, essay types questions and alternative techniques, like portfolio, performance assessment, peer assessment together in formative assessment and summative assessment reported to possess robust understandings about knowledge of methods. On the other hand; teachers who use only summative assessments, or only formative assessments, or only traditional assessment techniques in formative and summative assessment found to have partial understanding about knowledge of methods. Some examples of formative assessment techniques and summative assessment techniques are presented in Table 3.10.

Table 3.10

Examples of Formative Assessment and Summative Assessment Techniques

Type of Assessment	**Examples**	**Source**
Formative Assessment	Questioning (Closed or open ended), discussion, drama, presentation, observation of task, self-assessment, peer assessment, KWLH grid, concept map, quizzes, games, portfolios, journal entries, lab reports, poster	Barenholz & Tamir, 1992; Earle, 2014; Magnusson et al., 1999; Taşdere & Özsevgeç, 2012)
Summative Assessment	Multiple choice questions, gap filling, matching, problem solving, true false questions, essay types questions	(Earle, 2014; Lewis & Robinson, 2000; Uşak, 2009

3.6.2.5. Data Analysis of Knowledge of Instructional Strategies

Knowledge of instructional strategies includes two main parts, namely knowledge of subject specific strategies and knowledge of topic specific strategies in this case cell division. Knowledge of subject specific strategies is parallel to orientation towards science and includes teachers' general instructional knowledge regarding science while knowledge of topic specific strategies are related with techniques that teacher use in specific science topics (Magnusson et al., 1999).

Knowledge of topic specific strategies includes two sub-components which are knowledge of activities and knowledge of representations. Knowledge of activities includes activities and teaching methods in teaching specific science content, whereas knowledge of representations comprises drawings, analogies, figures, models, simulations and visuals.

As first dimension of knowledge of instructional strategies, participants' knowledge of subject specific strategies was assessed by use of pre-interview questions, observations and post-interview questions. Several questions were asked during pre-interviews to understand participants' subject specific strategies' knowledge, such as 'Which teaching strategy, methods or technic do you use when you teach science concepts in general?' and 'Why do you prefer to use these methods, technics and strategies?'. During the observations, researcher took notes whether participants use teacher centered methods such as didactic strategies which are direct instruction, questioning, teacher-led discussion or students centered methods which involves inquiry oriented and argumentation-based activities, including for example learning cycle, conceptual change approach etc.,. Post interviews were conducted to clarify possible inconsistencies.

Participants' knowledge of topic specific strategies, second dimension of knowledge of instructional strategies, regarding cell division was assessed by use of pre-interview questions. Data were triangulated with observations and inconsistencies between interviews and observations were eliminated by use of post-interview questions. Pre-interview questions about topic specific strategies were prepared by means of knowledge of representations and knowledge of activities. The question that assesses participants' knowledge of representation regarding cell division is:

> Do you use illustrations, examples, models, drawings, and analogues to assist students' learning cell division topics and concepts?
>
> If yes, what are these representations and can you give examples of these representations?
>
> If no, why do not you use illustrations, examples, models, drawings, and analogues?

Some examples of the representations used in cell division studies were presented below.

Table 3.11

Knowledge of Representation

Representation Types	**Specific Examples**
Illustrations	
Showing visuals (photo, video etc.)	Teacher shows diagrammatic representation of gamete formation, zygote, allele segregation (Cho et al., 1985).
Drawing figure	Teacher draws events of mitosis, meiosis and specific concepts such as crossing over (Kindfield, 1994)
Examples	Teacher gives examples of different cell types that undergo mitosis and meiosis (Lewis & Wood Robinson, 2000).
Models	
Hand models	Hand models are useful to make cell division topics concrete. For example, each finger represents a single chromosome in these models (Clark, 2000; Mickle, 1990; Kılınç, 2008; Sarıkaya et al., 2004).
Analogies, Comparison, Metaphors	Cell division is like a dance and chromosomes are the dancers .

Similar to knowledge of representations, participants' knowledge of activities was assessed based on pre-interview questions, observations and post-interview questions. Participants' knowledge of activities regarding cell division was assessed by the question asked in pre-interviews which are "Do you conduct activities in class regarding cell division? If you conduct, what are these activities?" After participants answered this question, researcher specifically asked about the activities that they conducted about basic concept of cell division which is mitosis, role of chromosome in cell division, asexual reproduction, meiosis, sexual reproduction, crossing over and the differences between mitosis and meiosis. Then, data obtained from pre-interviews was triangulated with observation and post interviews. Some examples of the activities used in cell division studies were presented below.

Table 3.12

Knowledge of Activities

Types of Activity	**Specific Examples**
Problem Solving Activity	Teacher asks problems regarding cell division. These problems were usually asked to link cell division and genetics topics (Clark, 2000; Kindfield, 1994; Williams et al., 2012).
Simulations	Computer assisted programs, instructional games and drill and practice programs are examples of simulations regarding cell division (Kara & Yeşilyurt, 2007).
Experiments	Microscope slides about different stages of cell division or observation of cell division events are examples of experiments regarding cell division (Cordero & Szewcak, 1994; Mickle, 1990).
Role playing Activity	Each student represent a chromosome and they present different stages of cell division in this activity such as duplication of chromosomes, separation of homolog chromosomes, and separation of sister chromatids etc. (Clark, 2000).
Play dough Activity	Students use play dough symbolizing different events of cell divisions then they make animations to show what happens in the process (Bogiages & Hitt, 2008).

3.7 Trustworthiness of the Study

The aim of qualitative study is different from the aim of quantitative study. Researchers care the variables and static situation in quantitative studies, on the other hand researchers in qualitative study consider on the meaning of human activities. Different aims found in different paradigms causes the difference for nomenclature about validity and reliability issues in research (Merriam, 2009). Therefore, Lincoln and Guba (1985) used alternative terms for qualitative research which are credibility, transferability, dependability, and confirmability. After these terms are integrated trustworthiness of the study is provided (Lincoln & Guba, 1985). In this section; credibility, transferability and dependability (consistency) of the study are covered.

3.7.1 Credibility

Credibility refers to internal validity of a study (Lincoln & Guba, 1985) and it refers to how findings of a study match with reality (Merriam, 2009). Because of researchers interpret their findings, credibility of a study never capture reality; however, it is possible to increase credibility of a study. According to Merriam (2009), there are different ways to increase credibility of a study namely triangulation, member check, adequate engagement in data collection, researcher position (reflexivity), and peer review.

Creswell (2007) explained that "In triangulation, researchers make use of multiple and different sources, methods, investigators, and theories to provide corroborating evidence. Typically, this process involves corroborating evidence from different sources to shed light on a theme or perspective." (p.208). Merriam (2009) claimed that triangulation is provided by use of multiple methods, multiple sources of data, multiple investigators, and multiple theories to confirm emerging data. Firstly, researcher in this study used multiple methods which are interviews, observations and documents. Participants' interviews as primary data source were checked with observations and documents. Inconsistencies between different methods were asked in during post-interview questions. Secondly, multiple sources of data were used in this study. Researcher conducted many observations. Field notes of same teachers' observations were compared and contrasted in this study and same teachers' transcripts were compared and contrasted too. Thirdly, investigator triangulation was applied too. Data were analyzed and findings compared with different researchers. Syntactic knowledge questions were assessed with a science education researcher who got Nature of Science course in her undergraduate. PCK questions were analyzed with another science education researcher who is familiar with PCK and got courses including teacher education and PCK. Finally, cell division substantive content knowledge questions were analyzed with a science education graduate. However, multiple theories to confirm emerging data were not used in this study. Findings of the study was formed under the Magnusson et al. (1999) model, other models explaining PCK were not used.

Member check is another way to increase credibility. It is respondent validation and participants give feedback to the researcher. These feedbacks identify researchers own biases (Merriam, 2009). After researcher analyzed pre-interviews and observations, he prepared post-interview questions to understand inconsistent situations occurred between pre-interviews and observations. While respondents explained these inconsistencies, they also had a chance to remember and see what they act and talked in pre-interviews and observations. So, they could check their answers and actions in classes and give feedback to the researcher or approved their speech and actions.

Adequate engagement in data collection is third way to increase credibility (Merriam, 2009). Before this study was conducted, researcher met the participants. Researcher both told the aim of the study and what researcher wanted to do. All the participants were older than researcher and they tried to assist in this study from the beginning of the study to the end. Then, researcher and participants became familiar with each other. Whenever researcher visited participants, participants accepted visits and facilitated the situations. So, researcher spent time with participants from

September 2013 to December 2013. Numerous observations, interviews and conservations were done with participants. During these conversations, researcher gathered so much information about the school context and participants daily life which were beneficial for thick description of this qualitative study.

Researcher position or reflexivity is another way to increase credibility (Merriam, 2009). Reflexivity is "the process of reflecting critically on the self as researcher, the 'human as instrument'" (Lincoln & Guba, 2000, p.183). Reflexivity is important because researcher's values and expectations affect the results of the study (Merriam, 2009). Credibility of researcher depends on the researcher experience according to Patton (2005). Researcher did not conduct so many qualitative researches which are disadvantage for this study. However, researcher used necessary aspects of qualitative study such as making naturalistic inquiry, using qualitative methods, analyzing inductively, sampling purposefully and thinking holistically which increase the credibility. In addition, although researcher did not take qualitative methodology course, researcher has read Merriam (2009), Creswell (2007) and Yıldırım & Şimşek (2006) qualitative research books to get insight what qualitative research is and how it is conducted. Apart from this, researcher participated in one of his colleagues' qualitative study caring in-service teachers' NOS, pedagogical knowledge, PCK, and contextual knowledge. This collaboration might increase researchers' skills on qualitative research such as forming codes and categories and writing reports from these findings. Furthermore, pilot study had some contributions for researcher's understandings about qualitative research and PCK. Because of researcher is not experienced in PCK and qualitative study, he had many discussions with PhD students caring and studying PCK, professor who has conducted many qualitative and PCK studies and assistant professors who conducted PCK study in their PhD thesis.

Last way for increasing credibility of a qualitative research is "peer review". According to Merriam (2009), the ones who are familiar with methodology and content can advise to naive researchers. In this study, two assistant professors and one professor advised and gave feedback to the researcher.

3.7.2 Transferability

Transferability refers to external validity of a qualitative research. It is “extent to which the findings of a study can be applied to other studies.”(Merriam, 2009, p.223). Aim of the qualitative studies is not to generalize the findings; however, other researchers can benefit from the qualitative studies sharing similar research questions, similar contexts. For example, other researchers who study PCK of experienced teacher in private middle schools may benefit this study’s findings because this study is conducted in private schools with experienced elementary science teachers. In this study, Merriam (2009) claimed that transferability of a study can be increased by two ways with respect to rich thick description and maximum variation in sample. In this study, it is supposed to be reached rich thick description explaining context, participants, findings and quotes in detail. Similarly, this study reached maximum variation too because there were three experienced-in service teacher participated in. Although, three of the participants worked in private middle schools, their schools were different from each other and so their contexts were different from each other. Explaining each of them as different cases, researcher increased the variation of the study.

3.7.3 Consistency

Dependability or consistency refers to reliability. However, human acts are not static, so replication of a qualitative study is not possible. Therefore, replication is not aim for qualitative research. The important thing is the consistency between results and collected data, so it is named as consistency or dependability (Merriam, 2009). Triangulation, peer examination and investigator position increase consistency of research. These criteria were explained in detail at credibility of the study. In addition, inter-rater agreement was provided for syntactic knowledge, substantive knowledge and PCK. Inter-rater agreement for syntactic knowledge was found 92 %. Inter rater agreement for PCK pre-interviews were found 90 % and inter rater agreement for substantive content knowledge was found as 85 %. Discussions for inconsistencies followed the inter-rater agreements to solve conflictions between researchers.

3.8 Ethics

When researcher found the private schools, he requested to work with teachers and he told them aim of the study. Science teachers and school principals accepted to study with researcher and researcher got school principals' and owners' permission to study with their teachers. This study protected participants and schools' rights. Researcher didn't use their real names and he coded them as Ahmet, Selim, and Burcu. In addition, Researcher protected the data which he did not share with anyone else. In addition, none of the participants were deceived. Similarly, no one was harmed in this study (Frankel & Wallen, 2006).

In addition, researcher noticed not to judge or criticizes participants during interviews. Questions of the interviews were prepared caring this concern, so participants didn't feel them under attack. Moreover, sometimes participants tended to show their actual teaching different from their own teaching unintentionally in pre-interviews that damages ethics and trustworthiness of the study, but researcher analyzed inconsistencies between teacher speech in interviews and actions in class observations and asked post-interview questions to increase ethics and trustworthiness.

Furthermore, researcher observed participants' cell division teaching. This situation might affect teacher actual teaching which may cause ethical problems. After observing a few hours, each of the teachers got familiar to researcher and they went on to their actual teaching.

Another ethical concern in qualitative study occurs in data analysis. Researchers may select some sort of data to analysis and not select some data which are problematic for findings of the study (Merriam, 2009). In this research, researcher needed to use all the data as much as he captured. The data which are inconsistent with each other were detected and the reason why they were not consistent with each other was sought in post-interviews. Finally, researcher gathered participants' documents and written exams to be used. Researcher requested to use these documents and participants gave permission to researcher for the use of documents in study.

3.9 Limitations of the Study

First limitation of the study is related with recording observations. Researcher did not use video-record or audio record during observations. Researcher got only field notes because researcher conducted this study in private schools; they did not give permission for recording class activities. Thus, researcher might miss some points related with the scope of the study when researcher took field notes. Secondly, researcher could not participate in observing all class activities regarding cell division because course schedule was tentative in first unit (cell division and heritage) when the schools opened recently and teachers did not call researcher that course schedule changed. In addition, sometimes different teachers' schedule clashed with each other and researcher had to observe just one of them. Researcher tried to minimize these limitations by use of multiple methods and collecting multiple sources of data. Next, researcher existence may affect teaching practice during observations for both students and teachers. Thanks to friendship with teachers and students, they accepted researcher's existence and researcher became a member of each class as complete observer.

Triangulation was provided by multiple uses of data, method and investigator. However, multiple uses of theories were not used in this study which might be limitation. The only model that explains PCK was Magnusson et al. (1999) model in this study. Other PCK models were not triangulated with this study's theoretical framework. Secondly, researcher experience in qualitative study and PCK can be another limitation because this study's researcher is naive for both qualitative and PCK research. Researcher might miss some points in this study and an experienced researcher might conduct this study different. I tried to minimize this limitation by reading qualitative books, PCK books, articles based on PCK, consulting with science educators studied on PCK and qualitative research and discussing with my friends interesting qualitative paradigm and PCK.

Although aim of the qualitative studies is not to generalize the findings to other situations; policy makers, researchers and teachers may benefit from findings of this study. Researcher selected the participants purposively based on some criteria. These criteria make this study beneficial to the other situations sharing similar contexts. For example; this study was conducted with private schools, so this study's results may not be suitable for public schools. Moreover, this study was conducted with experienced teachers who graduated from related universities' elementary science educations department. This means that results of this study's findings may not be generalized for teachers who graduated from art and science faculties or naive teachers. This study is based on teachers' PCK regarding cell division, so results of this study can't be generalized into other PCK studies regarding other science concepts. Convenient sampling may also be limitation because convenient sampling provides poor information. Maximum variation sampling or typical sampling could be better for representativeness of the study.

Another limitation of this study revealed in current study was about history threat (Frankel & Wallen, 2006). Acoording to this threat an unplanned event may affect the result of the study. In this study, historical threat was the curricular place of the unit and change on the schedule of High School Entrance Exam. Because of this study was conducted in first unit, some of the schools were not ready for instruction. For example, one of the schools did not distribute the textbook at the beginning of the unit therefore; this situation may affect science teacher performance on knowledge of curriculum and knowledge of instructional strategy. Similarly, date of High school Entrance Exam moved to an earlier time, therefore teachers had limited time for teaching and teachers performance can be affected by this unplanned change.

3.10 Assumptions of the Study

In this study, it was assumed that experienced teachers' teaching career is either five years or above because we are never sure whether a teacher is experienced or not. Moreover, it was assumed that experienced teachers have capacity for transforming their content knowledge.

Second assumption is that PCK is transformation of content knowledge because PCK can be identified in different ways such as the integration of different knowledge domains.

It was assumed that rubrics for content knowledge are good at assessing in-service teachers' content knowledge regarding PCK because different science educators can prepare different rubrics based on different sources, so results can be subjective.

Moreover, it was assumed that Magnusson et al. (1999) model have explanatory power for teacher PCK because this study considered on components of PCK to better analyze science teachers' PCK. If results of the current study are valid and reliable, it is because of the model that was used in the study.

It was assumed that private schools have better facilities about technological and laboratory equipment for science teaching than public schools have because knowledge of instructional strategies depends on the environmental factors such as existence of laboratory materials.

The last assumption in this study that participants were not affected by researcher during observations and they honestly gave answers to questions in interviews.

CHAPTER 4

FINDINGS

This is a multiple case study and findings of this study are presented case by case separately in. At the beginning of the each case, participants' content knowledge, both substantive and syntactic, are presented and interpreted based on the data obtained through pre-interviews. While the substantive structure of a discipline is the organization of concepts, facts, principles, and theories, syntactic structures are the rules of evidence and proof used to generate and justify knowledge claims in the discipline." (Abell, 2007, p.1107). Later, participants' PCK knowledge are reported and interpreted based on pre-interviews, observations, teacher documents and post interviews.

In the first part of each of the cases, participants' syntactic knowledge (i.e., Nature of Science knowledge) was presented. Syntactic knowledge refers to nature of scientific knowledge including tentative NOS, empirical NOS, inferential NOS, imaginative and creative NOS, socio-cultural NOS, subjective NOS, and functions of theories and laws, distinction between theory and law.

In the second part each of the cases, science teachers' substantive content knowledge regarding cell division sub-topics which are basic terms, cell cycle, mitosis and meiosis will be reported.

In the third part of the each cases science teachers' pedagogical content knowledge components which are orientation towards science, knowledge of curriculum, knowledge of students' understandings in science, knowledge of assessment and knowledge of instructional strategies and their sub-components will be reported one by one. At the end of the chapter, science teachers' summary of the findings regarding content knowledge and pedagogical content knowledge will be reported together.

4.1 CASE 1: Selim’s Content Knowledge and Pedagogical Content Knowledge regarding Cell Division

4.1.1 Selim’s Content Knowledge regarding Cell Division

Selim’s content knowledge which includes syntactic knowledge (i.e. Nature of Science) and substantive knowledge is presented. First, findings regarding syntactic knowledge were presented.

4.1.1.1 Selim’s Syntactic Knowledge

Interview results revealed that Selim had informed views on two NOS aspects which are empirical and inferential NOS. On the other hand, his understanding that scientific knowledge partly depends on scientist imaginative and creativity NOS found as adequate. Selim, however, held inadequate views on remaining four NOS aspects which are tentative NOS, socio cultural NOS, subjective NOS, and functions of theories and laws and the distinction between theories and laws. Table 4.1 presents Selim’s understanding of NOS aspects.

Table 4.1

Summary Table for Understandings of Selim's NOS Aspect

NOS ASPECT	Sample Excerpts	CATEGORY
Tentative NOS	Laws are the proven version of theories... Theories are subject to change because they are not proven. Theories may change in the future because the facilities will be better in the future. Change of theories depends on the use of technology.	Inadequate
Theory & Law	..Theories are not proven. On the other hand, laws are the proven theories. Theories are not certain. However, laws are certain. Theories are subject to change. When theories are proven they become laws.	Inadequate
Empirical NOS	Science is different from other disciplines because it provides evidence. Experiments are the ways scientist used to prove their inquiries. Experiments are used to prove what scientists want to do. Experiments are not the only way to enrich scientific knowledge. Some knowledge in biology may be gathered through observation, such as theoretical knowledge.	Informed
Inferential NOS	Observations are the data gather through our senses. You measure sound, you can use decibel, it is observation….. [Inference] seems to be something that needs to be proven. It [Inference] is related to the results. I mean they get some result, but we do not know whether this knowledge is true or false. We observe first, and then we connect it to inference.	Informed
Imaginative and Creative NOS	Creativity is necessary. … Scientists use their creativity mostly on designing stages [of experiment]. They minimize their creativity in data collection and planning [stages].	Adequate

Table 4.1 (cont'd)

NOS ASPECT	Sample Excerpts	CATEGORY
Socio-Cultural	Science should be universal... If something is true for me, it should be true for English. If you ask a chemical element to the people from different cultures, they give the same answer.	Inadequate
Subjectivity	This is not a proven idea because we have not a chance to go to past... It is related with imagination and data. Because of there are limited data, scientists interpret differently... There are no certain evidence.	Inadequate

In the following part, Selim's responses to each question of VNOS C were mentioned.

At first, his response to the question that 'What, in your view, is science?" "What makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g. religion, philosophy)?" was presented Selim's understanding of science.

> I: What, in your view, is science?
>
> Selim: Science should be related with the acquisition of scientific knowledge. Science is the fact. Scientists make observations, examine previous studies and benefit from technological equipment.
>
> I: What makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g. religion, philosophy)?
>
> Selim: Science can be proven, and improved unlike other disciplines.

Selim thought that science is factual knowledge that can be proved and this knowledge can be developed, through the time, by using technological equipment, observing and exploring studies conducted previously by scientists. Being aware of the developmental nature of science, he acknowledged that science can be developed in the light of technological development, and further appreciated the importance of communication in the development of scientific knowledge. He perceived science as a body of knowledge, method and process as well as a way of knowing.In fact, Selim's understanding of science also provided some insight into his understanding of both tentative, and empirical NOS which will be presented in the next sections.

Selim's Understanding of Tentative NOS

> I: After scientists have developed a scientific theory, does the theory ever change?
>
> Selim: Theories are subject to change because they are not proven. Theories may change in the future because the facilities will be better in the future. Change of theories depends on the use of technology.

His response revealed his inadequate views on tentative NOS. Although realized that scientific theories are subject to change, he believed scientific laws are certain and never change. Selim added that theories need to be proven, and therefore are subject to change. The teacher further claimed that scientific theories change in response to advancement in technology. Accordingly, his thinking that Theories *are not proven* and therefore they are subject to change makes his classification of tentative NOS as inadequate. In addition, he attributed these changes only to the technological developments. He underestimated many important factors contributing to changes of theories, such as reinterpretation of existing theories or changes on scientific knowledge.

Table 4.2

Selim's Sample Statement in Tentative NOS

Tentative NOS	**Category**	**Sample Statement**
After scientists have developed a scientific theory does the theory ever change?	Inadequate	Theories are subject to change because they are not proven. Theories may change in the future because the facilities will be better in the future. Change of theories depends on the use of technology.

His response to the question regarding the functions and differences of theories and laws, presented below, provided the further evidence about his understanding of the tentative nature of NOS.

Selim's Understanding of the Functions of and Differences between Theories and Laws

I: Is there a difference between a scientific theory and a scientific law?

Selim: You have a problem in proving theories because you cannot conduct experiment. Theories are not proven. On the other hand, laws are proven. Theories are not certain. However, laws are certain.

Although previous questions provided evidences to his understanding of the laws and theories (such as when theories are proven they become laws), his response to the above question, however, clarify his understanding of the functions and differences of theories and laws. Finally, his difficulties in defining theories and laws and holding a wide-spread misconception that there is a hierarchy between theory and laws demonstrated his inadequate view.

Table 4.3

Selim's Sample Statement in Theory and Laws Aspect of NOS

Theory and Laws aspect of NOS	**Category**	**Sample Statement**
Is there a difference between a scientific theory and a scientific law?	Inadequate	You have a problem to prove theories because you cannot conduct experiment. Theories are not proven. On the other hand, laws are the proven theories. Theories are not certain. However, laws are certain.
After scientists have developed a scientific theory does the theory ever change?		Theories are subject to change. When theories are proven they become laws.

Selim's Understanding of Empirical NOS

Following questions were used to assess Selim's understanding of empirical NOS:

> I: What is an experiment? Does the development of scientific knowledge require experiments?
>
> Selim: Experiments are the ways scientist use to prove their inquiries. Experiments are not the unique way to rich scientific knowledge. Scientific knowledge which is theoretical might be gathered by observations in biology.

Indeed, Selim's response to "What is science?" and "What makes science different from other disciplines of inquiry?" provided ample evidence for Selim's empirical NOS in advance. Close examination, however, showed that Selim possessed informed view about the empirical NOS because Selim realized the role of evidence in science and he was aware that science is empirical and this empirical knowledge is obtained by observations and experiments. In another word, he was aware that scientists do not always conduct experiment in their investigations, but also make observation about the related phenomena and collect data.

Table 4.4

Selim's Sample Statement in Empirical NOS

Empirical NOS	**Category**	**Sample Statement**
What is an experiment?	Informed	Experiments are used to prove what scientists want to do.
Does the development of scientific knowledge require experiments?		Experiments are not the unique way to get scientific knowledge. Scientific knowledge which is theoretical might be gathered by observations in biology.
What, in your view, is science? What makes science different from other disciplines of inquiry?		Science is different from other disciplines because it provides evidence.

Selim's Understanding of Inferential NOS

I: What is observation?

Selim: Observations are the data that we gather through our senses. If you measure by decibel, it is the observation based on sound.

I: What is inference?
Selim: [Inference] seems to be something that needs to be proven. It is related with result. I mean they get some result, but we do not know whether this knowledge is true or false.

I: What is the difference between observation and inference?
Selim: First we observe, and then we make inferences

Selim knew that observations depend on five senses, that inferences are the interpretations of those observations and also alleged that inferences are not certain. Accordingly his understanding of inferential NOS was categorized as informed.

Table 4.5

Selim's Sample Statement in Inferential NOS

Inferential NOS	**Category**	**Sample Statement**
What is observation?	Informed	Observations are the data that we gather through our senses. If you measure by decibel, it is the observation based on sound.
What is inference?		[Inference] seems to be something that needs to be proven. It is related with result. I mean they get some result, but we do not know whether this knowledge is true or false.
What is the difference between observation and inference?		First we observe, and then we make inferences.

Selim's Understanding of Imaginative and Creative NOS

To identify Selim's understanding of imaginative and creative NOS, following questions were directed to Selim.

> I: Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
>
> Selim: Of course, creativity is necessary. I think scientists use their creativity mostly on designing stages. They minimize their creativity in data collection and planning.

Although recognized the role of creativity, his knowledge that scientists use their creativity mostly in designing stages of scientific investigations showed that he did not fully comprehend the imaginative and creative NOS, and thus his understanding was categorized as adequate. In fact, as understood from his responses, he was aware that scientist also used his creativity in other stages but he thought that scientists use their creativity less often in other stages of scientific investigation.

Table 4.6

Selim's Sample Statement in Imaginative and Creative NOS

Imaginative and Creative NOS	**Category**	**Sample Statement**
Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?	Adequate	Of course, creativity is necessary. I think scientists use their creativity mostly on designing stages. They minimize their creativity in data collection and planning.

Selim's Understanding of Socio Cultural NOS

> I: If you believe that science reflects social and cultural values explain why and how and if you believe that science is universal, explain why and how.
>
> Selim: Science should be universal... If something is true for me, it should be true for English. If you ask an element to the people from different cultures, they give the same answer.

Selim's response uncovered that Selim held inadequate views regarding socio-cultural aspect of NOS. Selim believed that science is universal and does not reflect social and cultural values, means that it is not affected by social-cultural values. Instead, he addressed the importance of effective *communication* with one another- one of the science process skills.

Table 4.7

Selim's Sample Statement in Socio-Cultural NOS

Socio Cultural NOS	**Category**	**Sample Statement**
If you believe that science reflects social and cultural values, explain why and how and If you believe that science is universal, explain why and how.	Inadequate	Science should be universal... If something is true for me, it should be true for English. If you ask an element to the people from different cultures, they give the same answer.

Selim's Understanding of Subjective NOS

> I: It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

> Selim: This is not a proven idea because we have not a chance to return back. It is related with imagination and data. Because of there are limited data, scientists interpret differently... There are no certain evidence.

Selim did not held informed views about subjective NOS because Selim did not appreciate scientists' theoretical perspectives, their expertise and their personal differences that let them to interpret same data different from each other. Selim attributed scientists' different conclusions based on lack of evidence that they have. Hence, he was labeled in inadequate category for subjective NOS.

Table 4.8

Selim's Sample Statement in Subjective NOS

Subjective NOS	Category	Sample Statement
It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by…How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?	Inadequate	This is not a proven idea because we have not a chance to go to past... It is related with imagination and data. Because of there are limited data, scientists interpret differently... There is no certain evidence.

To sum up, Selim's nature of science knowledge referring his syntactic knowledge included lack of knowledge. Specifically, Selim held two informed views which are inferential NOS and empirical NOS and Selim held adequate understanding about creativity aspect of science. On the other hand, Selim held inadequate understanding about tentative NOS, socio-cultural NOS, functions and differences of theory and laws and subjective NOS. In the next section, Selim's substantive content knowledge will be presented.

4.1.1.2 Selim's Substantive Content Knowledge about Cell Division

In this part, Selim's substantive content knowledge regarding cell division is presented. To better grasp Selim's substantive content knowledge about cell division topics, Selim's substantive content knowledge was gathered under four dimensions which are basic terms of cell division, cell cycle knowledge, mitosis knowledge and meiosis knowledge.

4.1.1.2.1 Selim's Knowledge regarding Basic Terms about Cell Division

Selim's content knowledge regarding basic cell division terms was analyzed with respect to conceptual understanding and ontological category.

In terms of conceptual understanding, Selim was found to have sound understandings in five, out of sixteen, basic terms which are sister chromatids, centromeres, asexual reproduction, gamete and zygote. Selim's understandings of chromosome, homolog chromosome, DNA, gene, centriole, and sexual reproduction, however, were categorized as partial. Selim did not answer two concepts which are kinetochore, and somatic cells. Hence, he was not labelled for these two concepts.

Selim's understanding was also assessed based on ontological categories. Selim was in matter category in most of the concepts investigated; namely, homolog chromosomes, DNA, gene, allele, centrosome, centromere, fertilization and gametes. Selim was in process category in chromosome, sister chromatids, centriole, asexual reproduction, and zygote. Selim's responses which were in matter category correspond to his partial answers in general. Similarly, his sound understandings correspond to partial category in general.

Table 4.9 summarizes Selim's conceptual understandings and ontological categories regarding basic terms of cell division.

Table 4.9

Selim's Knowledge of Basic Concepts related with Cell Division

Concept	Selim's Response	Conceptual Understanding			Ontological categorization	
		Naive	**Partial**	**Sound**	**Matter**	**Process**
Write the items in order of size. Start with the largest	Organism>Cell>Nucleus>Chromosome> DNA>Allele>Gene	❖			-	-
Chromosome	Genetic information is found in chromosomes and chromosomes are located in nucleus…Its [chromosome's] function is to provide cell division.		❖			❖
Homolog Chromosomes	are the chromosomes that share common characteristics.		❖		❖	
DNA	… abbreviation of Deoxyribonucleic Acid. Genetic information is kept in it [DNA] …. DNA is located in chromosome.		❖		❖	
Gene	particular segment of the DNA		❖		❖	
Allele	two genes inherited from both of the parents. This gene pair share common traits	❖			❖	

Table 4.9 (cont'd)

Concept	Selim's Response	Conceptual Understanding			Ontological categorization	
		Naive	Partial	Sound	Matter	Process
Sister Chromatids	After DNA replicates itself, chromosomes are formed. When this structure [chromosome] is condensed and coiled, sister chromatids form.			❖		❖
Centrosome	an organelle that plays role in cell division		❖		❖	
Centriole	a material that provides the formation of spindle fiber.		❖			❖
Centromere	the region found at the center of chromosome.			❖	❖	
Asexual Reproduction	Reproduction of a single organism. For example; binary fusion is type of asexual reproduction. Asexual reproduction occurs without male and female organisms.			❖		❖
Sexual Reproduction	is occurred by one one female and one male.		❖		❖	
Gamete	is production of germ cell. Gametes carry n chromosomes. "N" chromosome refers to a set of chromosome transferred from one of the parent.			❖	❖	
Zygote	is fertilized egg cell that is fusion of sperm and egg cell.			❖		❖
Somatic Cell	No Answer				-	
Kinetochore	No Answer				-	

> I: There are some concepts regarding cell division which are cell, chromosome, gene, allele, DNA, organism and nucleus. Can you write the items in order of size? Start with the largest.

This question 'size sequence of cell division concepts' was asked to examine Selim's understanding of size of different basic terms which are cell, chromosome, gene, DNA, organism, allele and nucleus. Selim wrote the concepts depending on descending size as follows:

"Organism >Cell >Nucleus >Chromosome> DNA >Allele > Gene"

Selim's response was correct except the place of allele. Recognizing that gene is the smallest one and that DNA found in chromosome and that chromosomes are located in nucleus, he failed to understand that allele is alternate form of gene. Hence he was labeled in naïve understanding.

> I: What is chromosome? and what is the role of chromosome?
>
> Selim: Genetic information is found in chromosomes and chromosomes are located in nucleus…Its [chromosome's] function is to provide cell division.

Selim's explanation included insufficient knowledge because Selim did not point out DNA and protein bounding to DNA form chromosome. Hence, Selim had partial understanding about chromosome concept. Ontological category of Selim was in process regarding chromosome because Selim pointed out the function of chromosome.

> I: What is homolog chromosome?
>
> Selim: Homolog chromosomes are the chromosomes that share common characteristics.

Although Selim claimed that homolog chromosomes share common characteristics, he did not explain the origin of homolog chromosomes in his explanation. Thus, Selim had partial understanding about homolog chromosomes. Because of Selim thought that homolog chromosomes as passive particles sharing common characteristics, he was found in matter category for this term.

I: What is DNA?

Selim: DNA is abbreviation of Deoxyribonucleic Acid. Genetic information is kept in it [DNA]… DNA is located in chromosome.

Selim had partial understanding about DNA because he did not mention that DNA is a double stranded molecule and role of DNA in cell division, so Selim had partial understanding of DNA. Selim was placed in matter category for this concept because he considered on the location of DNA that "DNA places in chromosome".

I: What is gene?

Selim: Particular segment of the DNA is gene.

Selim's understanding of the gene was limited with gene's place. Selim did not mention that gene is the information sequence which takes role in protein synthesis. Thus, Selim had partial understanding about gene concept. Moreover, ontological category of Selim was matter regarding gene because Selim thought gene as passive particle placed on DNA.

I: What is allele?

Selim: Allele is two genes inherited from both of the parents. This gene pair share common traits.

Similar to his size sequence of the baisc cell division terms, this question identified Selim's misconception about allele concept. Selim thought that allele is two genes and ignore the scientific definition of allele that is the alternate form of gene. Thus, Selim was naïve in allele concept. Selim thought that allele is gene pair and did not refer to how allele affect our body, thus ontological category of Selim was matter regarding allele.

I: What is sister chromatids?

Selim: After DNA replicates itself, chromosomes are formed. When this structure [chromosome] is condensed and coiled, sister chromatids form.

Selim's explanation of sister chromatids was congruent with scientific explanation of concept. So, Selim held sound understanding in this concept. As far as ontological category was considered, Selim was in process because Selim explained the events and their sequence to explain sister chromatids.

I: What is centrosome?

Selim: Centrosome is an organelle that plays role in cell division.

Although Selim claimed that centrosome provides cell division, he included lack of knowledge because he did not mention centrosome produce spindle fibers in cell division. So, he had partial understanding about centrosome. Moreover, Selim was in matter in ontological category because of he did not refer to how centrosome assists in cell division.

I: What is centriole?

Selim: Centriole is a material that provides the formation of spindle fiber.

Selim's explanation of centriole included some lack of knowledge. Selim did not mention perpendicular hollow tubes for the structure of centriole. Thus, he had partial understanding about centriole. Moreover, ontological category of Selim was process because Selim mentioned the role of centriole in cell division.

I: What is centromere?

Selim: Centromere is the region found at the center of chromosome.

Selim's explanation of centromere was consistent with scientific explanation of centromere. Thus, Selim had sound understanding in centromere concept. On the other hand, Selim's ontological category was matter regarding centromere because Selim mentioned the place of centromere in his explanation and did not mention the events related centromere.

I: What is asexual reproduction?

Selim: Asexual reproduction is reproduction of a single organism. For example; binary fusion is type of asexual reproduction. Asexual reproduction occurs without male and female organisms.

Regarding asexual reproduction, Selim's definition of asexual reproduction was consistent with scientific explanation of this concept. Thus, Selim was put under sound understanding category. Ontological category of Selim was process regarding asexual reproduction because Selim mentioned the mechanism of asexual reproduction by referring that “occurs without male and female organisms”.

I: What is sexual reproduction?

Selim: Sexual reproduction is occurred by one one female and one male.

Selim’s explanation included inadequacy regarding sexual reproduction. Selim did not deal with fertilization in sexual reproduction although he mentioned implicitly by reporting “occurred by one female and one male”. Hence, Selim had partial understanding about sexual reprodcution. Ontological category of Selim was matter in sexual reproduction because he did not mention how this process occurs.

I: What is gamete?

Selim: Gamete is production of germ cell. Gametes carry n chromosomes. “N” chromosome refers to a set of chromosome transferred from one of the parent.

Selim’s explanation of gamete was congruent with scientific explanation of this term, so Selim was put under sound understanding category. Ontological category of Selim was matter since Selim considered cellular structure of gametes and did not mention how gametes are produced and affect our body.

I: What is zygote?

Selim: Zygote is fertilized egg cell that is fusion of sperm and egg cell.

Selim held sound understanding about zygote concept because his explanation of zygote was consistent with scientific explanation of zygote. As far as ontological category, Selim was in process category because Selim could clearly reported the mechanism of zygote formation that is “fusion of sperm and egg cell”.

Unfortunately, Selim could not answer the questions regarding kinetochore and somatic cell, his conception was labelled as no understanding. His ontological category about these two terms was not identified and he was not classified in any of the ontological categories.

To summarize, Selim had sound understanding in sister chromatids, centromere, asexual reproduction, gamete and zygote. Ontological category of Selim was process in chromosomes, sister chromatids, centriole, asexual reproduction and zygote over sixteen basic terms. Moreover, Selim's ontological category was matter in general. Because of Selim neither has sufficient conceptual understanding in basic terms nor pass to the process category, Selim may have problems in teaching these terms. Selim's cell cycle knowledge is reported in the following section.

4.1.1.2.2 Knowledge of Cell Cycle

Question regarding cell cycle which is what is a cell cycle? Can you identify the stages in the cell cycle and describe the principle events characteristic of each was asked to Selim to determine his understanding of cell cycle.

Table 4.10

Selim's Knowledge of Cell Cycle

		Understanding of concepts			**Ontological categorization**	
Concept	**Response**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Cell Cycle definition	It does not mean anything for me.	-	-	-	-	-

I: What is cell cycle?

Selim: It [cell cycle] does not mean anything for me.

Selim was not familiar with the concept of cell cycle. When cell cycle concept was asked to Selim, he claimed that he did not know this concept. Consistent with his cell cycle answer, Selim did not clarify to the stages of cell cycle and direction of cell cycle. Because of Selim did not answer the cell cycle question, neither his conceptual understanding nor ontological category regarding cell cycle was identified.

4.1.1.2.3 Knowledge of Mitosis

To reveal his understanding of mitosis, he was supplicated to define mitosis and then explain the events that occur in each stage of mitosis through drawing. Thereafter, he was asked to mitosis of a plant cell and its differences with mitosis of animal cell.

> I: What is mitosis?
>
> Selim: Mitosis is the formation of new cells which are identical to parent cell. Two new cells form through the mitosis. All cells undergo mitosis apart from germ cells, and neurons. Asexual reproduction happens through the mitosis.

Selim had included lack of knowledge about the definition of mitosis. Although Selim know that products of mitosis are identical and there are some cells which do not undergo mitosis such as neurons, he did not clarify that growth of multicellular eukaryotic organism is based on mitosis and that it is the basis of asexual reproduction of single-celled eukaryotes' asexual reproduction is based on mitosis. Hence, Selim had partial conceptual understanding regarding mitosis definition. Moreover, he was requested to draw mitosis' diagram.

> I: Assume that an animal has a diploid chromosome number of four (2n=4). Could you please explain and diagram the mitosis process?

Selim explained the stages of mitosis by referring to diagram below:

> I do not know the names of stages, I do not remember. I do not know their sequence, too. Now, you may say that when prophase ends, I cannot draw it for you… Let's assume that nuclear envelope disappears and chromosomes become visible [in prophase]… Chromosome number duplicates at first. Each of the chromosomes duplicates. Anymore, there are 4n chromosomes…After duplication, chromosomes arrange in equatorial plane and centrosomes pull chromosomes to the poles [by organizing microtubules] by use of spindle fibers. Cytokinesis occurs through the furrowing [in telophase]… Then nuclear envelope re-forms in telophase. Each nucleus has chromosomes and centrosome. There are two cells which are identical [at the end of

cytokinesis]. Although these new cells are smaller than original one, they are identical with each other and original cell.

In his drawing, Selim correctly showed chromosome number of diploid cell undergoing mitosis. Although he drew the stages of process correctly in general, he had some mistakes regarding process. For examples, he did not draw chromatin fiber in original cell. He had lack of knowledge about the names of the stages. Moreover, he did not show centromeres. Furthermore, he did not draw the anaphase. On the other hand, Selim was aware the general process such as sister chromatids, DNA replication, duplication of chromosomes and separation of sister chromatids. Hence, he was in process category in mitosis although he had some deficiency and false knowledge.

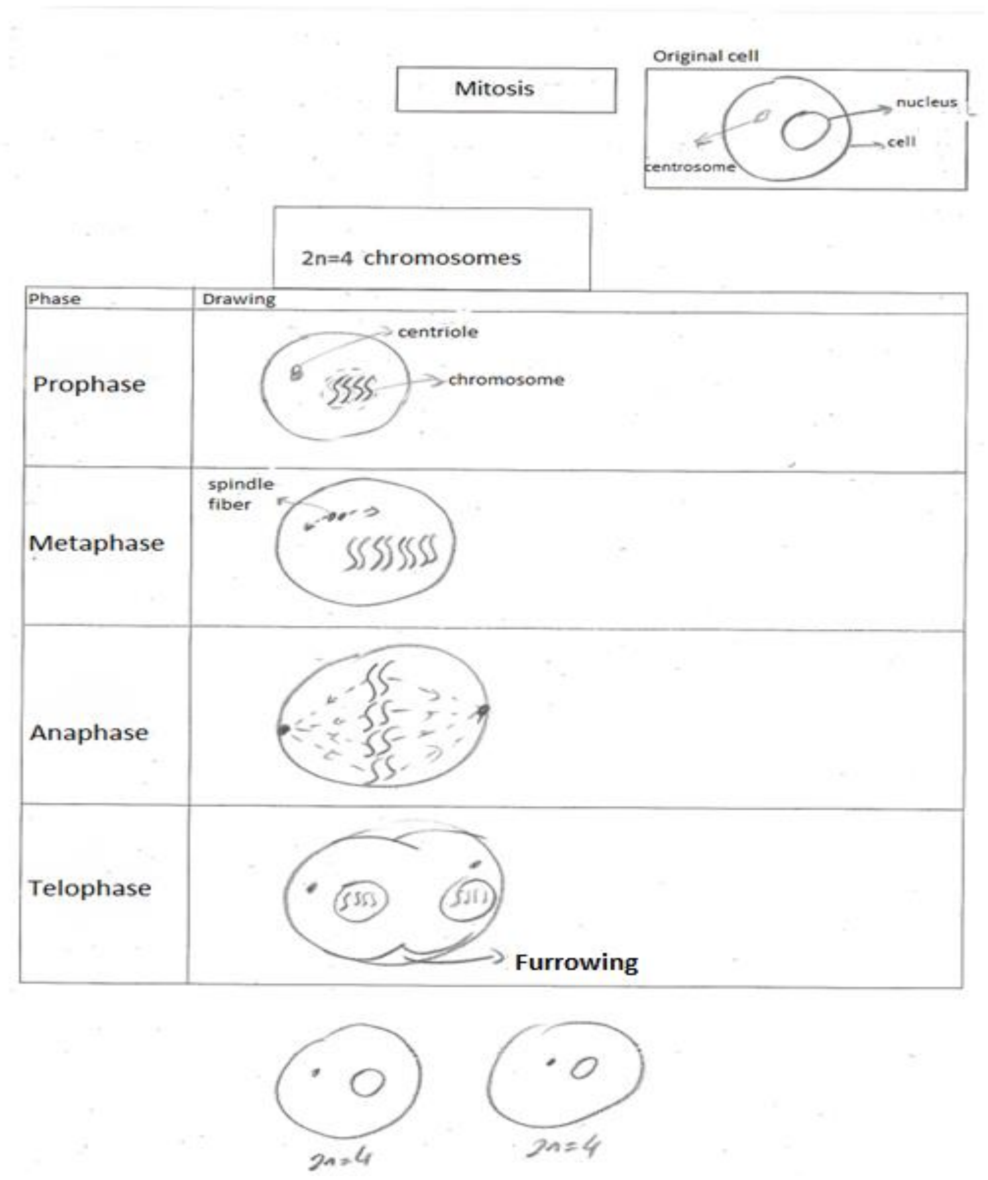

Figure 4.1 Selim's Mitosis Drawings

Selim clearly demonstrated the differences of mitosis between plant cell and animal cell:

> I: Do you think that mitosis in plant cells similar to that of animal cell?
>
> Selim: There is no centrosome in plant cell. Spindle fiber is produced in cytoplasm. Cell plate occurs in plants instead of formation of contractile ring.

Because of Selim indicated the differences correctly which are absence of centrosome and formation of cell plate in plant cell; he had sound understanding in mitosis in plant cell. In overall, Selim was in process category regarding mitosis although his explanation included lack of knowledge which put his conceptual understanding in partial category.

Table 4.11

Selim's Knowledge of Mitosis

		Conceptual Understanding			Ontological categorization	
Concept	**Answer of Selim**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Process of Mitosis	Mitosis is the formation of new cells which are identical to parent cell. Two new cells form through the mitosis. All cells undergo mitosis apart from germ cells, and neurons. Asexual reproduction happens through the mitosis.		❖			❖
Mitosis in Plant cell's	There is no centrosome in plant cell. Spindle fiber is produced in cytoplasm. Cell plate occurs in plants instead of formation of contractile ring.			❖		❖

4.1.1.2.4 Knowledge of Meiosis

To better comprehension of his understanding of meiosis, he was requested to define meiosis and then explain the events that occur in each stage of meiosis through drawing. Then, she was asked to meiosis of a plant cell and its differences with meiosis of animal cell.

> I: What is meiosis?
>
> Selim: Meiosis is cell division that produces gametes. Thanks to meiosis [and fertilization], number of chromosome remains constant. Moreover, genetic diversity occurs. Meiosis provides genetic diversity between organisms in a species. Meiosis is an obligation for sexual reproduction because sexual reproduction occurs by fusion of meiosis products [gametes].

Selim's definition of meiosis matched with scientific definition of meiosis. He was able to understand products of meiosis. He could also connect meiosis to sexual reproduction as meiosis is necessary for sexual reproduction. Selim also mentioned that meiosis cause genetic diversity.

> I: Assume that an animal has a diploid chromosome number of four (2n=4). Could you please explain and diagram the meiosis process?

Selim explained her views during her drawing of meiosis diagram as follows:

> Nuclear envelope disappears and chromosomes become visible [in prophase-1]… Let's draw four chromosomes. Then, chromosomes are duplicated. They [sister chromatids] are held together in meiosis-1. Crossing over is exchange of genetic material between homolog chromosomes… *Crossing over occurs in anaphase-1. Centromeres are (just) in meiosis.* Cytokinesis occurs through the furrowing after karyokinesis. After meiosis-1, cytokinesis occurs [not mentioning interkinesis]. I don't know whether nuclear envelope reform before meiosis-2. DNA is not replicated before meiosis-2. Number of chromosomes does not duplicate. Chromosome number 'n' is two anymore. We duplicate centrosomes here. [Sister Chromatids] are separated from their centromeres.

Selim had lack of knowledge in his drawings and explanation of the processes. For example; Selim did not draw chromatin fiber in original cell. Although he could recognize the events and their sequence in meiosis, he was not aware that which events happen in which stage because Selim did not know the names of the stages and stages' sequence as he mentioned in his mitosis drawings. He was also not aware about the interkinesis occurring between meiosis-1 and meiosis-2. Moreover, he did not draw re-formation of nuclear membrane at the end of meiosis-1. Because of Selim did not know names of the stages and their sequence, he estimated that crossing over occurs in anaphase. However, he knew that crossing over occurs before homolog chromosomes separate. In conclusion, Selim was aware of the meiosis process but, he had some lack of knowledge. To sum up, Selim had partial understanding and was in process category. Selim thought that gametes, germs cells, crossing over and reduction of chromosome number are specific to meiosis; however, he did not mention tetrade, synapsis, and chiasmata as specific concepts attributed to meiosis.

Selim was able to differentiate the meiotic events that occur in plant cells and animal cells:

> I: Do you think that meiosis in plant cells similar to that of animal cell?
>
> Selim: Differences are similar to mitosis; there is no centrosome [in plant cell]. Cell plate forms in meiosis in plant cell during cytokinesis because of cell plate.

Similar to his understanding about mitosis in plant cell, Selim had sound understanding about meiosis in plant. Selim considered the lack of centrosome in plant cell and cell plate formation in cytokinesis.

Moreover, Selim was able to distinguish mitosis and meiosis process and he had sound understanding and his ontological category was determined as process because Selim mentioned the different evidence in the process.

> I: What are the differences/similarities between the meiosis and mitosis? Could you explain your answer?
>
> Selim: Four cells are produced after meiotic division, but two cells are produced after mitosis. Genetic information changes in meiosis, but genetic information does not change in mitosis. Although chromosome number does not change in mitosis, chromosome number reduces in meiosis. Crossing

over, reduction in number of chromosome and genetic diversity are unique to meiosis. Only diploid germ cells undergo meiosis, however all cells undergo mitosis apart from gametes and neurons.

Although Selim was able to recognize process of meiosis, meiosis in plant cell, comparison of meiosis and mitosis process he was not able to recognize the relationship between genetics and meiosis. Stated differently, Selim did not mention the law of independent assortment that happens in anaphase-1 when he drew meiosis. Hence his understanding about the principle that connects genetics and cell division was not determined based on conceptual understanding. Similarly, his ontological category was not determined because of he did not respond. Table 4.12 summarizes Selim's understanding regarding meiosis.

In this section Selim's meiosis knowledge was resulted and presented in the next section; Selim's pedagogical content knowledge regarding cell division will be reported.

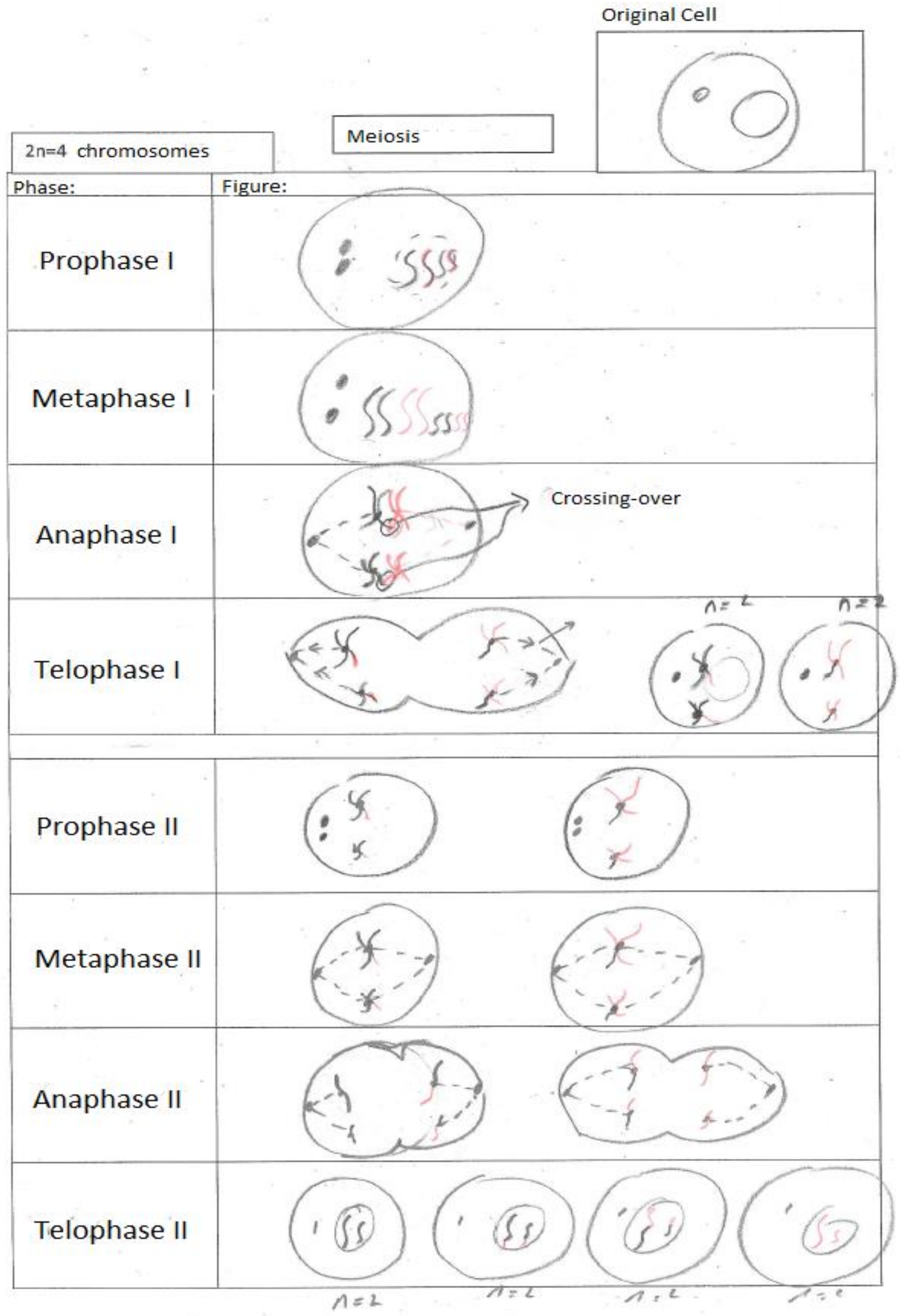

Figure 4.2 Selim's Drawing of Meiosis

Table 4.12

Selim’s Knowledge of Meiosis

		Conceptual Understanding			Ontological categorization	
Concept	**Selim’s Response**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Meiosis	Meiosis is cell division that produces gametes. Thanks to meiosis [and fertilization], number of chromosome remains constant. Moreover, genetic diversity occurs. Meiosis provides genetic diversity between organisms in a species. Meiosis is an obligation for sexual reproduction because sexual reproduction occurs by fusion of meiosis products [gametes].		❖			❖
Meiosis in Plant Cell	Differences are similar to mitosis; there is no centrosome [in plant cell meiosis]. Cell plate occurs in plant meiosis during cytokinesis.			❖		❖

Table 4.12 (cont'd)

Concept	Selim's Response	Conceptual Understanding: Naive	Partial	Sound	Ontological categorization: Matter	Process
Meiosis and Mitosis Differences	Four cells are produced after meiotic division, but two cells are produced after mitosis. Genetic information changes in meiosis, but genetic information does not change in mitosis. Although chromosome number does not change in mitosis, chromosome number reduces in meiosis. Crossing over, reduction in number of chromosome and genetic diversity are unique to meiosis. Only diploid germ cells undergo meiosis, however all cells undergo mitosis apart from gametes and neurons.			❖		❖
Principle that connect genetics and cell division	No idea	-			-	-

4.1.2 Selim's PCK Regarding Cell Division

Pre-interview questions, observation records, teacher documents and post-interview questions were used to get Selim's PCK about cell division. These data collection tools provided evidences for Selim's PCK components which are orientation towards science, knowledge of curriculum, knowledge of students' understanding of science, knowledge of assessment, and knowledge of instructional strategies. Findings obtained from analysis regarding Selim's PCK are presented in this section.

4.1.2.1 Selim's Orientation towards Science

Selim's beliefs about goals of science teaching were explored to understand his orientation towards science since beliefs shapes teacher's decision and practice. Beliefs about goals of science teaching were gathered through the pre-interviews, and observations. In this section, Selim's beliefs about goals of science teaching were categorized as central and peripheral goals which can be specified as schooling, affective and subject matter goals.

4.1.2.1.1 Selim's Beliefs about Goals of Science Teaching

In this section, firstly Selim's answers to pre-interview questions were presented as Selim's beliefs about goals of science teaching. Secondly, data gathered through observations were presented regarding Selim's beliefs about goals of science teaching. Table 4.13. presents Selim's beliefs about goals of science teaching based on pre-interviews.

Table 4.13

Beliefs about Goals of Science Teaching (Pre-interviews)

Question	Response	Central Goals	Peripheral Goals
What do you understand about the term "science teaching"?	Science teaching is *to teach scientific knowledge* to the students using different methods and sources.	Subject Matter Goals	-
What are the goals of science teaching in your opinion?	Science is *directly related with life*. The knowledge obtained from life is taught in science lessons. Because of students will use scientific knowledge in the future, science courses should be given. We prepare students to life, thus science courses are necessary.	Schooling Goals	-
As a science teacher, what is the meaning of teaching cell division topics for you?	Just like other lessons, this lesson should be thought too.	Subject Matter Goals	-
	Because of science lesson prepares students to life, cell division should be covered too. Moreover, cell division is *directly related with our [human beings'] nature*.	Schooling Goals	-

Table 4.13 (cont'd)

Question	Response	Central Goals	Peripheral Goals
Why do you teach cell division topics as a science teacher?	In order to *get students recognize that how they [students] grow, how they [students] reproduce and how other organisms develop in their [students'] surroundings*.	Schooling Goals	-
	Moreover, students are *curious* about how their [human beings'] length increases and how they [human beings] reproduce.	-	Affective Goals

I: What do you understand about the term "science teaching"?

Selim: Science teaching is to teach scientific knowledge to the students using different methods and sources.

Selim emphasized on transferring scientific knowledge to the learner by use of different methods and source. Hence, Selim's central goal is subject matter knowledge goals focusing content knowledge regarding his understanding of science teaching.

I: What are the goals of science teaching in your opinion?

Selim: Science is directly related with life. The knowledge obtained from life is taught in science lessons. Because of students will use scientific knowledge in the future, science courses should be given. We prepare students to life, thus science courses are necessary.

Although Selim mentioned subject matter goals in previous response, Selim focused on schooling goals in second question because Selim considered to connection between science and daily life relationship. Selim pointed out the importance of preparing students to life.

I: As a science teacher, what is the meaning of teaching cell division topics for you?

Selim: Just like other lessons, this lesson should be thought too. Because of science lesson prepares students to life, cell division should be covered too. Moreover, cell division is directly related with our [human beings'] nature.

This question assesses Selim's understanding of cell division teaching. Selim's beliefs about teaching cell division focused on subject matter and schooling goals as central goals. Selim emphasized on subject matter goals by claiming "Just like other lessons, this lesson should be thought too.". On the other hand, he also focused on schooling goals by claiming "science lesson prepares students to life".

I: Why do you teach cell division topics as a science teacher?

Selim: In order to get students recognize that how they [students] grow, how they [students] reproduce and how other organisms develop in their [students'] surroundings. Moreover, students are curious about how their [human beings'] length increases and how they [human beings] reproduce.

In his explanation, Selim aimed to make students aware of their body and their surroundings. Selim tried to connect science and daily life. Thus, his central goals regarding was schooling goals in this question. Selim had peripheral goals regarding his teaching of cell division. Selim's peripheral goal was related with student's curiosity about cell division which is an example of affective goal. According to pre-interview results, Selim mostly considered on preparing students to life, making them be aware of their surroundings as schooling goals; transferring content knowledge as subject matter knowledge. Because of Selim emphasized on schooling goals and subject matter goals, these goals were considered as Selim's central goals. On the other hand, Selim mentioned students' curiosity as affective goals which can be thought as peripheral goals because Selim mentioned affective goals less than other two goals types.

Data gathered through interviews were not sufficient solely, thus researcher observed Selim to get further evidence about Selim's beliefs about goals of science teaching. During observations, Selim's central goals focused on transmission of objectives that was subject matter goals. On the other hand, Selim's peripheral goals were schooling goals which aim to make students to understand the link between their bodies and cell division. An example of the events that give clue about Selim's peripheral orientation is presented.

> Digestion and growing is related with mitosis. If you do not get healthy food, you do not grow. Your length does not increase because of unhealthy diets (observation).

Table 4.14 summarizes Selim's beliefs about goals of science teaching based on observations.

Table 4.14

Beliefs about Goals of Science Teaching Based on Observations

Observation	**Central Goals**	**Peripheral Goals**
To transmit the objectives	Subject Matter Goals	-
To prepare students to life	-	Schooling Goals

In conclusion, although Selim's central goals were schooling goals in pre-interviews that he urged his students to connect learning about science to their daily life, subject matter goals substituted with schooling goals as central goals in observations. Moreover, Selim's schooling goals were peripheral in observations showing that these beliefs have less impact on his teaching. In the next section, Selim's knowledge of curriculum regarding cell division will be reported.

4.1.2.2 Selim's Knowledge of Curriculum

Results of two dimensions of knowledge of curriculum were presented which are knowledge of goals and objectives and knowledge of materials. Data regarding knowledge of goals and objectives were gathered through pre-interview questions and observation records. On the other hand, data regarding Selim's knowledge of materials were gathered through the pre-interviews, observations and post-interviews.

4.1.2.2.1 Selim's Knowledge of Goals and Objectives about Cell Division

Selim could know the place of cell division in curriculum, vertical and horizontal relations, cell division objectives, limitations in objectives, misconception caution in objectives, and the degree of knowledge supposed by curriculum regarding knowledge of goals and objectives. However, Selim did not know the reason why cell division place in curriculum. Selim did not sort the objectives based on their importance and he did not modify textbooks and objectives. Moreover, he was dependent to curricular materials regarding knowledge of goals and objectives.

> I: Why do cell division topics place in curriculum?
>
> Selim: We think that it is better for students to learn cell division concepts before puberty. We start to teach these topics starting from 6th grade level as reproduction.

This question assesses Selim's understanding of why curriculum cover cell division unit. He thought that this knowledge is prerequisite for students to understand what happens in their body. On the other hand, his response did not match with actual reason that was proposed by MoNE (2006). The reason of why cell division topics are taught in middle schools are determined as to prepare students in high school biology concepts such as genetics, cell division and evolution. Stated differently, cell division thought in this level was prerequisite knowledge for high school biology. To sum up, Selim was not aware the reason why cell division topics are included in curriculum.

> I: Do you know the place of cell division in curriculum? In which grade level is cell division taught and what are the topics taught before and after this unit?
>
> Selim: It is taught in 8th grade level. It is the first unit and buoyancy [force and motion] topics follow this unit.

This question assessed Selim's understanding of the place of cell division in curriculum. Selim could know cell division place in curriculum and the unit following it.

> I: Is there any science topic taught in earlier grades related with cell division?
>
> Selim: Reproduction unit in 6th grade level is related with cell division topics. Although we do not say directly cell division, we mention in this grade level.

This question assessed Selim's understanding of vertical relationship regarding cell division. Selim was aware that growth, development and reproduction topics thought in 6^{th} grade level. Thus he could know the vertical relations of cell division.

> I: Is there any science topic taught in 8^{th} grade level related with cell division?
>
> Selim: It is related with sexual and asexual reproduction but it is not related with another topics thought in 8^{th} level.

This question assessed Selim's knowledge about horizontal relationship. Selim stressed that sexual and asexual reproductions are related with cell division in same grade level. However, Selim ignored that evolution and genetics topics are related with cell division topics in same grade level too..

After that objectives regarding cell division were asked to Selim in pre-interviews. In his explanation, Selim mentioned four objectives regarding cell division during pre-interviews which are 'Explain that growth and development occurs through the cell division', 'Define Mitosis as process starting with karyokinesis and including stages following each other.', 'Deduce that gametes are produced in meiosis.' and 'Be Aware of the importance of meiosis for living organisms.' over the seven objectives regarding cell division. Although Selim mentioned four objectives regarding cell division in pre-interviews, he covered all the objectives in his teaching during observations. So, Selim was aware the objectives regarding cell division. Selim's knowledge about objectives are presented in the table below:

Table 4.15

Selim's Understanding of Cell Division Objectives

2006 Objectives Stated in Science Curriculum for Cell Division Topic	**Does Selim answer meet the curriculum objective?(Interviews)**		**Does Selim answer meet the curriculum objective?(Observations)**	
	Yes	**No**	**Yes**	**No**
Explain that growth and development occurs through the cell division.	❖		❖	
Define Mitosis as process starting with karyokinesis and including stages following each other.	❖		❖	
Be aware the importance of chromosomes in mitosis and refer that different species can have different number of chromosomes.		❖	❖	
Indicate the importance of mitosis for living organisms and relate mitosis with growth and reproduction.		❖	❖	
Deduce that gametes are produced in meiosis.	❖		❖	
Be Aware of the importance of meiosis for living organisms.	❖		❖	
List the differences between meiosis and mitosis.		❖	❖	

I: Could you sort the objectives based on their importance?

Selim: I think that all objectives have equal importance in cell division topics.

Teachers who have robust PCK are supposed to sort the objectives based on their importancve in specific topics and justify their answers. However, Selim did not sort the objectives regarding cell division based on their importance thinking that all objectives are equal in cell division.

I: Is there any important points to be emphasized for you apart from existing objectives?

Selim: I think that curriculum is sufficient. There is no need for extraction or addition in cell division objectives. I am the supporter of curriculum.

This question was asked to Selim to understand whether he could modify the objectives or content in textbook. Selim did not assert any modification to curricular objectives.

I: Is there any limitations implied in curriculum regarding cell division?

Selim: I remember that Latin names of the stages are not mentioned both in meiosis and mitosis.

Limitations in curriculum regarding cell division were also asked Selim. Selim just mentioned Latin names of the stages as limitation during pre-interviews and not mention other two limitations which are ‘Names of the stages of meiosis are not mentioned and Turkish name of crossing over (Parça Değişimi) is used.’ and ‘Differences of the stages of meiosis and stages of the mitosis are not mentioned. On the other hand, Selim obeyed all the limitations in his teaching. Thus, he had capability of understanding the limitations found in objectives. Table 4.16 presents Selim’s knowledge about limitations regarding cell division.

Table 4.16

Selim's Understanding of Cell Division Limitations

2006 Limitations Stated in Science Curriculum for Cell Division Topics	Does teacher answer meet limitation? (Interviews)		Does teacher answer meet limitation? (observations)	
	Yes	No	Yes	No
Names and properties of stages of mitosis are not mentioned.	❖		❖	
Names of the stages of meiosis are not mentioned and Turkish name of crossing over (Parça Değişimi) is used.		❖	❖	
Differences of the stages of meiosis and stages of the mitosis are not mentioned.		❖	❖	

Next, researcher asked Selim whether there is a misconception warning in curriculum regarding cell division topics. Selim did not answer this question because he did not know the term misconception. Then, researcher explained the misconception as "student's alternative conceptions which are not consistent with scientific explanations" but Selim still did not answer this question and passed. During observations, Selim considered the misconception warning in his teaching as follows:

> Selim drew a table on board. Different organisms' chromosome numbers were written in this table. Y and T organisms had same chromosome number. Both Selim and students emphasized that these organisms can be same species, but can be different species too such as human beings and molly fish. Then, Selim asked whether there is a relationship between organisms' chromosome number and their complexity or size. One of the students explained that there is no relationship between number of chromosome and organism's size or complexity. Selim confirmed this student. (observer comment).

To sum up, Selim focused on the misconception warning regarding cell division found in curriculum and he was aware of the misconception caution found in curriculum. Table 4.17 presents Selim's understanding of the misconception warning in curriculum.

Table 4.17

Selim's Understanding of Cell Division Misconception

2006 Misconception Stated in Science Curriculum for Cell Division Topics	**Does teacher answer the misconception? (Interviews)**		**Does teacher answer the misconception? (observations)**	
	Yes	No	Yes	No
There is a direct proportion between the size and complexity of organism and the number of chromosome.		❖	❖	

Then, dependence to curricular materials was another aspect of knowledge of goals and objectives. Data regarding Selim's dependence to curricular materials were gathered through observations. During observations, Selim used his notebook that he prepared in previous years. He covered the lesson based on notebook in his teaching and he was not independent from this material.

After all, the degree of knowledge that is supposed by curriculum was another aspect of knowledge of goals and objectives. Selim's knowledge about this dimension was gathered through the observations. This aspect examine whether teacher covers the content of the topic in curriculum or teacher gives advance knowledge in selected topics. In his teaching, Selim adjusted himself based on textbook and curricular objectives, therefore he hardly ever mention advance knowledge in his teaching. Hence, he was knowledgeable regarding the degree of knowledge that is supposed by curriculum.

4.1.2.2.2 Selim's Knowledge of Materials

Selim actively used five sources regarding cell division in his teaching which are textbooks, exercise books, videos, posters, and teacher notebook. Selim used textbook as main source during cell division teaching, let students to solve evaluation questions and showed visuals on it. Selim actively used exercise book to recall their learning. He used videos to show cell division is related with aliveness. To give feedback and eliminate student's false knowledge he used posters. Finally, Selim used his notebook to understand the degree of content and important points which can be asked in High School Entrance Exam.

Table 4.18

Knowledge of Materials

Sources that teacher use that make teaching easier	**Aim of using selected sources**
Textbooks	We use textbook during teaching (pre-interviews) Selim used textbook as main source during cell division teaching, let students to solve evaluation questions and showed visuals on it (observation).
Exercise Book	Selim actively used exercise book and textbook in cell division lessons. Selim let students to do exercises which are ‘cell is dividing’, ‘results of mitosis’, ‘what happens to cell’, ‘types of reproduction’, ‘events of meiosis’, ‘events of mitosis’ in exercise book (observation).
Video/Visual	We use visuals to facilitate students’ learning (pre-interviews) Selim also used visuals to show students cell division process (observation).
Poster	After teaching we attach posters prepared by students on the board and discuss their correct and wrong ideas regarding cell division (pre-interviews).
Notebook	[Notebook] informs me about the way that I follow during teaching. I sometimes forget something, concepts, figures and examples. Frequently asked questions in High School Entrance Exams exist in course notebook…This notebook prepares me to the lesson. I get my work right by the assistance of notebook. At least, I see what I teach and what degree I teach content when I look to notebook. This is something like lesson plan for me. In addition, my notebook shows me which topic I taught in previous lesson (post-interviews).

I: What are the sources that you use in cell division topics?

Selim: We use textbook, exercise book… We do the activity regarding mitosis found in textbook. As far as I remember we use spring in this activity to show how spindle fibers work and how cell division occurs. We use videos because students have difficulty in understanding whether cell division is exactly related with aliveness… We let students to prepare poster before we teach cell division. We also use test books to evaluate their understanding (pre-interviews).

I: What are the aims of using sources that you use in cell division topics?

Selim: We use tests to evaluate their understanding. We use textbook during teaching. We use visuals to facilitate students' learning. After teaching we attach posters prepared by students on the board and discuss their correct and wrong ideas regarding cell division (pre-interviews).

Selim mentioned five sources which are exercise book, textbook, videos, poster, and test books. However, he specified three of the sources with cell division which are textbooks, videos and posters. Selim did not mention why he used exercise book and test book specifically in cell division. Selim mentioned that he uses textbook during teaching as main source. The reason why he uses videos was to facilitate students' learning by visualization of knowledge. The reason why students prepare poster was to give students feedback regarding cell division drawings of students.

Moreover, observations were conducted to understand which sources Selim use in actual teaching. Selim actively used exercise book and textbook in cell division lessons. Selim let students to do exercises which are 'cell is dividing', 'results of mitosis', 'what happens to cell', 'types of reproduction', 'events of meiosis', 'events of mitosis' in exercise book. When Selim taught the asexual reproduction, mitosis and meiosis, Selim frequently used textbook to show visuals. Moreover, Selim and students answered the evaluation questions found in textbook after cell division unit. Selim also used visuals to show students cell division process. In addition, Selim allocated two hours to prepare posters to make students familiar to meiosis topics. Poster that Selim used will be explained in knowledge of assessment part in detail. On the other hand, Selim did not use test book in lesson.

When he explained why they did not use test book in lesson, he mentioned the additional science course hours regarding test solution as follows:

> Selim: We solved questions in test book to evaluate students' learning; however, it was at the weekend or evening hours which are additional course hours to teach science courses more (post-interview).

Although he did not mention, Selim used notebook in his teaching of cell division. Researcher asked Selim why he used this notebook. Selim justified his use of notebook in post-interviews:

> Selim: [Notebook] informs me about the way that I follow during teaching. I sometimes forget something, concepts, figures and examples. Frequently asked questions in High School Entrance Exams exist in course notebook…This notebook prepares me to the lesson. I get my work right by the assistance of notebook. At least, I see what I teach and what degree I teach content when I look to notebook. This is something like lesson plan for me. In addition, my notebook shows me which topic I taught in previous lesson.

In conclusion, Selim was aware the place of unit in curriculum, objectives, misconception warning in textbook, limitations in textbook, horizontal and vertical relations and the degree of knowledge suggested by curriculum; however, he did not sort the objective, and modify textbook. Moreover, he was dependent to notebook in his teaching. Similarly he did not recognize that cell division topics are placed in curriculum due to spiral education model. Regarding knowledge of materials, Selim used range of sources which are textbook, exercise book, notebook, poster and videos. In the next section, Selim's knowledge of students' understandings in science are reported.

4.1.2.3 Selim’s Knowledge of Students’ Understanding of Science

Two components of knowledge of students’ understanding of science which are knowledge of requirements for learning cell division and knowledge of students’ difficulties regarding cell division was categorized and resulted in this section.

4.1.2.3.1 Selim’s Knowledge of Requirements for Learning regarding Cell Division

> I: What prior knowledge should students have to understand cell division topic?
>
> Selim: [Students] need to know cell and organelles. We refer to nucleus; students need to know what nucleus is. Students need to know classification of organisms because we mention different organisms such as bacteria and fungi in teaching cell division. Moreover, they [students] need to know reproduction because we mention reproduction organs such as ovarian and testicle (pre-interviews).

Selim’s understanding of pre-requisite knowledge was gathered in pre-interviews. ‘What prior knowledge should students have to understand cell division topic?’ question was asked to Selim. In his answer Selim refers cell, nucleus, classification of organisms, and reproduction unit as pre-requisite knowledge to learn cell division. However, he did not mention chromosome structure, chromosomal movement, basic genetics terms and their relationships as pre-requisite knowledge.

4.1.2.3.2 Selim’s Knowledge of Students’ Difficulties regarding Cell Division

Selim could know wide range of misconceptions that students hold in cell division and he was aware of the sources of misconceptions. Moreover, he mentioned the points that students’ have difficulty and reasons of students’ difficulty; however, he was not sufficient knowledge for identification and remediation of misconceptions.

I: Which points do your students have difficulty in understanding cell division topics, in your opinion?

Selim: Students have more difficulty on meiosis comparing to mitosis. They [students] do not understand when number of chromosomes reduces and when meiosis-2 starts. The rest of the topic is enjoyable and students can understand. They [students] have no problem in mitosis (prior knowledge).

Selim reported that meiosis process is more difficult than mitosis process and mentioned specific point of this difficulty which is reduction of chromosome number. On the other hand, Selim did not stress the students' difficulties regarding with mechanisms such as mechanism of genetic transferring and basic cell division concepts which are homolog chromosome, allele, and sister chromatids as difficult points to be understood by learners.

I: What are the reasons of students' difficulties regarding cell division?

Selim: I think that it is related with students' readiness level… Students learn the topic, but students do not repeat the lesson after teaching and they [students] forgot. They have difficulty in meiosis because of lack of knowledge. Moreover, meiosis process is more detailed and complex than mitosis. There are two cells in meiosis-2 undergoing division (prior knowledge).

Secondly, the reasons of students' difficulty were questioned. Selim mentioned reasons of students' difficulty as students' readiness level, the lack of repetition of topic, the lack of prior knowledge, and detailed and complex nature of meiosis. Selim did not mention cell division specifically when he talked about readiness level, repetition and prior knowledge as reasons of difficulty. On the other hand, he specifically mentioned detailed and complex structure of meiosis make this topic difficult. Selim did not mention abstract nature of cell division, cell division terminology, invisible aspects of cell division, and assimilation of knowledge as reasons of students' difficulty.

I: What are the students' misconceptions regarding cell division?

Selim: Learning cell division is first time experience for students. So, they have no misconceptions in cell division.

Selim claimed that students have no misconception regarding cell division in pre-interviews. However, he identified many misconceptions during observations. Misconceptions that he identified regarding with cell division are as follows:

- Original cell dies after mitosis
- Cell membrane disappears in mitosis.
- Potato reproduces by budding.
- Gametes undergo meiosis.
- Original cell remains its life after meiosis
- Sperm and egg cells are diploid germ cells.
- All chromosomes are identical that a cell includes after mitosis.
- Number of chromosome increases after meiosis (observations).

Because of Selim identified many misconceptions in his teaching, he was aware of the misconceptions that students hold regarding cell division. Researcher asked Selim in post-interviews that:

> I: Although you claimed that students have no misconceptions regarding cell division because it is their first time experience about the topic, you have identified many misconceptions that students hold. What do you think about this situation?
>
> Selim: I was not aware that students have misconceptions though learning cell division is their first time experience. Anymore, I have this awareness. When student learn new things, they have already some previous knowledge such as uni-cellular organism and asexual reproduction. So, they have disequilibrium between previous knowledge and new knowledge. Learning is making equilibrium between old knowledge and new knowledge… They [student] have some previous knowledge that they [student] carry to class as their background, so my previous answer was wrong claiming they have no knowledge… When we say mitosis provides growth, students unavoidably have misconception that uni-cellular organisms grow through the mitosis (post-interviews).

During pre-interviews Selim thought that students have no misconception about cell division, hence he did not answer the question that 'What are sources of misconception that students holds in cell division topics?' in pre-interviews. After students misconceptions was revealed in observation. Selim's understanding about the sources of misconceptions was asked one more time in post-interviews.

> I: What are the sources of students' misconceptions regarding cell division?
>
> Selim: The ones who studied the lesson before teaching will have more misconception comparing with the other students who don't study before teaching. When they get information from one source such as textbook and teacher, they [students] can't understand topic and their [students'] mind confuses. However, I think that if number of sources increases that students benefit, students can learn better by the use of different knowledge sources together such as teacher and visuals… They [student] have some previous knowledge that they [student] carry to class as their background… (post-interviews).

Selim mentioned that sources of the students' misconceptions can be textbooks, students' background, and teachers. Selim's reasoning about the sources of students' misconceptions in cell division are mostly consistent with sources of misconceptions in literature; hence Selim was knowledgable about the sources of students' misconceptions.

In pre-interviews, Selim did not mention how he identify and remediate students' misconceptions regarding cell division. On the other hand, Selim identified misconceptions by asking questions to students and assigning students to draw concept maps and he tried to eliminate these misconceptions by drawing figures, concept maps and explaining the topic verbally during observations. Selim did not mention to quizzes, discussions, short tests, concept maps, and two tier diagnostic tests regarding identification of misconceptions. Moreover, he did not use conceptual change approach, analogy, and conceptual change texts. Selim only used concept mapping in consistent with identification and remediation of misconception, hence he had lack of knowledge about the identification and remediation of misconceptions.

In conclusion, Selim mentioned the cell topics as prerequisite knowledge and ignored chromosomal movement and understanding of basic genetics terms as prerequisite knowledge to learn cell division. Moreover, Selim gave some examples of students' difficulties on cell division such as the processes in cell division. Selim mentioned the complex structure of cell division as source of difficulty and did not mention abstract nature of cell division and its terminology what makes the content difficult. Although Selim could know students' misconceptions and their sources, he used only concept mapping, and questioning to identify and remediate students' misconceptions. He was not aware the other ways of eliminating misconceptions such as learning cycle. In the next section, Selim's understanding about knowledge of assessments in science is reported.

4.1.2.4 Selim's Knowledge of Assessment

Selim's knowledge of assessments were categorized and resulted in this section. Knowledge of assessment includes two dimensions which are knowledge of dimensions of science learning to assess and knowledge of methods of assessment. Data regarding these two sub-components of knowledge of assessment were collected by use of pre-interviews, observations, teacher documents (i.e. written exams) and post-interviews.

4.1.2.4.1 Selim's Knowledge of Dimensions of Science Learning to Assess

> I: What do you want to assess in depth when you assess your students' knowledge in terms of cell division topics?
>
> Selim: The thing that we want to assess is whether students get the objectives or not. If my assignment is to teach objectives, we assess them… I think assessing students' science process skills is illogical because students don't need to know logic of process. Students do not need to know science process skills to learn the topic.

When Selim released his understanding of what to assess, he only emphasized on the assessment of conceptual understanding. Selim had negative attitudes towards the assessment of other knowledge or skills such as science process skills. Selim thought that assessing students' science process skills is unnecessary because there are no specific objectives regarding science process skills.

Similar to his pre-interview reports, Selim did not focus on science process skills and other knowledge domains such as nature of science knowledge regarding cell division in observations. For example; Selim conducted an experiment regarding vegetative reproduction of a plant (Benjamin plant). However, Selim did not emphasize on science process skills such as observing, making hypothesis, making inferences, data collecting, and controlling variables during experiment nor assess students' science process skills. Photo presented below was taken during observations. This photo represents vegetative reproduction of a plant's (Benjamin plant) branch.

Figure 4.3Vegetative Reproduction in Plants

Similarly, Selim only assessed objectives in curriculum in his written exam. For example;

> Multiple Choice Questions 1: Somatic cells of multicellular organisms undergo mitosis. Which of the following statement regarding mitosis is not true?
>
> a) Daughter cells produced after mitosis are identical to original cell.
> b) Chromosome number does not change during mitosis.
> c) New organisms produce via mitosis due to chromosomes transferred from parents.
> d) 2 new cells form after mitosis.

The question above assesses students' understanding of general characteristics of mitosis which is a curricular objective. To sum up, Selim only assessed only students' conceptual understanding about the knowledge of dimensions of science learning to assess. Table 4.19 presents Selim's understanding of knowledge of dimensions of science learning to assess.

Table 4.19

Selim's Knowledge of Dimensions of Science Learning to Assess

Dimension	**Response**
What to Assess?	The thing that we want to assess is whether students get the objectives or not. If my assignment is to teach objectives, we assess them… I think assessing students' science process skills is illogical because students don't need to know logic of process. Students do not need to know science process skills to learn the topic.

> I: Why did you only assess students' conceptual understandings during the course?
>
> Selim: This [Assessment] should have some limits because we have limited time. Questions asked in High School Entrance Exam and curricular objectives are obvious. We have concerns about exam because we are teaching 8^{th} graders. If you teach in 6^{th} graders, you don't have such kind of concerns. You can teach in following lessons in 6^{th} grades, but you have not chance in 8^{th} grade and we pay attention to exams… We are anxious and stressful in 8^{th} grade levels. We had stress until students took SBS exam, we are better now (post-interviews).

During post-interviews, Selim was asked why he only assessed conceptual understanding regarding cell division. Selim pointed out limited time and exam pressure for assessment of conceptual understanding. Because of questions in High School Entrance Exam are based on curricular objectives, Selim thought that assessing objectives are more important than assessing other skills and knowledge types.

4.1.2.4.2 Selim's Knowledge of Methods of Assessment

Selim was knowledgable about how to assess cell division topics because Selim used both traditional techniques and alternative techniques. Similarly, Selim was knowledgeable about when to assess students in cell division topics because Selim both used formative assessments in whole class period, and summative assessment at the end of unit. Table 4.20 summarizes Selim's knowledge of methods of assessment.

Table 4.20

Selim's Knowledge of Methods of Assessment

Dimension	
How to assess?	Use of both traditional assessment techniques such as multiple choice questions, questioning (both closed and open ended) and alternative assessment techniques which are posters and concept maps.
When to assess?	Summative assessment at the end of the unit Formative assessment in whole class period

> I: Which assessment techniques do you use when you assess your students regarding cell division?
>
> Selim: There are short answer questions, matching, and multiple-choice questions. In addition, essay types questions are well for assessing objectives. Short answer questions are advantageous technic for students to learn foreign terms regarding cell division. Matching is very well and we can ask multiple-choice questions… We ask questions at the end of lesson…I apply mitosis test after mitosis…I follow guidebook and get students do suggested activities (pre-interviews).

The question given above was asked to understand how Selim assessed his students. During pre-interviews, Selim focused on only traditional assessment techniques regarding assessing cell division. Examples of the assessment techniques that Selim used were matching, short answer questions, essay types questions, and questions asked in teaching. Selim did not note alternative assessment technics in pre-interviews; however, Selim used some of the alternative technics in observations which are posters and concept mapping.

Selim let students to draw meiosis process on posters as project. Events occurred in poster activity is provided below:

- Students drew and painted meiotic division and its stage on big cardboards.
- Teacher assisted students when they prepared their posters. Teacher assesses neither students' performance nor their product by grading.
- Teacher also thought that posters are useful for rehearsal of stages of meiosis, crossing over and differences of daughter cells' genetic traits.

Examples of students' posters are presented below (observations).

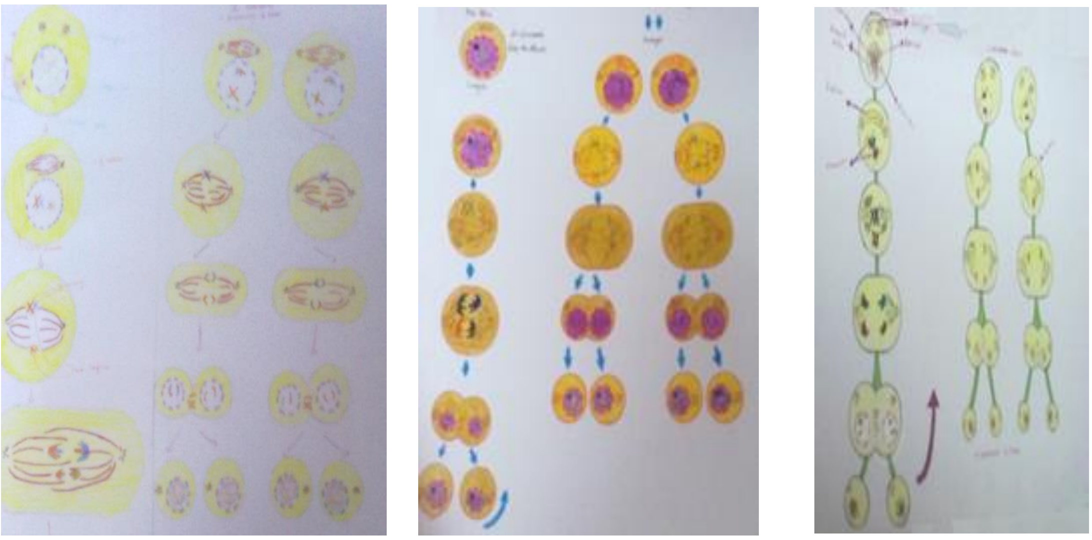

Figure 4.4 Students' Posters about Meiotic Division

Moreover after Selim taught cell division concepts, he asked students who wanted to draw a concept map regarding what they learnt in this unit. One of the students stood up and drew his concept map, and then another student added some drawings and adjusted his friends' missed and false drawings. Both teacher and other students discussed the events and structures. Furthermore, teacher and students repeated the topic in this way.

Selim also used traditional assessment techniques in his lessons such as questioning during the lesson. Moreover, Selim used traditional technics in his written exams as he mentioned in pre-interviews. Regarding traditional assessment techniques, Selim used nine multiple item questions, ten short answer questions, twelve true-false questions and two open ended questions. To sum up, Selim used both traditional technics and alternative technics in his teaching. Hence, he was good at how to assess cell division topics. It is also important to report that Selim did not try to grade students' understanding when using alternative technics, Selim tried to understand what his students know and in which points, students have lack of knowledge. Selim justified his use of concept map during post-interviews as follows:

> I: When I asked you the assessment methods that you used regarding cell division, you did not mention the concept map. However, you used this technic in your teaching during observations. What is the reason of this difference?
>
> Selim: Reason is to see students' efficacy. We can't identify whether they [students] know the topic or not before teaching. After teaching, we see some students are ambitious and we give them a chance. When they [students] draw on board, their [students'] friends can also repeat the topic… (post-interviews)

> I: When do you assess your students regarding cell division?
>
> Selim: We ask questions at the end of the lesson to understand whether students understand the content or not. We solve the questions in textbook and exercise book at the end of the unit. We have three exams per each semester.

This question was used to assess Selim's understanding of using formative and summative assessment. Selim mentioned both of these assessments. Although Selim pointed out that he used formative assessments, he ignored the formative assessments at the beginning of the lesson and in the middle of the lesson during pre-interviews. On the other hand, Selim used formative assessment in whole class period during observation. Some examples of Selim's formative assessments were presented below.

Selim: What does form spindle fibers?

Student: Centrioles (observations)

Selim: How does regeneration happen in human beings?

Selim: What is the chromatin fiber?

Selim: Let's try to remember from yesterday, what was n? For example; n=13.

Student: Chromosome number is 13.

Selim: OK. Then, what is 2n=26?

Student: Body cell

Selim: Why?

Student: Because n is the number of chromosome of gametes.

Selim asked the question above at the beginning of the lesson to recall previous lessons. Similarly, Selim asked the questions below to identify students' misconceptions and assess students' comprehension in the middle of the lesson.

Selim: What happens to [original cell] after division?

Student: It [original cell] dies.

Student: [Original cell] becomes daughter cell.

Selim: Why does not plant cell divide by furrowing?

[Class did not answer and teacher explains the answer.]

Selim: How does asexual reproduction occurs?

Class: through the mitosis.

Moreover, Selim asked open ended questions corresponding to the process. These questions started with ‘Why’ and ‘How’. Selim also asked closed ended questions corresponding to factual knowledge. These questions started with ‘What’.

At the end of the lesson, Selim assigned students to solve the questions in textbook and exercise book. These questions assessed whether students obtained the objectives about mitosis. Teacher assigned students to prepare posters in meiosis topics as formative assessment. After meiosis is taught, students attached their products (posters) on board. They discussed the processes of meiosis based on posters. If they have difficulty, teacher stressed the difficult points. At the end of the cell division topics, students drew concept map on board and they discussed the cell division topic based on their concept maps. Students’ misconceptions and lack of knowledge regarding cell division were identified by teacher. Teacher explained scientific explanation of phenomena. At the end of the unit, Selim conducted written exam that assessment of learning or summative assessment.

In conclusion, Selim focused on the assessment of conceptual understandings ignoring interdisciplinary themes, nature of science knowledge, social skills and science process skills about what to assess regarding cell division; however, he was knowledgeable on understanding the alternative assessment techniques which are concept mapping and poster. Moreover, he assessed his students’understandings by formative ways and summative ways regarding when to assess. In the next section, Selim’s knowledge of instructional strategies are reported.

4.1.2.5 Selim's Knowledge of Instructional Strategies

Selim's knowledge of subject specific strategies and knowledge of topic specific strategies which are two sub-components of knowledge of instructional strategies were categorized and reported in this section. Moreover, knowledge of activities and knowledge of representations were used to recognize Selim's knowledge of topic specific strategies about cell division.

4.1.2.5.1 Selim's Knowledge of Subject Specific Strategies

Selim's knowledge of subject specific strategies was presented in this section. Table 4.21 presents which strategy Selim prefers to use and the reason why Selim chose selected strategy.

Table 4.21

Selim's Knowledge of Subject Specific Strategies

Dimension	
Subject Specific Strategies	Direct instructions
The reason of why Selim chose these strategies	Limited time Lack of knowledge of students centered strategies

I: When you teach science concept in general, which teaching method, strategy and technic do you prefer to use?

Selim: We apply direct instruction and discovery learning. We do not apply 5E Learning. I have never heard conceptual change approach.

I: Why do you prefer to choose these methods, strategy and technics?

Selim: To facilitate students' understandings. If students understand the content, we do not have to spend much time… Our prior experiences showed that these are the best techniques in general teaching. If we have limited time we pass the activities which are not suitable for grade level.

Selim claimed that he uses direct instruction and discovery learning in his science courses and he added that he did not know student centered methods which are 5E Learning Cycle and Conceptual Change Approach. Similar to his interviews, Selim used direct instruction methods in his teaching. On the contrary to his pre-interviews, he did not use discovery teaching in observations because Selim did not let students to explore knowledge and his teaching was not student centered; so Selim did not use discovery learning.

Selim explained the reason of his subject specific strategies based on his experiences and mentioned the limited time. Selim implied that if he does not use the current methods, there will be waste of time. So, he aims to teach as much as he can in limited time. Moreover, Selim had limited knowledge about student centered approaches; hence there might be an obligation for Selim to use didactic strategies.

4.1.2.5.2. Selim's Knowledge of Topic Specific Strategies

Knowledge of activities and knowledge of representations which are sub-components of knowledge of topic specific strategies were categorized and resulted to understand Selim's knowledge of topic specific strategies about cell division in current section.

4.1.2.5.2.1. Selim's Knowledge of Representations

Results show that Selim used illustrations, drawings, and examples as representations to teach cell division. On the other hand, Selim did not mention hand models as representation of cell division. Selim also had partial understanding about analogies. Although he uses some comparisons, he did not extend these comparisons to the analogies. Hence analogies that Selim used were fragmented or can be categorized as simple analogies. Table 4.22 presents Selim's knowledge of representations regarding cell division.

Table 4.22

Selim's Knowledge of Representation

Representation Types	**Specific Examples**
Illustrations	
Showing visuals (photo, video etc.)	Selim used visuals to facilitate students understanding in his teaching during observations. For example; Selim showed a video from internet explaining mitosis and its stages.
Drawing figure	Drew many figures regarding mitosis, meiosis, asexual reproduction and sexual reproduction.
Examples	Selim gave many examples in cell division such as different types of asexual reproduction which are vegetative reproduction, budding, simple division. He gave examples which organisms undergo which type of asexual reproduction. Selim also gave different examples of gametes such as pollen, egg cell, and sperm cells.
Comparisons/Metaphor/Analogy	Role of spindle fibers compared that spider knits the web. Fork and spoons compared the chromosomes

> I: Do you use illustrations, examples, models, drawings, and analogues to assist students' learning cell division topics and concepts? If yes, what are these representations and can you give examples of these representations? If no, why do not you use illustrations, examples, models, drawings, and analogues?
>
> Selim: We show videos, visuals, photos using projector. I draw mitosis, meiosis and their stages. I draw crossing over. I frequently draw figures when I teach the differences and similarities between mitosis and meiosis. When I teach the differences of divisions between animal cell and plant cell, I draw furrowing, cell plate formation, centrosome, formation of spindle fiber. I also find some visuals from internet to show students (pre-interviews).

Selim pointed out showing visuals and drawing figures regarding knowledge of representations in pre-interviews. Similar to interview findings, Selim used visuals to facilitate students understanding in his teaching during observations. For example; Selim showed a video from internet explaining mitosis and its stages. After that Selim showed another video about mitosis that mitotic division is shown by grains. Selim also showed a video from internet regarding asexual reproduction and types of asexual reproduction. Finally, Selim showed a video about reproduction of uni-cellular organisms in his teaching. To sum up, Selim used internet actively to show visuals to the students in his teaching about cell division.

During observations, Selim actively used board and drew many figures regarding mitosis, meiosis, asexual reproduction and sexual reproduction on it. Some examples of Selim's drawings are presented below. For example; when Selim visualizes what happens in mitosis, he drew the figure on board (see figure 4.5). In this figure, Selim shows his students to prophase, metaphase, anaphase, telophase and two new cells forming after mitosis. Moreover; chromatin fibers, chromosomes, poles, equatorial plane are visible in his drawing.

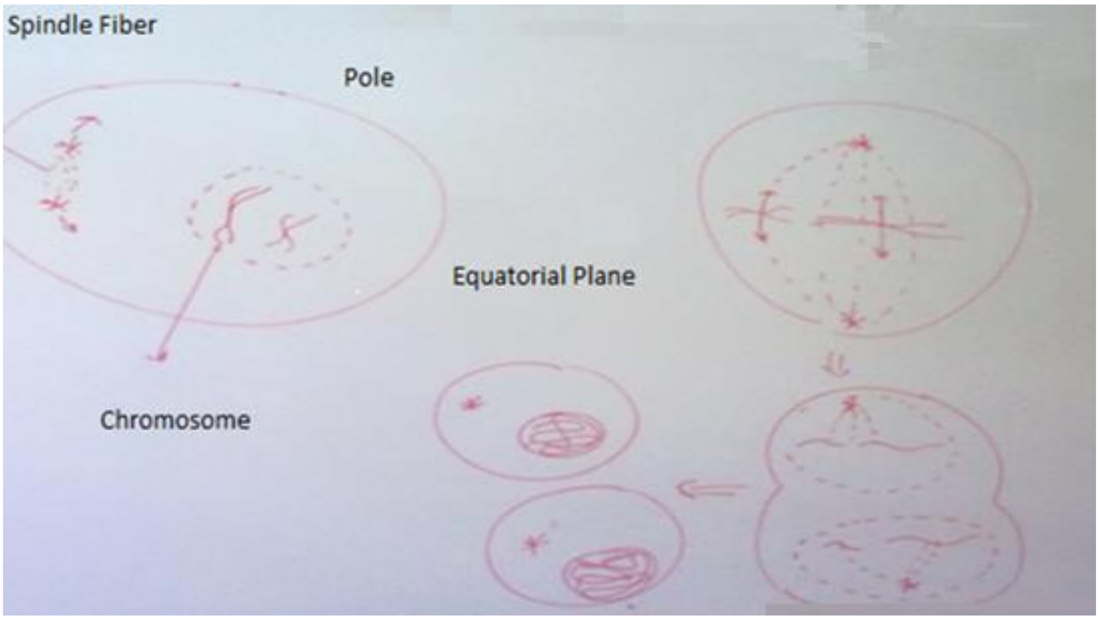

Figure 4.5 Selim’s Drawings of Stages of Mitosis

Moreover, Selim drew the cytokinesis difference between animal cell and plant cell therefore he drew the figure below. In this drawing, Selim showed the furrowing of animal cell and cell plate formation in plant cell during cytokinesis (See figure 4.6).

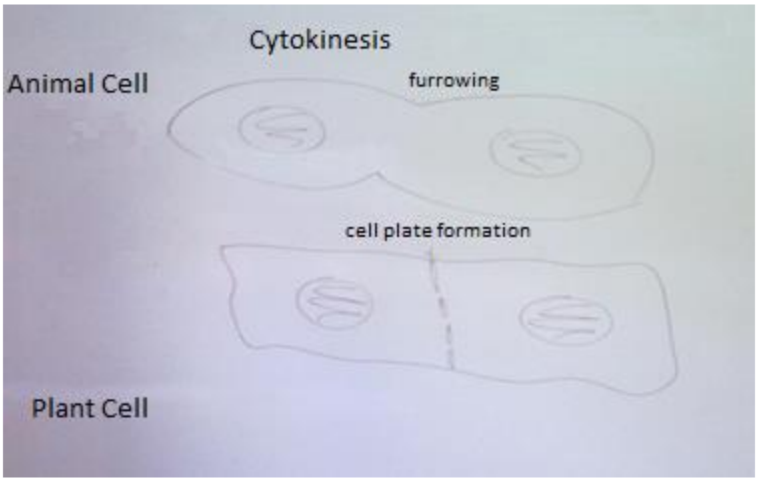

Figure 4.6 Differences of Cytokinesis between Animal and Plant Cell

Moreover, Selim drew two human beings figure (one male and one female) undergoing meiosis and producing gametes. Next, Selim showed that gametes of these two people fuse and egg is fertilized by sperm cell before zygote forms. Selim added that this zygote undergoes several numbers of mitosis and new infant is born. By this drawing, Selim summarizes the sexual reproduction (See figure 4.7)

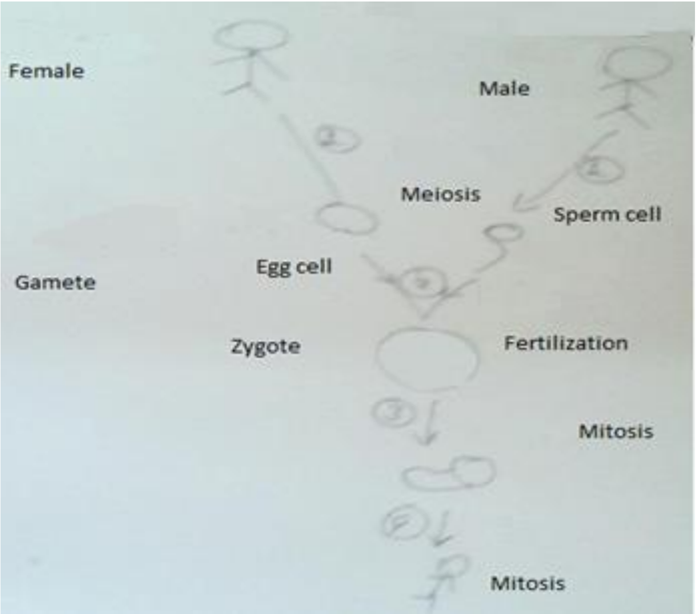

Figure 4.7 Drawing of Sexual Reproduction

Selim went on his drawings in meiosis topics too. Figure 4.9 represents meiosis-1. In this figure Selim shows original cell, tetrad, homolog chromosome and crossing over. Moreover, stages of the meiosis-1 were drawn which are prophase-1, metaphase-1 and telophase-1.

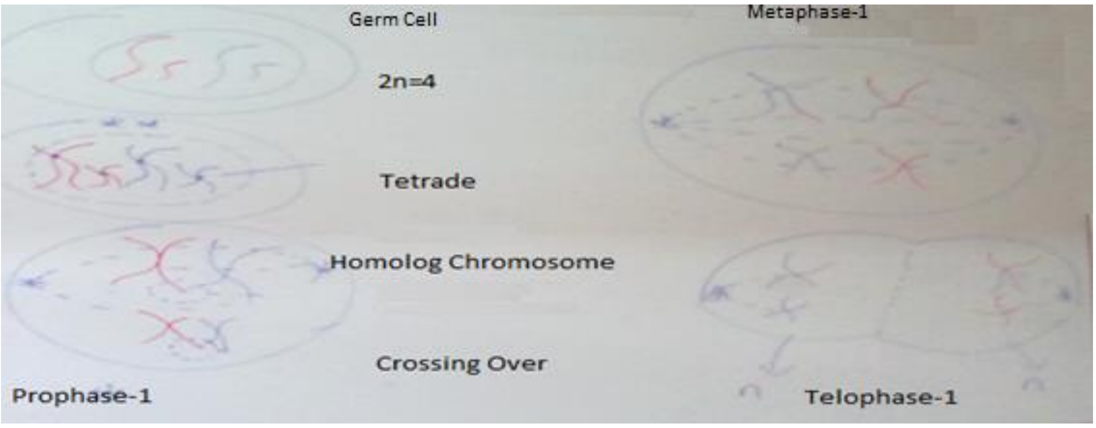

Figure 4.8 Representation of Meiosis-1' Stages

Another representation types that Selim used in his course was the examples. Some examples that Selim mentioned in observations are presented below.

- Examples of different types of asexual reproduction which are vegetative reproduction, budding, binary fission.
- Examples of organisms undergo which type of asexual reproduction such as rose, populous, earth worm, amebae, paramecium, coral etc.
- Examples of different types of gametes such as pollen, egg cell, and sperm cells.

Another type of representation that Selim used was analogy. During his teaching, Selim used simple analogies which did not extend to complex analogies because Selim did not mention the breaking points in analogy nor describe target and familiar concepts. Some examples of the comparison are presented below obtained in observations:

- These are spindle fibers. Spindle fibers surround the nucleus. This process likes that spider knits its web.

In this analogy, Selim compared that:

Target Concept	Familiar concept
Spindle fiber	Spider web
Centrosome	Spider
Invasion of microtubules in nucleus	Spiders' Knitting activity

- Selim compared fork and spoons to the chromosome regarding an activity found in textbook. (Observer comment). See figure 4.10 for this analogy.

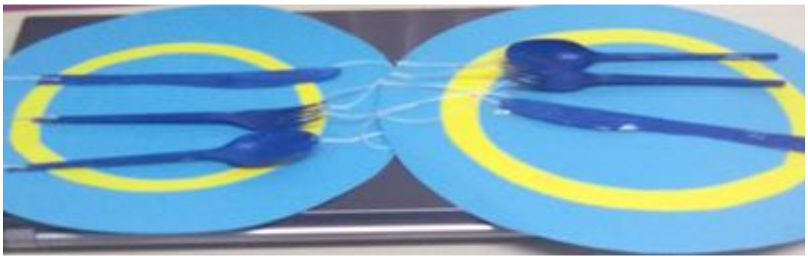

Figure 4.9 Sample Analogy that Selim used in his Class

4.1.2.5.2.2 Selim's Knowledge of Activities

Selim mentioned the role playing activity and play dough activity regarding topic specific activities. Selim passed the play dough activity because he and his students thought that this activity is childish, and so it was unnecessary for them. He also modified the play dough activity by replacing it with poster activity. The reason of this modification is that play dough activity requires much time and this activity appeals to lower grade students. Selim conducted experiment regarding asexual reproduction of Benjamin plant. Although he conducted this activity, he ignored the role of science process skills in experimenting. These topic specific activities which are asexual reproduction of Benjamin plant and play dough activity representing meiosis were also placed in textbook. Selim's knowledge of activities regarding cell division is presented in table 4.23.

Table 4.23

Knowledge of Activities

Types of Activity	**Specific Examples**
Experiments	Conducted vegetative reproduction of a plant but ignored science process skills.
Role playing Activity	(Not conducted) Although Selim know this activity, he passed it because students thought it is childish. Selim claimed that role playing activity does not appeal to this grade level.
Play dough Activity	Although Selim knows this activity, he did not conduct it because Selim thought that this activity requires much time and it is not suitable to 8^{th} grade level. Selim modified this activity by assigning students to prepare poster that has same aims with play dough activity. Also poster activity is more enjoyable for this grade level according to Selim.

> I: Do you conduct activities in class regarding cell division? If you conduct, what are these activities?
>
> Selim: Students prepare posters showing that how cell division occurs. They conduct play dough activity as group working. I do not let students to do role playing activity that student represent chromosomes because this activity is not well suited to this grade level. Students get bored when we do role playing activity.

Selim stressed two activities that he let students to do which are poster preparation and play dough activity. Selim also pointed out role playing activity. However, he thought that he does not use this activity, because this activity appeals to lower grades students. During observations, students prepared their posters regarding meiosis. However, they did not conduct play dough activity in class. Researcher asked Selim why they did not conduct play dough activity in class in post-interviews. Selim pointed out two factors that cause them not to conduct play dough activity during post-interviews. Firstly, play dough activity takes too much time. Secondly, this activity does not appeal to students' grade level.

I: Why did not you conduct play dough activity in class?

Selim: Play dough activity requires more than two hours and students do not complete this activity. They have to complete this activity at home. We wanted to save time and they produced the posters by drawing the big cardboards in this unit. Students liked this [poster] activity more because students thought that play dough activity is childish in previous year. They did not want to conduct play dough activity in previous year (post-interviews).

Selim's knowledge of activities was also gathered by specific questions about sub-topics of cell division which are mitosis, asexual reproduction, the role of chromosomes, meiosis, crossing over, sexual reproduction, and the differences between mitosis and meiosis.

I: What are the activities that you conduct when you specifically teach mitosis?

Selim: Direct instruction, I get students to take note in their notebook. So they can repeat the topic after teaching. It could be brain storming, and discussion but these [brain storming, and discussion] takes hours. The only problem is time. Why I prefer these strategies because these strategies are best for limited time (pre-interviews).

Selim did not mention any activity regarding mitosis specifically during pre-interviews. Similar to his mitosis answer, Selim did not indicate any activity regarding sub-topics of cell division.

Although Selim did not mention any activity regarding asexual reproduction in teaching, he conducted an activity regarding vegetative reproduction of Benjamin Plant. They took a branch of this plant and put it in a glass of water. However, this activity does not account an experiment because Selim and members of the class did not regard science process skills in this activity. When researcher asked Selim why he conducted this activity, Selim mentioned the formation of the roots from branch of a plant as vegetative reproduction. Selim did not regard to science process skills in this activity in post interviews as seen below:

I: Why did you conduct the vegetative reproduction activity even you did not mention it in pre-interviews?

Selim: This activity exists in textbook. This is not a difficult activity. The aim is whether plant reproduces asexually or not. I think students do not need science process skills in this experiment. If plant forms root, this activity ends. I think this is not a complex activity that requires science process skills (post-interviews).

There was another discrepancy occurred during teacher and students compared the mitosis and meiosis. Although general course of events was didactic, there were some clues for argumentation in class during comparison of different cell divisions. They interpreted a visual found in exercise book and they did not decide whether this visual belongs to mitosis or meiosis. They discussed, justified their answers and created rebuttals for counter arguments. Then, researcher asked Selim's views about argumentation in class.

I: When you compared the differences between mitosis and meiosis, argumentation aroused in your class. Some of the students claimed that visual belong to mitosis because homolog chromosomes do not exist together, on the other hand some others thought that this visual belongs to meiosis because different chromosomes attach each other in visual. What do you think about the situation arose in class?

Selim: Yes they have a confliction because some students thought that homolog chromosomes do not exist in mitosis. This lack of knowledge is caused by the textbook because textbook do not pay attention to homolog chromosomes in mitosis. Moreover, there was no crossing over in visual, so we cannot say whether there is mitosis and meiosis… This is not about me. Argumentation arouse spontaneously in class.

I: What do you think about this situation, is it good for teaching and learning?

Selim: Absolutely. We can understand students' lack of knowledge and false knowledge by this way. I think students should not be free in their discussions and teachers should monitor their discussion. If students are totally free, discussion can be misleading. Teacher has to say something to eliminate false knowledge (post-interviews).

Selim appreciated the argumentation occurred in class. Selim thought that this is good to eliminate students' misconceptions and lack of knowledge. However, he seemed to be supporter of guiding students when students make argumentation to eliminate misleading information that students attained.

In conclusion, Selim used teacher centered strategies which are direct instruction and questioning because of limited time and his lack of knowledge in student centered approaches. The representations that Selim used were visuals and drawings as illustrations; he also mentioned simple analogies and gave examples related with cell division topics. The activities that Selim mentioned was play dough activity, role playing activity and asexual reproduction of plants' experiment. However, Selim used poster activity and conducted an experiment about asexual reproduction of plants. Two of the activities that Selim mentioned, play dough activity and experiment, were also found in textbook that is closely related with his knowledge of curriculum.

4.2 CASE 2: Burcu's Content Knowledge and Pedagogical Content Knowledge regarding Cell Division

4.2.1. Burcu's Content Knowledge regarding Cell Division

Burcu's content knowledge which includes syntactic knowledge (i.e. Nature of Science) and substantive knowledge is presented. First, findings regarding syntactic knowledge were presented.

4.2.1.1. Burcu's Syntactic Knowledge

Interview results revealed that Burcu had informed views on two aspects of NOS which are imaginative and creative NOS and subjective NOS. On the other hand, Burcu had adequate understanding on two NOS tenets which are inferential NOS and empirical NOS. Burcu, however, held inadequate understanding about socio cultural NOS, tentative NOS and functions and differences of theory and law. Table 4.24 presents Burcu's understanding of NOS aspects.

Table 4.24

Summary Table for Understandings of Burcu's NOS Aspects:

NOS ASPECT	**Sample Excerpts**	**CATEGORY**
Tentative NOS	I taught atom concept to students and said that this is current version of atom but this [scientific knowledge] may change after 10 years…We are sure about laws, they are proven. Modern atom theory is not proven because it is just a theory. If it is proven, it is not called as theory. Scientific knowledge changes if it is not law	Inadequate
Theory & Law	Theory is proposed at first, they [theories] can be improved. Actually, laws are the things that we are sure… They [Laws] are proven…Modern atom theory is not proven, it is still theory. Theory is the assumption; science is universal when it [science] becomes law… All the results may change unless they are laws	Inadequate
Empirical NOS	Science is evidence based compared to other disciplines… Experiment is the study that we want to prove our hypothesis… Experiment is the last step for scientific study	Adequate
Inferential NOS	Observation is a study that is conducted in data collection. Scientists' perspective is very important in observing. Everyone sees that water lifts the bowl; however only Archimedes observes lifting… Actually, inference is assumption at the end. Inference happens after observations	Adequate
Imaginative and Creative NOS	We should begin with human being's mind. Our analytical thinking is a bit imagination. Scientists use their creativity in all stages. Scientists use their creativity in planning, design, data collection, interpretation and evaluation	Informed

Table 4.24 (cont'd)

NOS ASPECT	Sample Excerpts	CATEGORY
Socio-Cultural	Science is universal after it becomes law… I think that science is affected by society when inventions and theories are produced…Some of the scientific knowledge is universally accepted…Science is affected by society when it arises. However, if an invention is accepted and proven, it is accepted by everywhere and becomes universal	Inadequate
Subjectivity	Human beings interpret the results based on their own views. They like the evidences according to their own perspectives... Scientists' perspectives are different from each other. Although glass is same, one of them may claim glass is half full and other may claim glass is half empty. This is because they have different points of views.	Informed

In the following part, Burcu's responses to each question of VNOS—were mentioned.

At first, his response to the question that what, in your view, is science? What makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g. religion, philosophy)?" was presented Burcu's understanding of science.

> I: What, in your view, is science?
>
> Burcu: Our needs cause to scientific research. They [human beings] needed to investigation because of their deficiencies… Previous studies enlighten us to get knowledge…Science is universal after it [science] becomes law.
>
> I: What makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g. religion, philosophy)?
>
> Burcu: Physics, chemistry and so on provides direct evidences and these disciplines can be proven.

Burcu thought that science is sourced by our needs and deficiencies. Moreover, Burcu thought that current studies are based on previous ones mentioning the communication aspect of science process skills. Burcu had common idea that science is proven if it is law. This idea gives some insights about Burcu's views on tentative. Moreover, Burcu thought that science provides direct evidence comparing with other disciplines, enlightening her empirical NOS. These NOS aspects will be presented in next sections. Her idea about 'Science is universal after it [science] becomes law.' gives ample evidence for her socio-cultural NOS.

Burcu's Understanding of Tentative NOS

> I: After scientists have developed a scientific theory, does the theory ever change?
>
> Burcu: Modern atom theory is not proven because it is just a theory. If it is proven, it is not called as theory. Scientific knowledge changes if it is not law.

Her response revealed her inadequate views on tentative NOS. Although Burcu accepted that scientific knowledge may change in the future, she believed scientific laws are certain and never change. Burcu added that theories need to be proven, and therefore are subject to change. According to her thinking theories are *not proven* and they are *just a theory* makes her classification of tentative NOS as inadequate. Moreover, Burcu underestimated the factors supporting changes of theories which are reinterpretation of existing theories, new theories on scientific knowledge, and technological advance.

Table 4.25

Burcu's Sample Statement in Tentative NOS

Tentative NOS	**Category**	**Sample Statement**
After scientists have developed a scientific theory does the theory ever change?	Inadequate	Modern atom theory is not proven because it is just a theory. If it is proven, it is not called as theory. Scientific knowledge changes if it is not law.

Her response to the question regarding the functions and differences of theories and laws, presented below, provided the further evidence about his understanding of the tentative nature of NOS.

Burcu's Understanding of the Functions of and Differences of Theories and Laws

I: Is there a difference between a scientific theory and a scientific law?

Burcu: Theory is proposed at first, they [theories] can be improved. Actually, laws are the things that we are sure… They [Laws] are proven…

Though previous question give insight about Burcu's understanding of theories and laws (such as science is universal when it [science] becomes law), her responses clearly identifies her category in theories and laws aspect of NOS.

Moreover, hierarchical relationship between theories and laws was revealed in her explanation showing that she had inadequate views.

Table 4.26

Burcu's Sample Statement in the Functions and Differences of Theories and Laws

Theory and Laws aspect NOS	**Category**	**Sample Statement**
Is there a difference between a scientific theory and a scientific law?	Inadequate	Theory is proposed at first, they [theories] can be improved. Actually, laws are the things that we are sure… They [Laws] are proven…
After scientists have developed a scientific theory does the theory ever change?		Modern atom theory is not proven, it is still theory. Theory is the assumption, science is universal when it [science] becomes law… All the results may change unless they are laws (pre-interviews).

Burcu's Understanding of Empirical NOS

Following questions were used to assess Burcu's understanding of empirical NOS:

> I: What is an experiment? Does the development of scientific knowledge require experiments?
>
> Burcu: Experiment is the study that we want to prove our hypothesis… Experiment is the last step for scientific study… Experiment is always necessary.

Apart from her answers to questions dealing with empirical NOS, Burcu's response to 'what, in your view, is science? What makes science different from other disciplines of inquiry?' provided some insight for Burcu's empirical NOS. Analysis of the results showed that Burcu had adequate views regarding empirical NOS. Although she appreciated the role of experiment in science, she ignored role of observations in her explanation and possessed adequate understanding in empirical NOS.

Table 4.27

Burcu's Sample Statement in Empirical NOS

Empirical NOS	Category	Sample Statement
What is an experiment?	Adequate	Experiment is the study that we want to prove our hypothesis… Experiment is the last step for scientific study…
Does the development of scientific knowledge require experiments?		Experiment is always necessary.
What, in your view, is science? What makes science different from other disciplines of inquiry?		Science is evidence based compared to other disciplines…

Burcu's Understanding of Inferential NOS

I: What is observation?

Burcu: Observation is a study that is conducted in data collection. Scientists' perspective is very important in observing. Everyone sees that water lifts the bowl; however only Archimedes observes lifting.
I: What is inference?

Burcu: Actually, inference is the assumption at the end.

I: What is the difference between observation and inference?

Burcu: Inference happens after observations

Although Burcu knew that inferences are the assumptions revealed through the observations and observations are affected by scientists' point of views, she did not define observation that is gathered through the five senses. Because of her lack of understanding about observaion, her understanding of inferential NOS was categorized as adequate.

Table 4.28

Burcu's Sample Statement in Inferential NOS

Inferential NOS	Category	Sample Statement
What is observation?	Adequate	Observation is a study that is conducted in data collection. Scientists' perspective is very important in observing. Everyone sees that water lifts the bowl; however only Archimedes observes lifting…
What is inference?		Actually, inference is assumption at the end.
What is the difference between observation and inference?		Inference happens after observations (pre-interviews).

Burcu's Understanding of Imaginative and Creative NOS

To understand Burcu's understanding of imaginative and creative NOS, following questions were directed to Burcu.

> I: Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
>
> Burcu: We should begin with human being's mind. Our analytical thinking is related with imagination. Scientists use their creativity in all stages. Scientists use their creativity in planning, design, data collection, interpretation and evaluation.

Burcu appreciated the view that scientists use their imagination and creativity in all stages of the scientific investigations. This showed that she had fully understood the creative and imaginative NOS, and she was categorized as informed.

Table 4.29

Burcu's Sample Statement in Imaginative and Creative NOS

Imaginative and Creative NOS	**Category**	**Sample Statement**
Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?	Informed	We should begin with human being's mind. Our analytical thinking is a bit related with imagination. Scientists use their creativity in all stages. Scientists use their creativity in planning, design, data collection, interpretation and evaluation.

Burcu's Understanding of Socio Cultural NOS

> I: If you believe that science reflects social and cultural values explain why and how and if you believe that science is universal, explain why and how?
>
> Burcu: I think that science is affected by society when inventions and theories are produced…Some of the scientific knowledge is universally accepted…Science is affected by society when it arises. However, if an invention is accepted and proven, it becomes universal.

Burcu's response to 'what is science?' question provided ample evidence for Burcu's understanding of socio-cultural science. Moreover, her response to question regarding socio-cultural NOS, clarified her category. Her response covered that Burcu had inadequate views on socio-cultural NOS. Burcu believed that scientific knowledge is universally accepted and not affected by social norms after it is proven. However, Burcu claimed that science is affected by society when it arises although it is not affected by society after it is proven.

Table 4.30

Burcu's Sample Statement in Socio Cultural NOS

Socio Cultural NOS	Category	Sample Statement
If you believe that science reflects social and cultural values, explain why and how and If you believe that science is universal, explain why and how.	Inadequate	I think that science is affected by society when inventions and theories are produced…Some of the scientific knowledge is universally accepted…Science is affected by society when it arises. However, if an invention is accepted and proven, it becomes universal.
What is science, in your opinion?		Science is universal after it becomes law…

Burcu's Understanding of Subjective NOS

> I: It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?
>
> Burcu: Human beings interpret the results based on their own views. They like the evidences according to their own perspectives... Scientists' perspectives are different from each other. Although glass is same, one of them may claim glass is half full and other may claim glass is half empty. This is because they have different points of views.

Burcu held informed views about subjective NOS because she thought that scientist's background and expertise may affect them and they interpret the data different from each other. Moreover, Burcu extended her idea giving an example on subjectivity regarding half full a glass of water.

Table 4.31

Burcu's Sample Statement in Subjective NOS

Subjective NOS	Category	Sample Statement
How are different conclusions possible, if scientists in both groups have access to and use the same set of data to derive their conclusions?	Informed	Human beings interpret the results based on their own views. They compare the evidences to their own perspectives... Scientists' perspectives are different from each other. Although glass is same, one of them may claim glass is half full and other may claim glass is half empty. This is because they have different points of views.

As a result, Burcu's Nature of Science knowledge referred her syntactic knowledge. According to results, Burcu's syntactic knowledge included some lack of knowledge. In particular; Burcu held informed views about two NOS aspects which are imaginative and creative NOS and subjective NOS. On the other hand, Burcu had adequate knowledge on two aspects of NOS which are empirical NOS and inferential NOS. Moreover, Burcu had inadequate views on three aspects of NOS in terms of tentative NOS, socio cultural NOS and functions of and differences of theories and laws. In the next section, Burcu's substantive content knowledge will be reported.

4.2.1.2. Burcu's Substantive Content Knowledge about Cell Division

In this part, Burcu's substantive content knowledge regarding cell division is presented. To better understand Burcu's substantive content knowledge about cell division topics, Burcu's substantive content knowledge was gathered under four dimensions which are basic terms of cell division, cell cycle knowledge, mitosis knowledge and meiosis knowledge.

4.2.1.2.1. Burcu's Knowledge about Basic Terms about Cell Division

Burcu's answers to sixteen questions that were prepared by the researcher and asked during pre-interviews were used to understand Burcu's knowledge about basic terms of cell division. Responses were assessed under two parts which are conceptual understanding and ontological category.

Regarding Burcu's conceptual understanding of basic terms, Burcu had sound understanding about ten basic terms regarding cell division which are DNA, gene, sister chromatids, centrosomes, centromere, asexual reproduction, sexual reproduction, somatic cell, gametes, and zygote. On the other hand, her understanding of chromosome, homolog chromosome and centriole was partial. Burcu had naive ideas about size of cell division concepts, and allele. Because of Burcu did not answer to concept of kinetochore, her understanding of this concept was not taken account.

Further analysis revealed Burcu's ontological categories for basic cell division terms. Burcu's explanations of eleven concepts were process in ontological category which are homolog chromosomes, DNA, gene, allele, sister chromatids, centrosomes, asexual reproduction, sexual reproduction, somatic cell, gamete, and zygote. On the other hand, Burcu was in matter category for chromosomes, centriole, and centromere concepts. Table 4.32 summarizes Burcu's knowledge of basic concepts about cell division.

Table 4.32

Burcu's Knowledge of Basic Concepts related with Cell Division

		Conceptual Understanding			Ontological categorization	
Concept	**Answer of Burcu**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Write the items in order of size. Start with the largest	Organism>Cell>Nucleus>Chromosome> DNA>Allele>Gene	❖			-	
Chromosome	a structure that contain genes on it [chromosome].Chromosomes are found in nucleus. This structure is different from of DNA that binds to protein during cell division. Chromosome number differs between different species.		❖		❖	
Homolog Chromosome	Genes inherited from both of the parent include inherited characters. These genes are carried on homolog chromosomes. One chromosome of each pair comes from each of the organisms' two parents. Homolog chromosomes exist in organisms reproducing sexually.		❖			❖

Table 4.32 (cont'd)

		Conceptual Understanding			Ontological categorization	
Concept	**Answer of Burcu**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
DNA	Is a double stranded molecule that forms chromosome. Organism's cyphers called as genes exists in DNA. DNA is called as hereditary material found in nucleus. DNA controls the nucleus… Smallest unit of DNA is nucleotide. It has capability of duplication. This ability is called as replication. When DNA strand is condensed and shortened, it forms chromosome. DNA strand looks like long string and this structure is named as chromatin fiber.			❖		❖
Gene	Is the cyphers that determine the characters of organism. For example; the cyphers that determine color of my eye.			❖		❖
Allele	pair of gene that determines characters. They are found in homolog chromosomes that are inherited from parents… Allele is gene pair that are inherited from parent whereas gene is inherited from one organism of the parents.	❖				❖

Table 4.32 (cont’d)

Concept	Answer of Burcu	Conceptual Understanding			Ontological categorization	
		Naive	Partial	Sound	Matter	Process
Sister Chromatids	After DNA replicates, chromosomal structure forms [Mentioning duplicated chromosome]. Replicated DNA holds together because it binds to centromere. When DNA is replicated; double structure forms called as sister chromatids… Sister chromatids are identical… Sister chromatids form during DNA replication in interphase. Due to fact that chromosome structure forms in prophase, sister chromatids form in prophase too			❖		❖
Centrosome	are found only in animal cells, plant cells do not include centrosome…Centrosome is the structure that forms spindle fibers which attach to the sister chromatids and separate them [sister chromatids] in anaphase.			❖		❖
Centriole	Structures forming centrosomes (are centrioles). There are two hollow tubes one of which is vertical and another one is horizontal.		❖		❖	
Centromere	the region that sister chromatids join.			❖	❖	
Asexual Reproduction	A single organism can reproduce itself and this type of reproduction is called as asexual reproduction. Vegetative reproduction, regeneration, and division by budding are the examples of asexual reproduction.			❖		❖

Table 4.32 (cont'd)

Concept	**Answer of Burcu**	**Conceptual Understanding**			**Ontological categorization**	
		Naive	**Partial**	**Sound**	**Matter**	**Process**
Sexual Reproduction	a kind of reproduction occurred by the fusion of gametes of one species' male and female individuals…Pollen and egg cells fuse in plants…Female gamete and male gamete form zygote.			❖		❖
Somatic Cell	diploid cell called as body cell and these cells undergo mitosis apart from some exceptions such as neurons.			❖		❖
Gamete	do not undergo mitosis, they include n chromosome and they are produced at the end of meiosis… Haploid cells include n chromosome. For example, gametes are haploid. Egg cell contains n=23 chromosomes and this cell is gamete.			❖		❖
Zygote	is somatic and diploid…That is fertilized egg, fusion of sperm and egg in animals, and fusion of pollen and egg in plants…Zygote includes 2n chromosomes.			❖		❖
Kinetochore	No answer	-		-	-	-

I: There are some concepts regarding cell division which are cell, chromosome, gene, allele, DNA, organism and nucleus. Can you write the items in order of size? Start with the largest.

This question given above was used to understand whether Burcu relate the general cell division terms correctly as conceptual understanding. Burcu ranked the different concepts based on decreasing size as:

"Organism >Cell >Nucleus >Chromosome> DNA >Allele > Gene"

Burcu's response was correct apart from place of allele. Recognizing that gene is the smallest one and that DNA found in chromosome and that chromosomes are located in nucleus, he failed to understand that allele is alternate form of gene. Hence he was labeled in naïve understanding.

I: What is chromosome? And what is the role of chromosome?

Burcu: Chromosome is a structure that contain genes on it [chromosome].Chromosomes are found in nucleus. This structure is different form of DNA that binds to protein during cell division. Chromosome number differs between different species.

Burcu's explanation of chromosome included lack of knowledge because Burcu did not mention the role of chromosomes in cell division, so Burcu was put under partial category for chromosome concept. Ontological category of Burcu was matter since Burcu considered the chromosome as passive particle that carry genes and ignored the function of chromosomes in cell division.

I: What is homolog chromosome?

Burcu: Genes inherited from both of the parent include inherited characters. These genes are carried on homolog chromosomes. One chromosome of each pair comes from each of the organisms' two parents. Homolog chromosomes exist in organisms reproducing sexually.

Burcu's explanation of homolog chromosomes had lack of knowledge. Burcu did not state that homolog chromosomes carry different genetic information. Hence, Burcu had partial understanding about homolog chromosomes. In his definition, Burcu considered the events regarding the origin of homolog chromosomes. Burcu's ontological category, hence, determined as process.

I: What is DNA?

Burcu: DNA is a double stranded molecule that forms chromosome. Organism's cyphers called as genes exists in DNA. DNA is called as hereditary material found in nucleus. DNA controls the nucleus… Smallest unit of DNA is nucleotide. It has capability of duplication. This ability is called as replication. When DNA strand is condensed and shortened, it forms chromosome. DNA strand looks like long string and this structure is named as chromatin fiber.

Burcu's explanation of DNA was consistent with this terms' scientific explanation. Thus, Burcu had sound understanding in this term. Moreover, Burcu explanied the role of DNA and what it does in cell division, thus ontological category of Burcu was determined as process.

I: What is gene?

Burcu: Genes are the cyphers that determine the characters of organism. For example; the cyphers that determine color of my eye.

Burcu's explanation of gene was consistent with its scientific definition. Therefore, Burcu had sound understanding about gene concept. Accordingly, Burcu's ontological category was in process category because Burcu could explain how genes affect our body in his words "cyphers that determine the characters of organism."

I: What is allele?

Burcu: Allele is the pair of gene that determines characters. They are found in homolog chromosomes that are inherited from parents… Allele is gene pair that are inherited from parent whereas gene is inherited from one organism of the parents.

Burcu had misconception that allele is a pair of gene. Therefore, Burcu had naïve understanding in allele concept. On the other hand, Burcu explained the role of alleles in body reporting that 'pair of genes determines characters' that is why her ontological category was process regarding allele.

I: What is sister chromatids?

Burcu: After DNA replicates, chromosomal structure forms [Mentioning duplicated chromosome]. Replicated DNA holds together because it binds to centromere. When DNA is replicated; double structure forms called as sister chromatids… Sister chromatids are identical… Sister chromatids form during

DNA replication in interphase. Due to fact that chromosome structure forms in prophase, sister chromatids form in prophase too.

Burcu's explanation of sister chromatids was consistent with scientific explanation of the term and Burcu had sound understanding about sister chromatids. Similarly, Burcu's ontological category of sister chromatids was process since Burcu explained the events about how sister chromatids form.

I: What is centrosome?

Burcu: Centrosomes are found only in animal cells, plant cells do not include centrosome…Centrosome is the structure that forms spindle fibers which attach to the sister chromatids and separate them [sister chromatids] in anaphase.

Burcu's explanation of centrosome matched with scientific definition of centrosome, thus Burcu had sound understanding about centrosome concepts. As far as ontological category was considered, her conception of centrosome was in process category because Burcu clearly explained what centrosomes do in cell division.

I: What is centriole?

Burcu: Structures forming centrosomes (are centrioles). There are two hollow tubes one of which is vertical and another one is horizontal.

Although Burcu could explain the structure of the centrioles, she did not explain the role of centrioles that is the organization of microtubules and so she was put under partial understanding regarding centriole concept. Because of Burcu did not maintain the role of centrioles and emphasized the structure of centrioles, her ontological category for centriole was in matter.

I: What is centromere?

Burcu: Centromere is the region that sister chromatids join.

Burcu's explanation of centromere was scientifically correct, thus she was put under sound understanding category. Ontological category of Burcu regarding centromere was decided in matter category because Burcu focused on the structure and ignored the events related centriole.

I: What is asexual reproduction?

> Burcu: A single organism can reproduce itself and this type of reproduction is called as asexual reproduction. Vegetative reproduction, regeneration, and division by budding are the examples of asexual reproduction.

> I: What is sexual reproduction?

> Burcu: [Sexual reproduction is] a kind of reproduction occurred by the fusion of gametes of one species' male and female individuals…Pollen and egg cells fuse in plants…Female gamete and male gamete form zygote.

Burcu's explanation of asexual reproduction was consistent with scientific explanation, and she was labeled under sound understanding category. Ontological category of Burcu about asexual reproduction was process inasmuch as she was knowledgeable about the event and could exemplify it. Similarly, her understanding about sexual reproduction was sound that match with scientific explanation and her ontological category was in process regarding sexual reproduction. Burcu was aware of the fertilization process, thus she was put under process category for this concept.

I: What is somatic cell?

> Burcu: Somatic cell is diploid cell called as body cell and these cells undergo mitosis apart from some exceptions such as neurons.

Burcu had sound understanding about somatic cells because Burcu was aware that somatic cells are diploid and they undergo mitosis. Ontological category of Burcu with respect to somatic cell was process since Burcu recognized that what somatic cells do by pointing out "somatic cells undergo mitosis."

I: What is gamete?

> Burcu: Gametes do not undergo mitosis, they include n chromosome and they are produced at the end of meiosis… Haploid cells include n chromosome. For example, gametes are haploid. Egg cell contains n=23 chromosomes and this cell is gamete.

Burcu held informed views regarding gametes. She recognized that gametes are the products of meiosis and they include "n" chromosome. Burcu also added that gametes do not undergo mitosis; as a result Burcu had sound understanding about gametes. Moreover, Burcu provided information about how gametes are formed, thus she was in process category regarding gamete.

> I: What is zygote?
>
> Burcu: Zygote is somatic and diploid…That is fertilized egg, fusion of sperm and egg in animals, and fusion of pollen and egg in plants…Zygote includes 2n chromosomes.

Burcu's explanation of zygote was consistent with scientific definition of zygote. Hence, Burcu held sound understanding about zygote concept. Ontological category of Burcu was process because Burcu was aware that fertilization event to form zygote.

Because of Burcu did not answer the kinetochore question, her conception was labelled as no understanding. Her ontological category was not identified due to fact that she did not answer this concept.

As a result, Burcu had sound understanding in ten concepts of DNA, gene, sister chromatids, centrosomes, centromere, asexual reproduction, sexual reproduction, somatic cell, gametes, and zygote over sixteen concepts. Moreover, Burcu's ontological category was process in eleven concepts which are homolog chromosomes, DNA, gene, allele, sister chromatids, centrosomes, asexual reproduction, sexual reproduction, somatic cell, gamete, and zygote. Burcu's sound understandings correspond to her answers which were in process category regarding ontology. Burcu's understanding of cell cycle is reported in the next section.

4.2.1.2.2. Knowledge of Cell Cycle

Question regarding cell cycle which is what is a cell cycle? Can you identify the stages of cell cycle and describe the principle events characteristic of each was asked to Burcu to grasp her understanding of cell cycle.

Table 4.33

Burcu's Knowledge of Cell Cycle

		Conceptual understanding			Ontological categorization	
Concept	**Response**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Cell Cycle definition	I don't know, we only draw life cycle of organisms.	-	-	-	-	-

I: What is cell cycle?

Burcu: I do not know, what it means. We only draw life cycle of the organisms that starts with fertilization and goes on with mitosis. Then, organism undergoes meiosis and product fuse for new individual in the life cycle that we draw.

Burcu's response to questions regarding the cell cycle indicated that she did not know this concept and she confused the cell cycle and life cycle of sexually reproducing organisms. Accordingly, she could not answer the subsequent question regarding the principle events that occur at each stage of the cell cycle. To be brief, she classified under no category for conceptual understanding regarding and her ontological category could not be determined.

4.2.1.2.3. Knowledge of Mitosis

To identify her understanding of mitosis, she was requested to define mitosis and then explain the events that occur in each stage of mitosis through drawing. Lastly, she was asked to mitosis of a plant cell and its differences with mitosis of animal cell.

I: What is mitosis?

Burcu: Basically, mitosis is the formation of diploid [2n] cell from another diploid [2n] cell. Two [new] cells are produced. Somatic cells undergo mitosis. Injuries recover via mitosis. In addition, function of mitosis is the growth of multi-cellular organisms. Uni-cellular organisms reproduce

> through mitosis. During mitosis, high amount of energy is consumed. Somatic cells undergo mitosis. In addition, uni-cellular organisms undergo mitosis to reproduce. There are some exceptions that do not undergo mitosis such as neurons. Asexual reproduction is based on mitosis. Asexual reproduction does not occur without mitosis.

She was not only able to explain process of mitosis scientifically but also correctly draw and describe the events that occur in each stage. She knew that growth of multicellular eukaryotic organism is based on mitosis and that it is the basis of asexual reproduction of single-celled eukaryotes' asexual reproduction is based on mitosis. She was aware that some cell types like nerve cells do not divide when they become mature. Besides, she clearly addressed the differences in mitosis between plant and animal cell and therefore assigned under the category of sound understanding. Burcu's ontological category was determined as process

> I: Assume that an animal has a diploid chromosome number of four (2n=4). Could you please explain and diagram the mitosis process?

She explained the stages of mitosis by referring to diagram below:

> DNA is replicated during interphase. Chromatin fiber exists before they are condensed and shortened to form chromosomes [in interphase] …, There are 4 chromosomes in prophase. Nucleolus and nuclear envelope disappears in prophase. Centrosomes are duplicated before the prophase and DNA strand is condensed and shortened when they form the structure called chromosome…Chromosomes arrange in equatorial plate in [metaphase]. … Chromosomes are most visible in this stage [metaphase]. Moreover, [in metaphase] spindle fibers are clearly seen. Spindle fibers found in centrosome pull this [pointing sister chromatids] to this side [mentioning poles]…Spindle fibers shorten here [in anaphase] and pull towards the poles. Sister chromatids separate here [in the anaphase] … in telophase, opposite events of prophase occur. Chromosomes begin to dissolve in telophase and contractile ring forms. After dissolving of chromosomes, chromatin fiber forms. Nucleolus and nuclear envelope re-form. The size of daughter cells can be different from original cell that undergoes mitosis at the beginning of the process… Some of the organelles end up in each of the new cells and some others end up in other new cell. Each of the new cells is genetically identical [to the parent cell]

In her drawing, she also correctly identified chromosome number of somatic cell that undergoes mitosis and associated mitosis and asexual reproduction. She diagrammed the characters of each stage correctly. For example, she drew chromatin fiber correctly in original cell, showed sister chromatids correctly; and knew that sister chromatids are identical, mentioned about breaking down of nuclear membrane in prophase and arranged the chromosomes in equatorial plane in metaphase, separated the sister chromatids in anaphase; drew furrowing to prepare cell into cytokinesis and yielding two daughter cells which are genetically identical. Her explanations consisted with her drawing and all together reflected her sound understanding regarding the definition and process of mitosis.

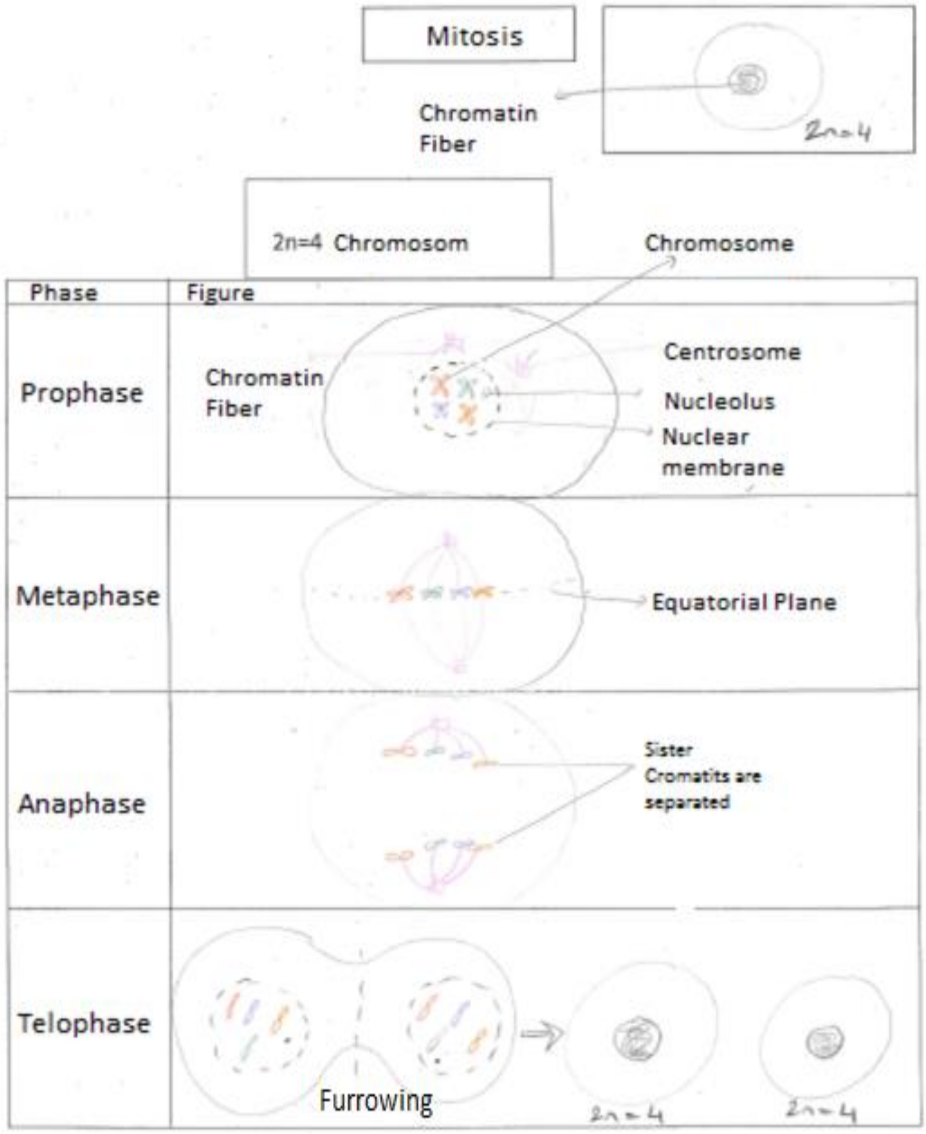

Figure 4.10 Burcu's Drawing of Mitosis

She also clearly contrasts the mitotic events that occur in plant cells and animal cells:

> I: Do you think that mitosis in plant cells similar to that of animal cell?
>
> Burcu: Plant cell does not contain centrosome. [Instead]There is another structure that plays the same role with centrosome in plant cell. In addition, cell plate occurs during cytokinesis in plant cell because cell wall is hard enough that change easily its shape.

Burcu correctly identified the differences in mitosis between plant cell and animal cell. She indicated lack of centrosome in plant cell, also was aware that in plant cell, cytokinesis occurs by the formation of a cell plate. Ontological category of Burcu was in process in overall idea of mitosis because she could aware the process of mitosis and clearly explained the events occurred in mitosis.

Table 4.34

Burcu's Knowledge of Mitosis

		Conceptual Understanding			Ontological Category	
Concept	**Burcu's Response**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Process of Mitosis	Basically, mitosis is the formation of diploid (2n) cell from another diploid (2n) cell. 2 (new) cells are produced. Somatic cells undergo mitosis. Injuries recover via mitosis. In addition, mitosis provides growth of multi-cellular organisms. Mitosis produces reproduction of uni-cellular organisms. During mitosis, so much energy is consumed. Somatic cells undergo mitosis. In addition, uni-cellular organisms undergo mitosis to reproduce. There are some exceptions that do not undergo mitosis such as neurons. Asexual reproduction is based on mitosis. Asexual reproduction does not occur without mitosis.			❖		❖
Mitosis in Plant cell's	Plant cell does not contain centrosome. There is another structure that has the same role with centrosome in plant cell. In addition, cell plate occurs during cytokinesis in plant cell because cell wall is hard that does not easily change its shape. Waste material in plant cell forms cell plate.			❖		❖

4.2.1.2.4. Knowledge of Meiosis

To identify her understanding of meiosis, she was requested to define meiosis and then explain the events that occur in each stage of meiosis through drawing. Lastly, she was asked to meiosis of a plant cell and its differences with meiosis of animal cell.

> I: What is meiosis?
>
> Burcu: Meiosis is different from mitosis because its products which are gametes serve to sexual reproduction. Unlike mitosis products, gametes are different from each other and parent cell regarding the genetic information they carry. Organisms reproduce by asexual reproduction do not undergo meiosis. A cell that undergoes mitosis can divides more than one time. However, products of meiosis do not undergo cell division because haploid cells do not divide. Haploid cells fuse to form zygote. Crossing over promotes genetic variation between products of meiosis because genetic material is reshuffled between homolog chromosomes. Products of meiosis fuse to form zygote that is called sexual reproduction.

Burcu had clear understanding on meiosis since she was aware the products of meiosis and that is role in sexual reproduction. Moreover, Burcu was aware that reshuffling of genetic material, crossing over, as a cause of genetic variation. Burcu implied that gametes do not undergo cell division on the other hand gametes fuse to form zygote.

> I: Assume that an animal has a diploid chromosome number of four (2n=4). Could you please explain and diagram the meiosis process?

Burcu explained her views during her drawing of meiosis diagram as follows:

> Crossing over happens in prophase-1. Nucleolus and nuclear disappear in prophase-1. Crossing over happens between homolog chromosomes' chromatids which are not sister chromatids. Crossing over provides genetic diversity among individuals of species. Human beings and different organisms of same species are not identical due to crossing over leading genetic variation. Homolog chromosomes separate in meiosis-1 [Anaphase-1]. Homolog Chromosomes arrange in equatorial plate [Metaphase-1]. Chromosome number reduces in anaphase-1 from diploid to haploid. Sister chromatids separate in meiosis-2 [Anaphase-2]. Crossing over occurring between homolog chromosomes is unique to meiosis. This event causes

genetic variation. Moreover, meiosis reduces the chromosome number from diploid to haploid.

Both Burcu's definition and drawings of meiosis was consistent with scientific explanation. Burcu included chromatin fiber, showed number chromosomes correctly. She deepened her drawings as drawing early prophase and late prophase. All the events and stages were explained by Burcu. Although Burcu had sound understanding and was in process category regarding meiosis, she did not mention the structures occurred in prophase-1 which are tetrade, synapsis and chiasmata. Moreover, Burcu did not mention the interkinesis event that is similar to mitotic interphase, but there is no DNA replication in interkinesis.

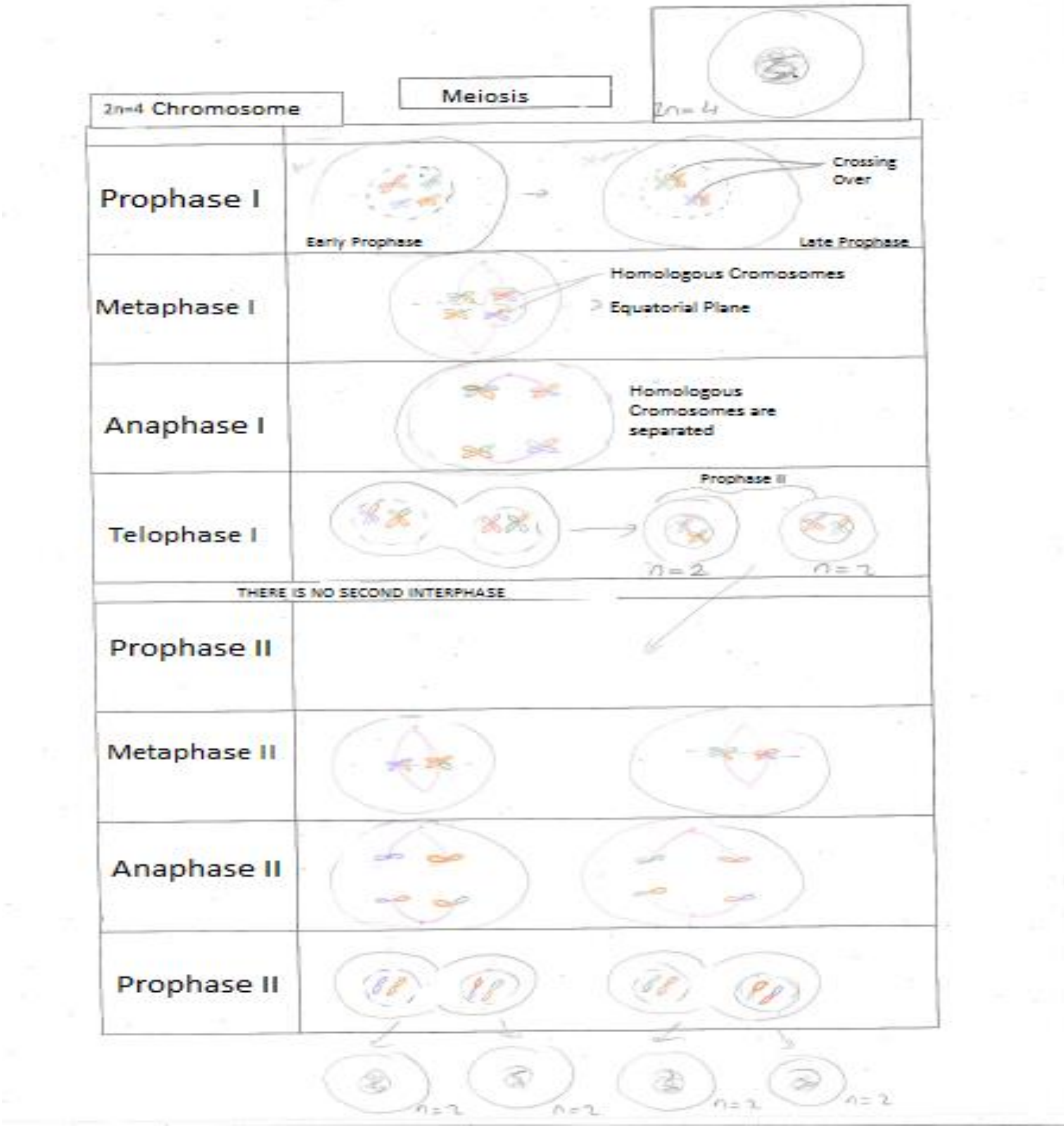

Figure 4.11Burcu's Drawing of Meiosis

She also clearly contrasts the meiotic events that occur in plant cells and animal cells:

> I: Do you think that meiosis in plant cells similar to that of animal cell?
>
> Burcu: Plant cells undergo meiosis and its products are pollen and egg cells. Plant cells' meiosis is similar to meiosis in animal cell in general; however, centrosome is not found in plant cell. Moreover, plant cells do not divide by furrowing in cytokinesis. Instead of furrowing, plant cells divide through the formation of cell plate.

Burcu explained the mechanism of meiosis in plant cells and its products which are pollen and egg cell. Moreover, Burcu sorted the differences between meiosis in plant cell and animal cell such as absence of centrosome in plant cells and the cell plate difference in cytokinesis. As a result, Burcu had sound understanding and was in process category regarding meiosis in plants.

Burcu clearly distinguished the differences and similarities between meiosis and mitosis in general hence she had sound understanding and was in process category regarding the differences and similarities between meiosis and mitosis.

> I: What are the differences/similarities between the meiosis and mitosis? Could you explain your answer?
>
> Burcu: Mitosis results in two identical cells which are identical to parent cell on the other hand four cells are produced after meiosis. Because of duplicated chromosomes are separated into two new cells, chromosome number does not change in mitosis. On the other hand chromosome number reduces in meiosis. Somatic cells which are not differentiated for reproduction undergo mitosis whereas germ cells undergo meiosis.

Although Burcu had sound understanding in meiosis, meiosis in plant cell, and comparison between mitosis and meiosis, she did not mention any relationship between genetics and cell division. When it is asked whether there is a genetic principle that connect meiosis and genetics in anaphase-1, Burcu did not mention 'the law of independent assortment' that connect genetics and cell division, hence neither her conceptual understanding nor ontological category that she belonged regarding the relation between cell division and genetics were not determined. Table 4.35 summarizes Burcu's substantive content knowledge regarding meiosis.

Table 4.35

Burcu's Knowledge of Meiosis

		Conceptual Understanding			Ontological categorization	
Concept	**Burcu's Response**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Meiosis	Type of a cell division that produces gametes… is a basis of gamete formation that prepares cells to sexual reproduction. Meiosis is different because it produces gametes. Only diploid germ cells can undergo meiosis, other cells cannot… Only organisms that reproduce sexually undergo meiosis. Because of meiosis facilitate sexual reproduction organisms reproducing asexually do not undergo meiosis. After a cell undergoes meiosis, its products do not undergo cell division anymore… Crossing over that cause genetic diversity. In addition, meiosis and fertilization cause constancy on the number of chromosomes that individuals of species have. Sexual reproduction is based on meiosis…			❖		❖
Meiosis in Plant Cell	Plant cells undergo meiosis too. Pollen and egg cell are the gametes that are produced by meiosis in plant. Plant cell does not have centrosome. Plant cells are not separated by furrowing unlike to animal cell. Plant cells are separated by forming solid cell plate that is the beginning of new cells' cell wall.			❖		❖

Table 4.35 (cont'd)

Concept	Burcu's Response	Conceptual Understanding: Naive	Partial	Sound	Ontological categorization: Matter	Process
Meiosis and Mitosis Differences	Four cells which are different from each other and their parent cell are produced after meiosis. On the other hand, two identical cells are produced after mitosis. Products of meiosis fuse with other gametes and play role in sexual reproduction and genetic diversity. On the other hand products of mitosis provide genetic constancy and play role in asexual reproduction.			❖		❖
Principle that connect genetics and cell division	No idea	-			-	-

In this section Burcu's meiosis knowledge was resulted and presented in the next section; Burcu's pedagogical content knowledge regarding cell division will be reported.

4.2.2. Burcu's PCK Regarding Cell Division

Burcu's PCK regarding cell division was gathered by use of pre-interviews, post-interviews, observations and teacher documents which are written exams. In this section; results of the Burcu's PCK were presented. PCK components which are orientation towards science, knowledge of curriculum, knowledge of students' understanding of science, knowledge of assessments and knowledge of instructional strategies and their sub-components were explored to understand Burcu's PCK.

4.2.2.1. Burcu's Orientation towards Science

Burcu's beliefs about goals of science teaching were presented in this section. Burcu's beliefs about goals of science teaching refer her orientation towards science. Beliefs about goals of science teaching were gathered by use of pre-interview questions, observations and post-interview questions. Burcu's beliefs about goals of science teaching are categorized under two categories: central and peripheral goals. To further analysis, these beliefs were classified as schooling, affective and subject matter goals.

4.2.2.1.1. Burcu's Beliefs about Goals of Science Teaching

Beliefs about goals of science teaching were presented as pre-interview results and observation results. Due to fact that what teachers want to do in class, and what teachers do in class are different from each other, Burcu's beliefs about goals of science teaching were presented as pre-interview results at first (what teacher wants to do) and then, Burcu's beliefs about goals of science teaching were presented (what teachers actually do in class). Results showed that Burcu had schooling goals and subject matter goals regarding central goals obtained in pre-interviews. The schooling goals were to make students to understand the connection between daily life and science and to understand their own body. The subject matter goals that Burcu referred were to understand the underlying scientific phenomena about the content. On the other hand, Burcu's central orientations were only subject matter goals in observations. Burcu substituted the place of schooling goals from central orientations to peripheral orientations. Moreover, Burcu's representations in class increased students' attention to lesson. Therefore, Burcu may have affective goals as peripheral goals. Table 4.36 presents Burcu's beliefs about goals of science teaching based on pre-interview results.

Table 4.36

Beliefs about Goals of Science Teaching (Pre-interviews)

Question	**Response**	**Central Goals**	**Peripheral Goals**
What do you understand about the term “science teaching”?	Science is learnt by doing and acting. Being scientific literate is to be aware of something. Students will *understand the logic of something*. I do not want students’ to memorize science content.	Subject Matter Goals	-
	Students will understand the logic of content and *apply this knowledge in their life.*	Schooling Goals	-
What are the goals of science teaching in your opinion?	Nature of science is related with life. Students reach this knowledge by themselves. They will explore the end of the lesson. *Students can make different inferences when they connect the scientific knowledge and daily life.*	Schooling Goals	-
As a science teacher, what is the meaning of teaching cell division topics for you?	[Cell division] increases students’ awareness. *Students explore themselves biologically*.	Schooling Goals	-

-

Table 4.36 (cont'd)

Question	Response	Central Goals	Peripheral Goals
Why do you teach cell division topics as a science teacher?	First of all, *curriculum determines what we teach*.	Subject Matter Goals	
	Then, *students explore themselves such as understanding how injury gets wel*l… Students prefer to eat some diet and do not eat some others. If they understand which substances a cell needs to divide, they start to eat diet even they do not like. Diet that students do not like may be beneficial for students' growth. Students start to eat healthy food for their own growth.	-	Schooling Goals

I: What do you understand about the term “science teaching”?

Burcu: Science is learnt by doing and acting. We have learned scientific literacy in university. For example; people pickle and add vinegar, garlic and salt into the pickle. They [villager] do not know scientific aim of adding vinegar, garlic and salt. After they [students] learn scientific literacy, they [students] could understand that adding garlic, vinegar and salt kill the bacteria in the pickle… Being scientific literate is to be aware of something. Students will understand the logic of something. I do not want students to memorize science content. Students will understand the logic of content and apply this knowledge in their life.

In her explanation of science teaching, Burcu’s central goals focused on the meaningful understanding of scientific knowledge and using this knowledge in daily life consciously. Because of Burcu wanted students to understand the logic of scientific phenomena, Burcu’s central goal is subject matter goals. Moreover, Burcu aimed that students use knowledge in daily life which is another central goal classified as schooling goal.

I: What are the goals of science teaching in your opinion?

Burcu: Nature of science is related with life. Students will look at first, and then they will understand. Students reach this knowledge by themselves. They will explore the end of the lesson. Students can make different inferences when they connect the scientific knowledge and daily life.

In her explanation of the aim of science teaching, Burcu emphasized on constructivism that students explore the knowledge. Burcu aimed to prepare students to daily life by connecting science in their life, so her central goal in this question was determined as schooling goals.

I: As a science teacher, what is the meaning of teaching cell division topics for you?

Burcu: [Cell division] increases students’ awareness. Students understand how their body works after learning cell division.

Similar to previous questions, Burcu maintained her central goals as schooling goals in the question that assess her understanding of teaching cell division. By claiming “students explore themselves biologically.”, Burcu revealed her schooling goal.

> I: Why do you teach cell division topics as a science teacher?
>
> Burcu: First of all, curriculum determines what we teach. Then, students explore themselves such as understanding how injury gets well… Students prefer to eat some diet and do not eat some others. If they understand which substances a cell needs to divide, they start to eat diet even they do not like. Diet that students do not like may be beneficial for students’ growth. Students start to eat healthy food for their own growth.

Burcu’s beliefs about goals of science teaching were revealed as peripheral and central goals in this question. Burcu’s priority is to obey the curricular expectations. So, Burcu’s central goals regarding teaching cell division is subject matter goals. Burcu also wanted students to explore their body and to apply this learning in their life. Hence, her peripheral goals were determined as schooling goals in this question.

Burcu’s cell division courses were observed to get further information about her beliefs that shape her decision and practice. Burcu usually asked students open ended questions to make students understand science content meaningfully. For example;

> Burcu: How does cell divide? Why does cell divide? (Observation).

These kinds of questions increased students’ subject matter knowledge. Teacher aimed her students to become master of content. Her teaching based on students’ meaningful understanding was common in all observations. So her central goals were determined as subject matter goals in observations.

Burcu’s peripheral orientation regarding cell division teaching was determined as schooling goals and affective goals. Burcu connected her teaching in daily life such as asexual reproduction, so one of her peripheral orientation was schooling goals that:

> Burcu: Have you ever seen example of vegetative reproduction? For example; your mother likes a neighbor's plants. Then, she [mother] takes a branch of plant. This branch reproduces new plant in your home and this process is vegetative reproduction. (observation)

Another peripheral goal was found as affective goals in Burcu's teaching. During her teaching, Burcu used board marker model to show mitosis, meiosis and crossing over. These kind of representations increased students' motivation, curiosity and attention towards lesson and students wanted to repeat the activity by them in next lesson. Table 4.37 summarizes Burcu's beliefs about goals of science teaching.

Table 4.37

Beliefs about Goals of Science Teaching Based on Observations

Observation	**Central Goals**	**Peripheral Goals**
To promote meaningful learning of science content	Subject Matter Goals	-
To connect science and daily life	-	Schooling Goals
To increase students motivation and attention towards lesson	-	Affective Goals

To sum up, Although Burcu had schooling goals and subject matter goals as central goals regarding beliefs about science teaching in pre-interviews; however, Burcu only realized her subject matter goals in her teaching as central orientation. Burcu's schooling goals as central goals were shadowed and placed in her peripheral goals in observations. In the next section, Burcu's knowledge of curriculum will be reported.

4.2.2.2. Burcu's Knowledge of Curriculum

Burcu's understanding of knowledge of curriculum was assessed by its two sub-components which are knowledge of goals and objectives and knowledge of materials. Data were collected by use of pre-interviews and observations for knowledge of goals and objectives. Conversely, data were gathered by pre-interviews, observations and post-interviews for knowledge of materials

4.2.2.2.1. Burcu's Knowledge of Goals and Objectives about Cell Division

Burcu could know the reason why cell division place in curriculum, place of cell division in curriculum, vertical and horizontal relations, objectives, misconception warning in objectives. Burcu could also sort objectives regarding their importance. Similarly, Burcu suggested modification of textbooks and objectives. Burcu could answer students' needs without dependence any specific materials. On the other hand, Burcu violated the curriculum giving advance level of knowledge that is related with the degree of knowledge suggested by curriculum. Moreover, Burcu missed some limitations found in curriculum regarding cell division.

> I: Why do cell division topics place in curriculum?
>
> Burcu: Helical model of curriculum is aimed. I started from cell because it will be inductive learning…Actually it is also related with deductive learning because we give superficial knowledge at first, then we give detailed knowledge. We start from basic to complex. This knowledge will accumulate in future.

First of all, the question given above assesses Burcu's understanding of why cell division topics are placed in curriculum. Burcu mentioned the spiral curriculum to explain the reason why cell division topics are thought in curriculum. Burcu's answer was consistent with MoNE (2006) explanation of the reason why cell division place in curriculum. Thus, Burcu was aware of the reason of why cell division place in curriculum.

> I: Do you know the place of cell division in curriculum? In which grade level is cell division taught and what are the topics taught before and after this unit?
>
> Burcu: Cell division is taught in 8th grade level. This topic is also taught in 6th grade in reproduction, growth and development in less detailed format. Cell division is first unit and following unit is force and motion.

Second pre-interview question assessed Burcu's understanding of the place of cell division in curriculum. Burcu could respond that cell division is taught in 8th grades before force and motion topics. Hence, Burcu was aware of the place of cell division in curriculum.

> I: Is there any science topic taught in earlier grades related with cell division?
>
> Burcu: [It is] related with reproduction, growth and development unit in 6th grade because students can not learn cell division without cell knowledge. We will go deeper in cell to the nucleus.

Burcu's understanding of vertical relationship was questioned by 'Is there any science topic taught in earlier grades related with cell division?'. Burcu could respond that cell division is related with reproduction, growth and development unit in 6th grade.

> I: Is there any science topic taught in 8th grade level related with cell division?
>
> Burcu: Only meiosis and mitosis are related with each other in 8th grade level.

The question given above aimed to assess her understanding about horizontal relationships and Burcu only associated mitosis and meiosis each other. Burcu ignored the relationship between cell division, genetics and evolution in her explanation.

Then, Burcu's knowledge of objectives regarding cell division was sought. Burcu mentioned three of the objectives which are 'Define Mitosis as process starting with karyokinesis and including stages following each other.', 'Deduce that gametes are produced in meiosis.', and 'List the differences between meiosis and mitosis.' during pre-interviews. On the other hand, Burcu mentioned all the objectives during her teaching; therefore Burcu was aware of the cell division objectives. Table 4.38 summarizes Burcu's knowledge about cell division objectives based on pre-interviews and observations.

Table 4.38

Burcu's Understanding of Cell Division Objectives

2006 Objectives Stated in Science Curriculum for Cell Division Topic	**Does teacher answer meet the curriculum objective?(Interviews)**		**Does teacher answer meet the curriculum objective? (Observations)**	
	Yes	No	Yes	No
Explain that growth and development occurs through the cell division.		❖	❖	
Define Mitosis as process starting with karyokinesis and including stages following each other.	❖		❖	
Be aware the importance of chromosomes in mitosis and refer that different species can have different number of chromosomes.		❖	❖	
Indicate the importance of mitosis for living organisms and relate mitosis with growth and reproduction.		❖	❖	
Deduce that gametes are produced in meiosis.	❖		❖	
Be Aware of the importance of meiosis for living organisms.		❖	❖	
List the differences between meiosis and mitosis.	❖		❖	

> I: Could you sort the objectives based on their importance?
>
> Burcu: Mitosis is more important because all living organisms undergo mitosis. Meiosis is more specific than mitosis. In addition, students who learn mitosis also learn meiosis too.

After gathering Burcu's knowledge about cell division objectives, she was requested to sort objectives based on their importance. Burcu sorted the objectives and thought that mitosis objectives are more important because mitosis facilitates students' learning of meiosis. According to Burcu, students who learn mitosis could learn meiosis too.

> I: Is there any important points to be emphasized for you apart from existing objectives?
>
> Burcu: I think DNA should be taught before mitosis. We teach chromosome in mitosis but students learn what chromosome is in DNA. Place of mitosis and DNA should change in curriculum. Students do rote learning in chromosome because of its place in curriculum.

After sorting the objectives, it was argued whether Burcu modify textbooks or not. Burcu modified the places of the topics in her explanation during pre-interview. She recognized that the sequence of cell division and inheritance unit as mitosis-inheritance-meiosis-DNA. She pointed out that they teach the chromosome concept in mitosis before detail explanation of concept. After meiosis, students learn what chromosome is in DNA chapter. Hence, they could not understand the chromosome concept. Because of this reason Burcu offered to place DNA before mitosis topic in textbook. Hence, Burcu suggested that place of the cell division topics should be as DNA-mitosis-inheritance-meiosis.

Next, limitations found in curriculum regarding cell division teaching were asked to Burcu. Burcu could not explain the limitations regarding cell division teaching in pre-interviews. During observations, Burcu obeyed two of the three limitations regarding cell division. She did not tell crossing over and preferred to use Turkish version of it. Similarly, she did not mention differences of the stages between mitosis and meiosis. However, she used the names of the stages in her teaching. In conclusion, Burcu missed some points of the limitations found in curriculum about cell division. Table 4.39 presents Burcu's understanding of cell division limitations found in curriculum.

Table 4.39

Burcu's Understanding of Cell Division Limitations

2006 Limitations Stated in Science Curriculum for Cell Division Topics	**Does teacher Answer meet limitation?(Interviews)**		**Does teacher answer meet limitation? (observations)**	
	Yes	No	Yes	No
Names and properties of stages of mitosis are not mentioned.		❖		❖
Names of the stages of meiosis are not mentioned and Turkish name of crossing over (Parça Değişimi) is used.		❖	❖	
Differences of the stages of meiosis and stages of the mitosis are not mentioned.		❖	❖	

After limitations about cell division topics found in curriculum, misconception warning about cell division was asked to Burcu. Although Burcu could not respond this question in pre-interviews, she mentioned the misconception during observations as follows:

> Burcu: What do you think about human beings and molly fish have equal number of chromosome?
>
> Student: Their [Molly fish and human beings] chromosome number is same but, their genes [Molly fish and human beings] are different.
>
> Burcu: Yes, their [Molly fish and human beings] genes' order, sequence and number are different. Complexity of living organism and number of chromosome are not related. For example; ferns have more numbers of chromosomes than human beings have, but they [ferns] are less complex living organisms.

Due to fact that Burcu focused on the misconception warning in her teaching, she was aware of the misconception warning found in curriculum about cell division. Table 4.40 presents Burcu's understanding of misconception warning in curriculum.

Table 4.40

Burcu's Understanding of Cell Division Misconception in Curriculum

2006 Misconception Stated in Science Curriculum for Cell Division Topics	**Does teacher answer the misconception? (Interviews)**		**Does teacher answer the misconception? (observations)**	
	Yes	No	Yes	No
There is a direct proportion between the size and complexity of organism and the number of chromosome.		❖	❖	

Dependence to curricular material was another aspect of knowledge of goals and objectives. Burcu was not dependent to any one of the sources and she tried to answer students' need as much as she could. When students did not understand topic, she used metaphors, visuals, internet and models to facilitate learning. She did not use textbook definitions, and she adjusted this knowledge as students could understand in her teaching.

The last aspect of the knowledge of goals and objectives was the degree of knowledge that is supposed by curriculum. Unfortunately, Burcu taught advance level knowledge in her teaching in some points. Some examples that Burcu taught advance level knowledge about cell division are presented below:

> Burcu: Females have two ovaries, one of which undergoes meiosis for each month. The one which does not undergo meiosis that month undergoes meiosis in following month (observation).
>
> Burcu: Meiosis starts with puberty age and ends with menopause for women and andropause for men (observation).

4.2.2.2.2. Burcu's Knowledge of Materials

Burcu used only internet and her presentation regarding sources in teaching cell division specifically. She explained the reason why she uses internet to visualize the abstract concept such as mitosis and meiosis. When she covered the lesson she preferred to use her presentation. On the other hand, she did not use actively exercise book in teaching because she taught that exercise book should be used after students' comprehension level is sufficient to do activities. Moreover, Burcu did not use textbook properly in cell division topics addressing schedule and school related problems. Because of textbooks were distributed to students after teaching of the unit started, Burcu could not use textbooks based on her explanations. As a result, Burcu used only few of sources which are internet and her presentation in cell division teaching. Table 4.41 presents Burcu's knowledge of materials.

Table 4.41

Knowledge of Materials

Sources that teacher use that make teaching easier	**Aim of using selected sources**
Internet	I use the internet to show visuals. There are different techniques and presentation in internet. Moreover, there are some animations in internet that visualize abstract topics such as mitosis and meiosis (pre-interviews).
Presentation	During teaching of cell division unit Burcu actively used presentation that she prepared (observation).
Textbook &Exercise Book	She did not use actively because she preferred to use exercise book after teaching. Moreover school administrations distributed the textbook at the end of the unit.

I: What are the sources that you use in cell division topics?

Burcu: I use textbook and exercise book. However, when I write question on board, I write from my mind because of I was author of test book of a cram school in the past. I prefer to use teacher guide book to recall limitations of topic. I do not prefer commercial test books because knowledge in these books conflict with the knowledge that curricular knowledge. I use the internet to show visuals. There are different techniques and presentation in internet. Moreover, there are some animations in internet that visualize abstract topics such as mitosis and meiosis.

I: What are the aims of using sources that you use in cell division topics?

Burcu: To visualize abstract concepts which facilitate students' conceptual understandings. When I teach cell division showing animations it is very well. I show students science games in internet similar to 'Who wants to be millionaire?' These kinds of activities make course enjoyable. I use university books when content of the curriculum change to inform about new content. I use internet to show visuals.

During interviews, Burcu said she use four sources which are textbook, exercise book, teacher guide book, and internet. However, she only gave specific examples about cell divisions when she explained the use of internet. Burcu claimed that she preferred to use internet to visualize abstract topics such as mitosis and meiosis which facilitate students' understanding.

During observations, Burcu actively used her presentation and internet to teach cell division. When she wanted to show activities such as mitosis process, she opened animations and explored the activities with students. Burcu did not actively use exercise book and textbook in her teaching. Then, researcher asked her why she did not prefer to use textbook and exercise book. Burcu mentioned students' lack of knowledge before teaching when she explained why she did not use exercise book. Moreover, she pointed out curricular place of the topic regarding why she did not use textbook in her teaching.

Burcu: I started to use exercise book recently after we completed the teaching of unit because their conceptual understanding was low when I taught the topic. We cannot say open this page and solve this question to the students. However, I think that exercise book should be solved because activities in exercise book are asked in High School Entrance Exam. I scanned the

> activities in my flash memory and show these activities to students from smart board anymore… Because of this [unit] was the first unit, we distribute the textbooks after we started to teach the content. Hence, I could not use the textbook regularly.

To sum up, Burcu was good at the knowledge of goals and objectives although she taught advance level of knowledge. Regarding knowledge of materials, Burcu preferred to use internet and her presentation actively. Burcu did not prefer textbook and exercise book properly because of two reasons. Burcu preferred to use exercise book when students have grasp understanding. Another reason was late distribution of textbook and exercise book in her school. In the next section, Burcu's knowledge of students' understanding of science are reported.

4.2.2.3. Burcu's Knowledge of Students' Understanding of Science

Burcu's understanding of students' understanding was gathered through the pre-interviews and observations. Results of the knowledge of requirements and knowledge of students' difficulties which are two components of knowledge of students' understanding were presented in this section.

4.2.2.3.1. Burcu's Knowledge of Requirements for Learning regarding Cell Division

> I: What prior knowledge should students have to understand cell division topic?
>
> Burcu: They need to know cell very well. They need to know nucleus of cell that was taught in 6^{th} grade level. Moreover, DNA is prerequisite to understand cell division. Students need to know chromatin fiber very well (pre-interviews).

Burcu's understanding of the pre-requisite knowledge to learn cell division was assessed by the question that is 'What prior knowledge should students have to understand cell division topic?' Although Burcu considered cell, nucleus and chromosomal structures such as DNA and chromatin fiber as prerequisite knowledge to learn cell division, she ignored the basic genetics terms such as homolog chromosome, allele, sister chromatids, gene and their relationship as prerequisite knowledge to learn cell division.

4.2.2.3.2. Burcu's Knowledge of Students' Difficulties regarding Cell Division

Burcu's knowledge about students' difficulties regarding cell division was gathered through five dimensions which are difficult points that students holds, reasons of difficulties, students' misconceptions, sources of misconceptions, and way of Burcu's identification and remediation of misconceptions. Data regarding Burcu's knowledge of students' difficulties were gathered by use of pre-interview questions and observations. Burcu was aware of the students' misconceptions about cell division. Similarly, Burcu had some idea about the points that students have difficulty, reasons of students' difficulty and sources of misconceptions. Burcu had lack of knowledge in identification and remediation of misconceptions.

> I: Which points do your students have difficulty in understanding cell division topics, in your opinion?
>
> Burcu: They [students] have difficulty in understanding foreign terms…Separation of chromosomes and chromosome duplication… Textbook shows 4 leaved structure as chromosome. Students show duplicated chromosome and say that there are two chromosomes. There are not 2 chromosomes, there is one chromosome…

When Burcu explained the difficulties regarding cell division topics, Burcu mentioned both conceptual difficulties which are foreign terms and process based difficulties such as separation of chromosome. However, Burcu did not focus on the mechanisms as difficult points such as mechanism of genetic transfer in cell division.

> I: What are the reasons of students' difficulties regarding cell division?
>
> Burcu: We have limited time and curriculum wants us to teach superficially… Latin words intimidate students. It is their first time experience to concepts… Because they don't know DNA.

Regarding the reasons of students' difficulties, Burcu pointed on three aspects which are superficial teaching of science content, terminology of cell division, and the lack of pre-requisite knowledge such as insufficient knowledge of

DNA. Burcu's first reason for students' difficulty was not specific to cell division. However, terminology of cell division and lack of DNA knowledge is directly related with cell division as reasons of cell division. On the other hand, Burcu did not stress abstract nature, invisible nature (micro level aspect), assimilation of new knowledge, and complex structure of cell division as reasons of difficulties.

> I: What are the students' misconceptions regarding cell division?
>
> Burcu: They [students] confuse on allele, gene, homozygote, heterozygote, hybrid, diploid, haploid, 2n-n chromosome. They [students] don't understand the difference that homolog chromosomes separate in meiosis and sister chromatids separate in mitosis. Due to fact that we firstly teach mitosis, they think that homolog chromosomes should not separate in meiosis. They compare meiosis to mitosis. They [students] thought that gametes undergo meiosis but gametes are the products of meiosis. In addition, they [students] thought that egg cell and sperm reproduce by mitosis.

During pre-interviews Burcu mentioned many misconceptions such as gametes reproduce by mitosis, homolog chromosomes do not separate, gametes undergo meiosis etc. Moreover, Burcu identified many misconceptions regarding cell division during observations. Some examples of the misconceptions identified in observations are:

- Chromosome is bigger than nucleus.
- Worms' asexual reproduction type is vegetative
- All gametes have 23 chromosomes
- Ovarian is same with egg cell.

Because of Burcu pointed out many misconceptions during pre-interviews and identified misconceptions during observations, it is concluded that she was aware of the misconceptions about cell division.

> I: What are the sources of students' misconceptions regarding cell division?
>
> Burcu: Place of the DNA is wrong that leads students to have misconceptions, this is curricular problem. Students may not know the chromosomes structure, so they hold misconceptions.

Although Burcu could respond that lack of prior knowledge and textbook can be source of misconceptions, she did not mention teacher and daily life language as sources of misconceptions.

> I: How do you identify students' misconceptions regarding cell division?
>
> Burcu: By questioning. Sometimes, by the questions that students ask.

Burcu explained that she identified students' misconceptions by questioning. Similarly, she identified students' misconceptions through the questions in her teaching during observations.

> I: What are the teaching strategies that you used to eliminate students misconceptions?
>
> Burcu: We use visuals. I show them similar questions, I emphasize and I get them compare similar questions.

When she explained how she remediates students' misconceptions, she focused on showing questions and visuals. Burcu did not know how misconceptions are identified and eliminated because she only focused on questioning and showing visuals to identify and eliminate misconceptions which are not sufficient to remediate misconceptions. Burcu did not mention quizzes, discussion, short tests, and concept maps to identify misconceptions. She did not mention conceptual change approach, analogy, concept map, and conceptual change texts to eliminate students' misconceptions.

In conclusion, Burcu considered cell, nucleus and chromosomal structures such as DNA and chromatin fiber as prerequisite knowledge to learn cell division, whereas she did not mention the basic genetics terms and their relationship with each other as pre-requisite knowledge. Burcu mentioned foreign words of cell division concepts and processes in cell division as difficult points wheras she did not mention the mechanism of genetic transferring that is difficult for students. On the other hand, Burcu was aware of the students' misconceptions regarding cell division. Moreover, Burcu pointed out that sources of misconceptions are textbooks and students lack of knowledge. Although she recognized students' misconceptions, Burcu did not know the ways of identifying and eliminating misconceptions. In the next section, Burcu's understanding of knowledge of assessment is reported.

4.2.2.4. Burcu's Knowledge of Assessment

Results of Burcu's knowledge of assessment were categorized and presented by use of pre-interviews, observations, post-interview questions and teacher documents which are written exams. Burcu's knowledge of dimensions of science learning to assess and knowledge of methods of assessments are presented in this section.

4.2.2.4.1. Burcu's Knowledge of Dimensions of Science Learning to Assess

> I: What do you want to assess in depth when you assess your students' knowledge in terms of cell division topics?
>
> Burcu: We prepare the questions based on objectives because we depend on curriculum. We notice whether objectives were gained when we prepare the questions. [The important thing for students is] to comprehend the knowledge, not to memorize knowledge (pre-interviews).

This question was asked to understand what Burcu assess in science teaching. According to Burcu's response, she notices the assessment of objectives that is curricular obligation. Similar to her answer, she assessed students' understanding about curricular objectives in observations. For example, she assessed the objective that is related with the importance of meiosis for individuals as shown below:

> Burcu: What does crossing over provide?
>
> Student: It provides that people do not look like each other.
>
> Burcu: OK. Then, what is the result of this?
>
> Student: Genetic diversity occurs between individuals of same species (observations).

Moreover, it was revealed Burcu preferred to assess objectives regarding the stages of the cell division and sequence of the events when her written documents were analyzed. For example;

Exam Question 1: Sort letters of the given stages of mitosis from beginning to end of cell division (Written exam- Sorting the events question).

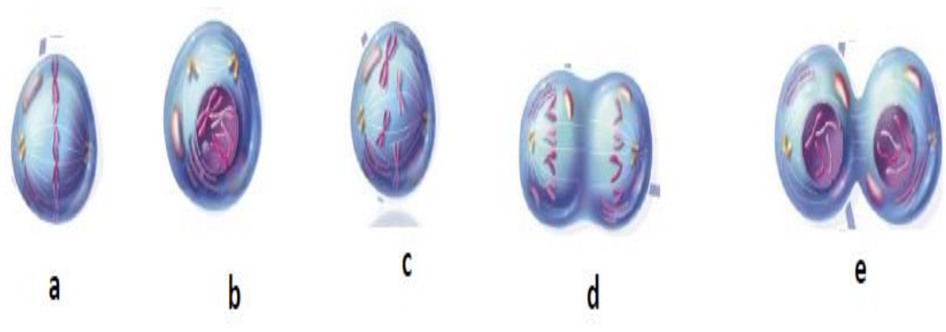

Figure 4.12 Mitosis's Stages Visual from Burcu's written exam

To sum up, Burcu preferred to assess objectives or subject matter knowledge in her cell division teaching. Burcu did not prefer to assess interdisciplinary themes, nature of science knowledge, and problem solving skills in her teaching. Table 4.42 presents Burcu's knowledge of dimensions of science learning to assess.

Table 4.42

Burcu's Knowledge of Dimensions of Science Learning to Assess

Dimension	**Response**
What to Assess	We prepare the questions based on objectives because we depend on curriculum. We notice whether objectives were gained when we prepare the questions. [The important thing for students is] to comprehend the knowledge, not to memorize knowledge (pre-interviews).

4.2.2.4.2. Burcu's Knowledge of Methods of Assessment

Burcu did not assess students based on alternative assessment technics and she preferred to use traditional assessment technics. On the other hand, Burcu had adequate understanding about when to assess students' understandings because Burcu applied both formative assessment technics and summative assessment technics in whole teaching process. Table 4.43 summarizes Burcu's knowledge of methods of assessment.

Table 4.43

Burcu's Knowledge of Methods of Assessment

Dimension	
How to assess?	Only traditional assessment techniques such as multiple choice questions, questioning (open ended and closed ended).
When to assess?	Summative assessment at the end of the unit Formative assessment in whole process

> I: Which assessment techniques do you use when you assess your students regarding cell division?
>
> Burcu: We hold exam and pilot tests including short answer, true-false, matching, and multiple test questions. Each of the students expresses themselves in different test techniques. Some of them are successful in multiple choice questions and some others are successful in open ended questions…Multiple choice questions directly assess result and this is more beneficial for meiosis and mitosis to understand students' learning. Distracters are available in meiosis and mitosis such as asexual reproduction type of lizard and worms…Both lizard and worm get regeneration, but only worms reproduce by regeneration. Multiple choice questions are good to assess this difference. When I ask this question as open ended question, it is sufficient to write worms to get point in this question…Students draw mitosis and meiosis on card board and bring us like poster; however, we do not apply this activity this year because it takes too much time and students do not prepare this project by their own. Thus, school administrations do not let us to make projects such as cell division poster in this year. Projects are not useful when students' parents do the projects. So, I do not use project assignment.

In her explanation, Burcu mentioned traditional techniques such as multiple choice items, short items, matching and open ended questions. Burcu also mentioned alternative assessment techniques which are poster and project assignments.

However, Burcu said that she would not use these alternative methods because of two reasons. First reason was that students do not produce projects and their parents do it. Second reason was principles of administration of school. Because of doing projects require much time, school principals do not let teachers to assign students for projects such as posters.

During observations, Burcu did not use alternative ways of assessment consistent with her explanation in pre-interviews. Burcu preferred to use questioning in her teaching that is traditional. When Burcu's written exam was explored, she preferred to use traditional assessment techniques such as short answer, multiple choice questions, matching and true-false questions. Some examples of the exam questions were presented below.

- (…) Mitosis provides growth and development in uni-cellular organisms and reproduction in multi-cellular organisms (Sample item of true-false question).

- Match the organisms and their reproduction types which are presented below (Sample item of matching question gathered from Burcu's test).

A) Budding	1. Earth Worm
B) Simple Division	2. Hydra
C) Regeneration	3. Amebae
D) Vegetative Reproduction	4. Euglena

- Chromosome number halves in ………… division (Sample item of short answer question)

- What are the differences between mitosis and meiosis? Write at least 5 differences. (Sample item of open ended question).

In conclusion, Burcu only preferred to use traditional assessment techniques in her teaching.

I: When do you assess your students regarding cell division?

Burcu: We always assess them [students]. We need to assess always because they construct their misconceptions during the lesson. I always assess their understandings to identify their [students'] misconceptions. The aim is to understand students' misconceptions, the points that students have difficulties and to what extent they [students] learn the content. At the beginning of the lesson, we assess their [students'] prerequisite knowledge regarding as cell knowledge. At the end of the lesson, I ask a question that comprehends whole lesson objectives to repeat the content and to understand what extent they gain the objectives of that lesson (pre-interviews).

Burcu considered that she always assesses students in her teaching to eliminate students' possible misconceptions. Moreover, she pointed out assessing students' pre-requisite knowledge at the beginning of the lesson. Furthermore, Burcu reported that she asked a question involving the objective of that lesson to understand whether that lesson was efficient or not. Similar to her interview results, Burcu preferred to use formative assessment in whole process of teaching by questioning during observations. Some examples of the Burcu's formative assessments through the questioning were provided below:

At the beginning of the lesson (Burcu asked the questions at the beginning of the lesson to evoke students regarding previous content).

Burcu: If ovarian cell undergo meiosis, how many cells do produce after meiosis?

Student: 4 cells form. 3 of them die and 1 of them live.

Burcu: What does not happen again in meiosis-2?

Student: Chromosomes do not replicate them again.

In the middle of the lesson (Burcu asked questions to identify students' misconceptions).

Burcu: What is the function of crossing over?

Student: It provides that human beings do not look like each other.

Burcu: What happens as a result of this?

Student: Genetic diversity occurs

Burcu: What does asexual reproduction depend on?

Student: It depends on mitosis.

Burcu: What is the function of mitosis?

Student: Cell divides in two. Two cells which have same traits produce (observation).

Similar to her answer in pre-interviews Burcu preferred to ask a comprehensive question at the end of the each lesson to determine whether they reached to objectives. For example; Burcu asked students to explain the differences between meiosis and mitosis after she finished the cell division unit. Burcu's formative assessments included both factual knowledge (closed ended questions) and procedural knowledge (open ended). Regarding summative assessment, Burcu applied a written test at the end of the unit. To sum up, Burcu was knowledgeable about when to assess her students in cell division topics. In other words, Burcu used both formative assessment and summative assessment in her teaching.

In conclusion, Burcu only assessed students' conceptual understanding. Moreover, Burcu used traditional assessment techniques and she did not use alternative assessment technics. On the other hand, Burcu used formative and summative assessment technics properly regarding when she assesses her students. In the next section, Burcu's knowledge of instructional strategies are reported.

4.2.2.5. Burcu's Knowledge of Instructional Strategies

Burcu's knowledge of instructional strategies are categorized and reported in this section. Knowledge of subject specific strategies and knowledge of topic specific strategies were resulted to understand Burcu's knowledge of instructional strategies. Knowledge of activities and knowledge of representation represents Burcu's knowledge of topic specific strategies.

4.2.2.5.1. Burcu's Knowledge of Subject Specific Strategies

Although Burcu mentioned both teacher centered and student centered strategies in pre-interviews, she preferred to use teacher centered instructions due to contextual factors and grade level in her teaching. Moreover, past experiences let her to use direct instructions. (See table 4.44 for Burcu's knowledge of subject specific strategies.)

Table 4.44

Burcu's Knowledge of Subject Specific Strategies

Dimension	
Subject Specific Strategies	Direct instruction and questioning
The reasons of why Burcu chose these strategies	Contextual Factors Students' Grade Level

> I: When you teach science concept in general, which teaching method, strategy and technic do you prefer to use?
>
> Burcu: I may have a robust content knowledge, but presenting this information is more important. If I cannot present this information, content knowledge is meaningless. Each topic has its own strategy or methods. So, you have to use different strategies for different topics. There are some topics which should be taught in direct instruction. Other topics can be taught in experimenting or demonstration.
>
> I: Why do you prefer to choose these methods, strategy and technics?
>
> Burcu: I am happy when I transfer this knowledge when I get feedback from students about their learning, and when they are motivated. Because of my past experiences were at cram school we preferred direct instruction at most. Sometimes, we prefer constructivist based strategies such as drama and role playing in lower grades. We prefer constructivism in private schools. Students have to conduct experiment, but laboratory facilities should be sufficient for this. If we have time, I will conduct experiment in this year (pre-interviews).

Burcu mentioned both teacher centered strategies such as direct instructions, experimenting, and demonstration and constructivist based strategies such as drama. Burcu was also aware that a robust content knowledge does not guarantee for adequate teaching. She was also informed about teaching is topic-specific. In another word, Burcu explained that each topic is taught in different ways to the learners.

On the other hand, Burcu did not use constructivist based strategies in her teaching during observations. Direct instruction and questioning dominated her teaching. Burcu also did not conduct experiment during observations. When researcher asked Burcu why she did not conduct experiment in teaching, she pointed out insufficient equipment of laboratory as contextual factors in post-interviews. For example; microscopes did not reach the school laboratory in first unit. Although Burcu could be aware of both teacher centered and student centered strategies, she only used teacher centered strategies in her teaching because of contextual factors such as laboratory facilities. Moreover, students' grade level also affected her teaching because she explained that they prefer drama that is student centered in lower grade levels. She implied that they prefer teacher centered strategies for higher grade levels such as 8th grades.

4.2.2.5.2. Burcu's Knowledge of Topic Specific Strategies

Data regarding Burcu's topic specific strategies were collected by use of pre-interviews, observations and post-interviews. Results about knowledge of activities and knowledge of representations sub-components of topic specific strategies were categorized and presented.

4.2.2.5.2.1. Burcu's Knowledge of Representations

Burcu's representations regarding representations were showing visuals, drawing figures, giving examples, and models to facilitate students' understandings. Although Burcu pointed out many comparison in her teaching and pre-interviews, these comparisons did not reach the analogy strategy. Table 4.45 presents Burcu's knowledge of representations regarding cell division.

Table 4.45

Burcu's Knowledge of Representation

Representation Types	**Specific Examples**
Illustrations	
Showing visuals (photo, video etc.)	Burcu showed many visuals regarding mitosis, meiosis, sexual reproduction and asexual reproduction.
Drawing figure	Burcu drew many figure to show mitosis and meiosis process.
Examples	Burcu gave several examples about mitosis and its daily life interaction such as recovery of injury.
Models	
Hand models	Burcu mentioned a model to show mitosis and meiosis. Burcu got 2 board markers each of which represents a chromosome. Then, Burcu got 2 additional board markers to show duplication of chromosomes. Then, she showed each stages of mitosis through this model.
Comparisons/Metaphor/Analogy	Compared chromosome to scarf Compared separation of chromosome to fishing. Compared growth of uni-cellular organism to inflation of balloon.

I: Do you use illustrations, examples, models, drawings, and analogues to assist students' learning cell division topics and concepts? If yes, what are these representations and can you give examples of these representations? If no, why do not you use illustrations, examples, models, drawings, and analogues?

Burcu: I compare chromosomes to the scarf. I gave mitosis examples such as injuries and their recovery in daily life. I draw on boards regarding cell division. I also use visuals to show mitosis and meiosis.

Burcu explained her knowledge of representations based on scarf comparison as analogy, daily life examples regarding mitosis, drawing figures and showing visuals regarding cell divisions. During observations, Burcu showed many illustrations. For example; Burcu showed a video regarding mitosis. In this video, students did role playing activity. Each student represented a chromosome and they acted mitosis in school garden. Then Burcu showed another video regarding the stages of meiosis from internet. Moreover, Burcu used presentation in her teaching and there were numerous numbers of visuals to show cell division topics.

Apart from showing visuals Burcu drew many figures regarding cell division topics. Some examples of the figures are presented below. For example; Burcu drew examples of different organisms that reproduce asexually.

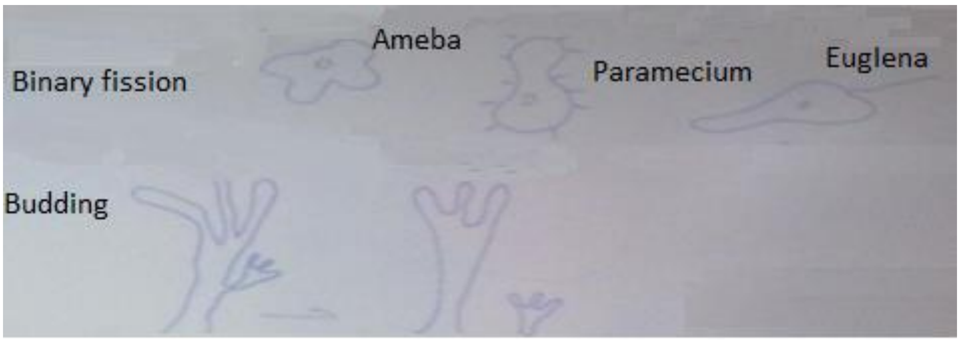

Figure 4.13 Burcu's Drawings of Examples of Different Types of Asexual Reproduction

When she wanted to show the differences between sister chromatids and homologous chromosomes, Burcu drew the figure below representing sister chromatids and homologous chromosomes.

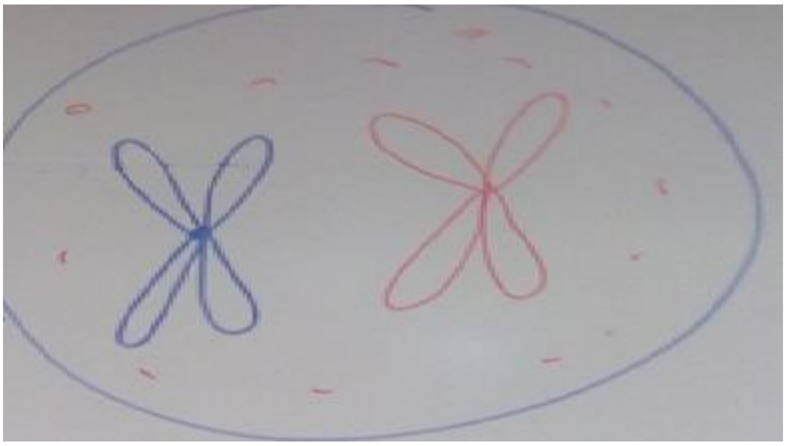

Figure 4.14 Burcu's Drawing of Sister Chromatids and Homolog Chromosomes

When Burcu showed how crossing over occurs between non-sister chromatids of homolog chromosomes, Burcu drew the figure below representing non-sister chromatids and homologous chromosomes.

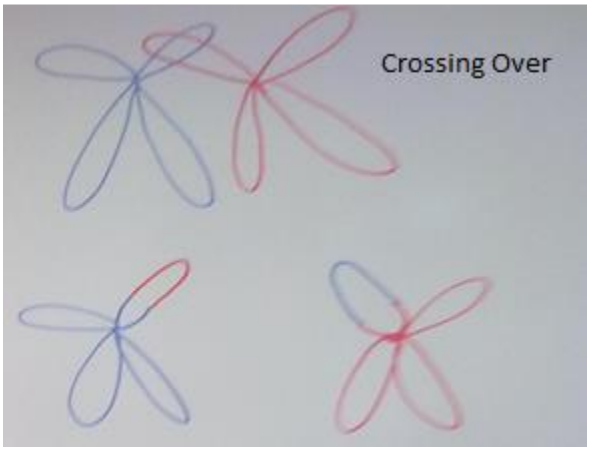

Figure 4.15 Burcu's Drawings of Crossing Over

Burcu not only drew sister chromatids, homologous chromosomes and crossing over, Burcu also drew the processes of mitosis and meiosis. Sample figure that was drawn by Burcu is provided below.

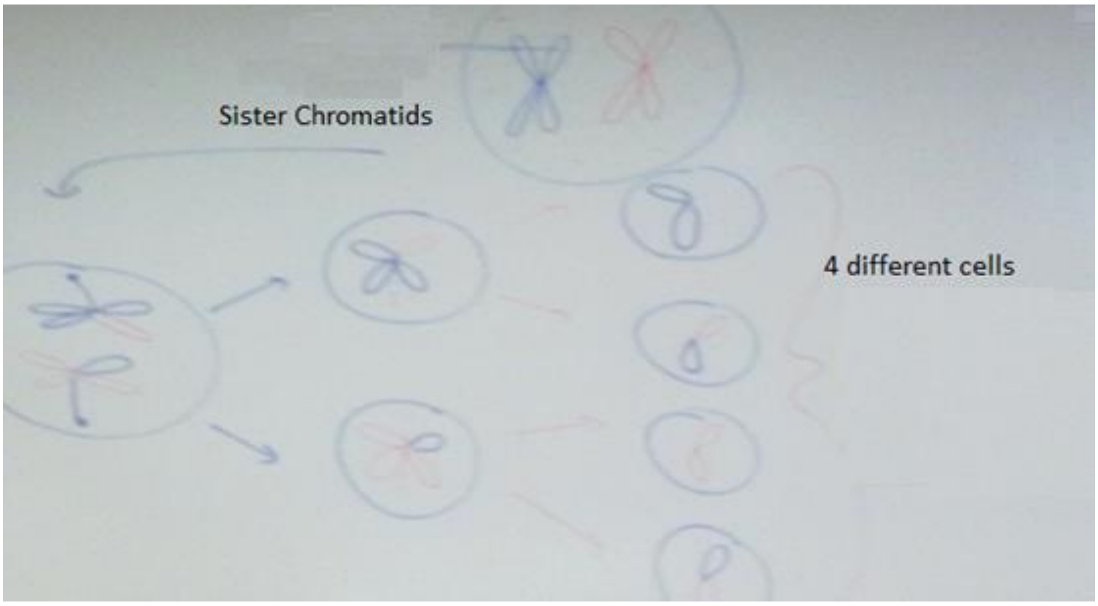

Figure 4.16 Burcu's Drawings of Meiosis

Burcu pointed out many examples such as daily life examples and different types of asexual reproductions. Moreover, Burcu considered the different types of cells which undergo mitosis such as cheek cell and liver cell. The examples that Burcu mentioned in observations are sorted below:

Examples about cells that do not undergo: Burcu said that neurons, egg cells, retina, and sperms cells are the examples of cells that do not undergo mitosis.

Examples about the organisms that undergo mitosis: Burcu said that human beings undergo mitosis for growing and recovery.

Examples about organisms that reproduce by vegetative reproduction: Burcu said that plants reproduce both sexually and asexually. She added that rose and poplar are the two examples of the plants that reproduce asexually.

Examples about organisms that reproduce by binary fission: Burcu said that amebae, paramecium, euglena, and bacteria are the examples of organisms that reproduce by binary fission.

Examples of gametes: Burcu said that pollen and egg cells are the examples of plant cells which are gametes. She added that sperm and egg cells are the examples of human beings' cells which are gametes.

Moreover, Burcu used board markers to show students how cells undergo mitosis. Stated differently, Burcu used a model to facilitate students' understandings of mitosis process. First of all, Burcu took one black board marker and one red board marker. She said that board markers represent chromosomes. She said that lets our original cell includes two chromosomes (2n=2 chromosomes) (See figure 4.17)

Figure 4.17 Model Representing Original cell (2n=2 chromosomes).

After that Burcu said that DNA replicates itself and so chromosome number is duplicated before cell division starts. Burcu added that these duplicated chromosomes arrange in equatorial plane implying metaphase (See figure 4.18 for chromosomes arrangement in equatorial plate.)

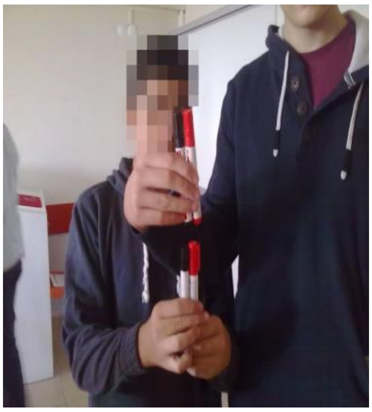

Figure 4.18 Model Representing Chromosomes' arrangement in equatorial plane

Later, Burcu explained that these chromosomes arranged in equatorial plane are separated and moves to different poles implying anaphase. (See figure 4.19 for separation of sister chromatids.)

Figure 4.19 Model that represent separation of sister chromatids

Burcu explained that after sister chromatids are separated new cells are formed. Then she resulted that there are two new cells at the end of mitosis process.

She added that these two cells are copies of each other and original cell. She said that although new cells are same regarding genetic information (2n=2) that they carry; they are smaller than original cell in size. Figure 4.20 represents two new cells formed as a result of mitosis.

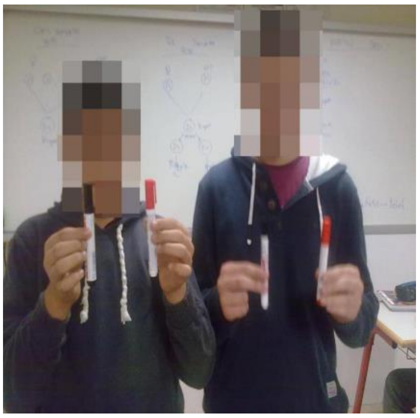

Figure 4.20 Model representing two new cells produced after mitosis

Burcu also used many comparisons in her teaching during observations; however, these comparisons did not extend to analogy because Burcu did not say the breaking points, similarities and limitations between concepts. Some examples of the comparisons that Burcu used in her teaching are as follows:

- There are chromosomes serve a function in cell division. These chromosomes compare to scarf. Before we knit this scarf (chromosome), we have rope. This rope likes to chromatin fiber.

Target Concept	Familiar Concept
Chromosome	Scarf
Chromatin Fiber	Rope

- Centrosomes produce spindle fibers that attach in chromosomes. After this attachment chromatids of attached chromosomes are separated and move to different poles. This process likes to fishing activity.

Target Concept	Familiar Concept
Separation of sister chromatids	Fishing activity
Centrosome	Fisherman
Spindle Fiber	Fishing Line
Sister Chromatids	Fish

- When showing Amebae as an example of organism that reproduce by binary fission, she said that amebae likes omelet. (See figure 4.21)

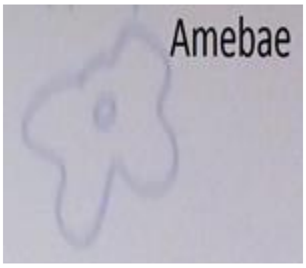

Figure 4.21 Burcu's Amebae drawing similar to omelet

- Uni-cellular organisms do not undergo mitosis when they grow because mitosis provides reproduction in uni-cellular organisms. Uni-cellular organisms grow like inflation of balloons.

Target Concept	Familiar Concept
Growth of Uni-cellular organism	Inflation of Balloon
Uni-cellular organism	Balloon

4.2.2.5.2.2. Burcu's Knowledge of Activities

Burcu did not conduct activities regarding cell division. Although Burcu aimed to conduct an experiment about yeasts' division by budding, she could not conduct this experiment because of lack of equipment. Burcu's knowledge of activities regarding cell division is presented in the table 4.46.

Table 4.46

Knowledge of Activities of Burcu

Types of Activity	
Experiments	Because of lack of laboratory equipment Burcu did not conduct experiment
Activities found in text book and exercise book	Because of textbook and exercise book were distributed at the end of unit, Burcu did not conduct activities found in textbook and exercise book.

I: Do you conduct activities in class regarding cell division? If you conduct, what are these activities?

Burcu: We use the activities found in exercise book. I use visuals in mitosis and meiosis. There is no so much experiment. I use models that represent chromosomes more than other activities. At first, I present the knowledge. When I started to teach mitosis, I prefer to use board markers as models. Then I show video for students to grasp knowledge.

I: What are the activities that you conduct when you specifically teach mitosis?

Burcu: I show mitosis via board marker models and animations. We explore yeast reproduction on microscope.

I: What are the activities that you conduct when you specifically teach the role of chromosomes in cell division?

Burcu: I use models that I mentioned earlier. Direct instruction and questioning are two technic that we use most.

I: What are the activities that you conduct when you specifically teach asexual reproduction?

Burcu: Direct instruction and questioning.

I: What are the activities that you conduct when you specifically teach meiosis?

Burcu: I use same with mitosis. I use direct instruction, questioning, showing models, and showing visuals.

I: What are the activities that you conduct when you specifically teach crossing over?

Burcu: I use model. I exchange the covers of board marker to show crossing over. I also show visuals.

I: What are the activities that you conduct when you specifically teach the differences between mitosis and meiosis?

Burcu: I compare them. First I tell mitosis, and then I tell meiosis. I draw them on board one by one. I use visuals too. I also use my model example.

Burcu pointed out that she preferred to use representations rather than activities in this lesson; hence she could not give specific example of activities regarding cell divisions. Observation results were similar to her pre-interview results, Burcu consider on knowledge of representations in her teaching rather than activities. Direct instruction and questioning dominated Burcu's course in cell division unit. She also used her power point presentation and internet actively during teaching. To get more information, researcher asked specific questions about sub-topics of the cell division.

Burcu did not conduct reproduction of yeast experiment in observations. Then, researcher asked Burcu why she did not conduct this experiment during post interviews. Burcu said that lack of equipment in school cause them not to conduct this experiment.

> I: Although you said that you conduct an experiment based on reproduction of yeast by budding, you did not conduct this experiment during observations. Can you explain why you did not conduct this experiment in your teaching?
>
> Burcu: Because of lack of laboratory equipment. I wanted to conduct that experiment; however, microscope did not reach school. Hence, I could not conduct this experiment (post-interviews).

Similar to lack of laboratory equipment, Burcu did not conduct activities found in exercise book and textbook because their school did not distribute the textbook in first unit. Burcu reported that school administrations distributed the textbook at the end of the first unit and she said that she started to use exercise book in second unit.

> I: Although you said that you actively use exercise book and textbook in pre-interviews. You did not use these curricular materials during observations. Can you explain the reason of discrepancy occurred between pre-interviews and observations?
>
> Burcu: Textbooks and activity book has recently reached us at the end of the first unit [cell division]. Hence, we could not conduct the activities found in textbook (post-interviews).

In conclusion, Burcu used teacher centered strategies in her class as subject specific strategies. Burcu used visuals and her drawings as illustrations, gave examples about topics, showed model by using board markers and used simple analogies in her lesson. Although she used a wide range of representations, Burcu did not use wide range of activities. Burcu did not conduct activities found in textbook and exercise book. Similarly; she did not conduct asexual reproduction experiment due to absence of microscopes in school laboratory. In this part, Burcu's case was reported and Ahmet's case is reported in next section.

4.3. CASE 3: Ahmet's Content Knowledge and Pedagogical Content Knowledge regarding Cell Division

4.3.1. Ahmet's Content Knowledge

Ahmet's content knowledge which includes syntactic knowledge (i.e. Nature of Science) and substantive knowledge is presented. First, findings regarding syntactic knowledge were presented.

4.3.1.1 Ahmet's Syntactic Knowledge

Interview results reveled that Ahmet had no informed views on any one of the NOS aspects. On the other hand, Ahmet had adequate views on three NOS aspects which are empirical NOS, inferential NOS, and imaginative and creative NOS. Ahmet, however, had inadequate views on four NOS aspects which are tentative NOS, socio cultural NOS, subjective NOS and functions of theories and laws, distinction between theory and laws. Table 4.47 presents Ahmet's understanding of Nature of science aspects.

Table 4.47

Summary Table for Understandings of Ahmet's NOS Aspects:

NOS ASPECT	Sample Excerpts	CATEGORY
Tentative NOS	Scientific knowledge is certain... Laws are proven and they do not change... Cell theory can change based on the new advance on technology...	Inadequate
Theory & Law	Law is proven and does not change; however, theories are not proven… Gravity is a law and it never changes… If we prove theories, [theories] become laws.	Inadequate
Empirical NOS	Experimenting makes science different from other disciplines... Experiment is a process starting with observation to check whether something is true or not.	Adequate
Inferential NOS	Observation is recording data…Observation is something to investigate and look. There is no impact of culture, society and personal differences on observations. Inferences are the information that is close to result. Inferences are based on observations. Inferences are affected by personal life.	Adequate
Imaginative and Creative NOS	Absolutely, science is based on creativity... I think planning stage is more logical to use creativity... Data collection is concrete, thus you need to see and prove. You need to get data.	Adequate

Table 4.47 (cont'd)

NOS ASPECT	Sample Excerpts	CATEGORY
Socio-Cultural	Science is isolated from place and time that it practices... Physics, chemistry, biology and math are value free and are not affected by social values... Science is universal and we use the mobile phones and technology produced by others [foreign countries].	Inadequate
Subjectivity	It is related with imagination. Scientists produce different conclusions. For example; someone says that it is related with volcano eruption and other one may claim meteorite hit. They are all imagination because human beings could not go to events occur before volcano eruption… Results of the experiment are independent from people. Everyone reach the same conclusion, if they conduct the experiment systematically	Inadequate

In the following part, Ahmet's responses to each question of VNOS C were mentioned.

At first, his response to the question that what, in your view, is science? What makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g. religion, philosophy)?" was presented Ahmet's understanding of science.

> I: What, in your view, is science?
>
> Ahmet: Science is the knowledge of facts. We gather this [science] knowledge through the experiments over the time and this knowledge increases over time as scientists prove their experiments.
>
> I: What makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g. religion, philosophy)?
>
> Ahmet: Doing experiments make science different from other disciplines. Science is not affected by person, place and time. Science is systematic and everyone can reach same results if they follow the same procedure

Ahmet thought that science is knowledge of facts and this knowledge increases over time. Development of scientific knowledge is based on experiments according to Ahmet. Ahmet also thought that scientific knowledge is isolated from socio-cultural values and scientists' characteristics. Moreover, Ahmet thought that science is based on systematic experiment. In fact, Ahmet's understanding of science also provided some insight into understand about his understanding of tentative NOS, functions and differences of theories and laws, empirical NOS and socio-cultural NOS will be presented in the next sections.

Ahmet's Understanding of Tentative NOS

> I: After scientists have developed a scientific theory, does the theory ever change?
>
> Ahmet: Cell theory can change based on the new advance on technology... Atomic theory may change in the future because we cannot examine it in detail.

His response revealed his inadequate views on tentative. Although Ahmet did not reveal his views in laws, he claimed that scientific knowledge does not change if it is laws in the question about the differences and functions of theories and laws presented in the next section. Ahmet further claimed that scientific theories change in response to advancement in technology, but he undervalued the factors causing change on scientific knowledge which are reinterpretation of existing theories or changes on scientific knowledge. Ahmet's answer to 'what is science question?' also gives insights about his tentative NOS.

Table 4.48

Ahmet's Sample Statement in Tentative NOS

Tentative NOS	**Category**	**Sample Statement**
After scientists have developed a scientific theory does the theory ever change?	Inadequate	Cell theory can change based on the new advance on technology... Atomic theory may change in the future because we cannot examine it in detail.
What is science?		Science is not affected by person, place and time… Science is the knowledge of facts.

His response to the question regarding the functions and differences of theories and laws, presented below, provided the further evidence about his understanding of the tentative nature of NOS.

Ahmet's Understanding of the Functions and Differences of Theories and Laws

I: Is there a difference between a scientific theory and a scientific law?

Ahmet: Law is proven and does not change; however, theories are not proven… Gravity is a law and it never changes… If we prove theories, [theories] become laws

Question given above clearly explain Ahmet's understanding of functions and differences of theories and laws. Moreover, Ahmet holds with common misconception that is hierarchical relationship between theory and law demonstrating his inadequate views about theories and laws. Ahmet's answer to 'what is science question?' also gives insights about his understandings of theories and laws' functions and differences.

Table 4.49

Ahmet's Sample Statement in the Functions and Differences of Theories and Laws

Theory and Laws aspect NOS	**Category**	**Sample Statement**
Is there a difference between a scientific theory and a scientific law?	Inadequate	Law is proven and does not change; however, theories are not proven… Gravity is a law and it never changes… If we prove theories, [theories] become laws.
What is science?		… Science is systematic and everyone can reach same results if they follow the same procedure

Ahmet's Understanding of Empirical NOS

Following questions were used to assess Ahmet's understanding of empirical NOS:

> I: What is an experiment? Does the development of scientific knowledge require experiments?
> Ahmet: Experiment is a process starting with observation to check whether something is true or not. Experiment is always necessary because we have to verify knowledge that we obtain.

Moreover, Ahmet's answer to "What is science?" and "What makes science different from other disciplines of inquiry?" provided some evidence for Ahmet's empirical NOS. This examination showed that Ahmet's empirical aspect of NOS was adequate because although he realized that experiments are used for verification of scientific knowledge and observation is the part of this process, he did not mention that aim of experiment and observation is to get evidence. Thus, he did not deepen his empirical NOS understanding.

Table 4.50

Ahmet's Sample Statement in Empirical NOS

Empirical NOS	**Category**	**Sample Statement**
What is an experiment?	Adequate	Experiment is a process starting with observation to check whether something is true or not.
Does the development of scientific knowledge require experiments?		Experiment is always necessary because we have to verify knowledge that we obtain
What, in your view, is science? What makes science different from other disciplines of inquiry?		Experimenting makes science different from other disciplines...

Ahmet's Understanding of Inferential NOS

> I: What is observation?
> Ahmet: Observation is recording data based on numerical values, observation is something to investigate and look. There is no impact of culture, society and personal differences on observations.
>
> I: What is inference?
> Ahmet: Inferences are the information which is not certain.
>
> I: What are the differences between observation and inferences?
>
> Ahmet: Inferences are gathered through the observations. Inferences are affected by personal life

Although Ahmet recognized that inferences follows observations, inferences are affected by our personality and observation is a process obtained in scientific research, he could not define the observation as it depends on five senses. Thus, Ahmet had adequate understanding in inferential NOS.

Table 4.51

Ahmet's Sample Statement in Inferential NOS

Inferential NOS	**Category**	**Sample Statement**
What is observation?	Adequate	Observation is recording data based on numerical values, observation is something to investigate and look. There is no impact of culture, society and personal differences on observations.
What is inference?		Inferences are the information that is close to result.
What is the difference between observation and inference?		Inferences are gathered through the observations. Inferences are affected by personal life.

Ahmet's Understanding of Imaginative and Creative NOS

To identify Ahmet's understanding of imaginative and creative NOS, following questions were directed to Ahmet.

I: Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

Ahmet: Absolutely, science is based on creativity... I think it is logical that scientists use their creativity in planning. They do not use it in data collection because data collection is concrete, thus you need to see and prove.

Although recognized the role of creativity, his knowledge that scientists use their creativity in planning stage of scientific research indicated that he had not grasp understanding about imaginative and creative NOS, and so he was categorized in adequate category. Ahmet refused other stages of scientific research about use of creativity and imagination such as data collection because he thought that creativity is only used in abstract stages such as planning.

Table 4.52

Ahmet's Sample Statement in Imaginative and Creative NOS

Imaginative and Creative NOS	**Category**	**Sample Statement**
Scientists perform experiments, investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?	Adequate	Absolutely, science is based on creativity... I think it is logical that scientists use their creativity in planning. They do not use it in data collection because data collection is concrete, thus you need to see and prove.

Ahmet's Understanding of Socio Cultural NOS

> I: If you believe that science reflects social and cultural values explain why and how and if you believe that science is universal, explain why and how.
>
> Ahmet: Science is isolated from place and time that it practices... Physics, chemistry, biology and math are value free and are not affected by social values... Science is universal and we use the mobile phones and technology produced by others [foreign countries].

Ahmet's response revealed that he had inadequate views regarding socio-cultural NOS. Ahmet believed that science is isolated and value free claiming that it is not affected by social norms and it is universal. On the other hand, Ahmet consider on the *communication* aspect of science process skills. Moreover, Ahmet's answer to 'what is science?' questions provided further evidence to grasp his socio-cultural NOS.

Table 4.53

Ahmet's Sample Statement in Socio Cultural NOS

Socio Cultural NOS	**Category**	**Sample Statement**
If you believe that science reflects social and cultural values, explain why and how and If you believe that science is universal, explain why and how.	Inadequate	Science is isolated from place and time that it practices... Physics, chemistry, biology and math are value free and are not affected by social values... Science is universal and we use the mobile phones and technology produced by others
What is science?		Science is not affected by person, place and time

Ahmet's Understanding of Subjective NOS

> I: It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?
>
> Ahmet: It is related with imagination. Scientists produce different conclusions. For example; someone says that it is related with volcano eruption and other one may claim meteorite hit. They are all imagination because human beings could not know events occur before volcano eruption.

In his response, Ahmet mentions the imagination aspect of NOS. However, his last sentence implies that if human beings knew the events before volcano eruption, they would reach the same conclusion. Stated differently, Ahmet pointed out scientists lack of knowledge regarding the events. Moreover, Ahmet's response to 'what is experiment?' question supports this argument. Furthermore, Ahmet did not appreciate scientists' theoretical perspectives, their expertise and their personal differences let them to interpret same data different from each other. Hence, he was labeled in inadequate category.

Table 4.54

Ahmet Sample Statement in Subjective NOS

Subjectivity NOS	Category	Sample Statement
It is believed that about 65 million years ago the dinosaurs became extinct....How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?	Inadequate	It is related with imagination. Scientists produce different conclusions. For example; someone says that it is related with volcano eruption and other one may claim meteorite hit. They are all imagination because human beings could not go to events occur before volcano eruption.
What is experiment?		Results of the experiment are independent from people. Everyone reach the same conclusion, if they conduct the experiment systematically…

In conclusion, Ahmet's nature of science knowledge that is syntactic structures in this study had insufficient knowledge. Specifically, Ahmet held adequate views on inferential NOS, empirical NOS and imaginative and creative NOS; however, Ahmet held inadequate views about tentative NOS, socio-cultural NOS, the functions of and differences of theory and laws, and subjective NOS. Moreover, Ahmet does not hold informed views in none of the seven NOS tenets. In the next section, Ahmet's substantive content knowledge will be presented.

4.3.1.2. Ahmet's Substantive Content Knowledge about Cell Division

In this part, Ahmet's substantive content knowledge regarding cell division is resulted and presented. To better recognize Ahmet's substantive content knowledge about cell division topics, Ahmet's substantive content knowledge was obtained under four dimensions which are basic terms of cell division, cell cycle knowledge, mitosis knowledge and meiosis knowledge.

4.3.1.2.1. Ahmet's Knowledge about Basic Terms about Cell Division

According to conceptual understanding of the knowledge dimension, Ahmet had sound understanding about centrosome, asexual reproduction, sexual reproduction and zygote. On the other hand, his understanding of chromosome, DNA, gene, centriole, somatic cell and gamete were labelled as partial understanding. Ahmet had naive ideas in the concepts regarding size of concepts, homolog chromosome, allele, and sister chromatids. Ahmet did not respond to centromere and kinetochore concepts therefore he was not labelled in these two concepts regarding conceptual understanding.

Alternatively, participants' basic concepts' knowledge was revealed based on the ontological categories, Ahmet was at matter category in concepts as regards chromosome, homolog chromosome, DNA, gene, allele, sister chromatid, centriole, somatic cell and gamete whereas Ahmet was in process category in four concept as regards centrosome, asexual reproduction, sexual reproduction, and zygote. Ahmet's responses which were in matter category correspond to his partial answers in general. Table 4.55 summarizes Ahmet's knowledge of basic concepts about cell division.

Table 4.55

Ahmet's Knowledge of Basic Concepts related with Cell Division

		Conceptual Understanding			**Ontological categorization**	
Concept	**Answer of Ahmet**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Write the items in order of size. Start with the largest	Organism>Cell>Nucleus>Chromosome> DNA>Allele>Gene	❖			-	-
Chromosome	a structure where DNA is found in. It contains genetic material.		❖		❖	
Homolog Chromosome	Pair of chromosomes because homolog means same. These chromosomes are identical.	❖			❖	
DNA	Component of chromosome that is composed of protein.		❖		❖	
Gene	The smallest significant code of chromosome.		❖		❖	
Allele	total number of genes that come from parents. Gene is inherited from one organism while allele is inherited from two organisms.	❖			❖	
Sister Chromatids	form in meiosis. They [Sister Chromatids] are not identical. They [Sister Chromatids] are chromosome that is produced after crossing over.	❖			❖	

Table 4.55 (cont'd)

Concept	Answer of Ahmet	Conceptual Understanding			Ontological categorization	
		Naive	Partial	Sound	Matter	Process
Centrosome	A structure that is unique to animal cell. It plays roles in cell division. It produces spindle fibers.			❖		❖
Centriole	Centrioles are the double structures found in centrosome.		❖		❖	
Asexual Reproduction	Production of a new organism through the mitosis.			❖		❖
Sexual Reproduction	Production of a new organism through meiosis …. formed by fusion of sperm and egg cell.			❖		❖
Somatic Cell	Body cells which are different from gamete.		❖		❖	
Gamete	The common name of germ cell. Egg cell, sperm cell and pollen cell can be examples of gamete.		❖		❖	
Zygote	The structure that is formed after the fertilization of egg and sperm.			❖		❖
Centromere	No answer	-				-
Kinetochore	No answer	-				-

I: There are some concepts regarding cell division which are cell, chromosome, gene, allele, DNA, organism and nucleus. Can you write the items in order of size? Start with the largest.

This question '*size sequence of cell division concepts'* was asked to probe Ahmet's understanding of the relationship between cell, chromosome, gene, DNA, organism, allele and nucleus.

Ahmet sorted decreasing size of concepts as:

"Organism >Cell >Nucleus >Chromosome> DNA >Allele > Gene"

Ahmet's response was correct except the place of allele. Ahmet thought that gene is the smallest one and that DNA found in chromosome and that chromosomes are found in nucleus, he did not recognize that allele is alternate form of gene. Hence he was labeled in naïve category.

I: What is chromosome? and what is the role of chromosome?

Ahmet: Chromosome is a structure where DNA is found in. It contains genetic material.

Ahmet's explanation of chromosome included lack of knowledge, Although Ahmet implied that chromosomes consist of DNA and genetic material, he ignored protein bounds to DNA to form chromosome. Hence, Ahmet had partial understanding of chromosome concept and its role. In his definition, he focused only on the structure of chromosome and ignored the role of chromosome during cell division. His conception of chromosome concepts, therefore, is categorized as matter.

I: What is homolog chromosome?

Ahmet: Homolog chromosomes are pair of chromosomes. Homolog means the same. These chromosomes are identical.

Ahmet's explanation of homolog chromosome indicated his naïve understanding of homolog chromosomes due to the fact that homolog chromosomes contain different alleles and so they are not identical. In his definition, he concentrated only on the structure and ignored the event of the formation of homolog chromosomes and gene sequence that homolog chromosomes have. Ahmet's ontological category, hence, determined as matter.

I: What is DNA?

Ahmet: DNA is a component of chromosome that is composed of protein.

Ahmet's explanation of DNA "DNA is a component of chromosome that is composed of protein." included insufficiency since Ahmet ignore DNA's role in protein synthesis, so Ahmet was partial understanding in DNA concept. Similar to previous concepts, he focused on the structure of DNA rather than its function in protein synthesis. Therefore, Ahmet's ontological category was identified as matter.

I: What is gene?

Ahmet: Gene is the smallest significant code of chromosome.

Ahmet's explanation of gene "gene is the smallest significant code of chromosome." included lack of knowledge that the information about the productive sequence for protein synthesis aspect of gene. Ahmet did not mention the role of genes in cell division as well. In other word, he did not emphasize what genes do, what their functions are and how genes affect our body which is related with process aspect of entity. Accordingly, Ahmet's ontological category was in matter level since Ahmet thought gene as passive particle placed on chromosome.

I: What is allele?

Ahmet: Allele is total number of genes that come from parents. Gene is inherited from one organism while allele is inherited from two organisms.

According to Ahmet, allele is inherited from both of the parents whereas gene is inherited from just one of the parents. This result is similar with his understanding about the relationships of cell division concepts in which question he sorted the size of concepts as allele is bigger than gene. On the other hand, Ahmet could not give scientific explanation of allele that is alternate form of gene. Thus, Ahmet was naïve in allele concept. Ahmet's ontological category was matter regarding allele. The reason for this is Ahmet stands for allele is the passive particle. In addition, Ahmet implies what happens to allele that is another code for matter category.

> I: What is sister chromatids?
>
> Ahmet: Sister Chromatids form in meiosis. They [Sister Chromatids] are not identical. They [Sister Chromatids] are chromosome that is produced after crossing over.

Ahmet's explanation clearly revealed his naïve understanding of the concept of sister chromatids. He failed to realize that sister chromatids are identical and that are seen not only in meiosis but also in mitosis. Moreover, Ahmet's ontological category based on his sister chromatids view was in matter category because Ahmet focused on the chromosomal structure and Ahmet did not explain the process correctly about how sister chromatids form.

> I: What is centrosome?
>
> Ahmet: Centrosome is a structure that is unique to animal cell and its role in cell division is to produce spindle fibers.

Ahmet's explanation of centrosome "Centrosome is a structure that is unique to animal cell and its role in cell division is to produce spindle fibers." is classified as sound understanding. As far as ontological category was considered, his conception of centrosome was in process category because Ahmet stressed the role of centrosome in cell division.

> I: What is centriole?
>
> Ahmet: Centrioles are the double structures found in centrosome.

Although Ahmet had grasp understanding about centrosome, his understanding of centriole concept was insufficient. Ahmet neither provided detail information about the structure nor mentioned about the function of the centriole in cell division that is providing organization of microtubules help organization of microtubules during cell division. Stated differently, Ahmet just mentioned the structure of centriole as a passive particle; and did not consider what centriole does in cell division, as a result his conception of centriole was within the ontological categories of matter.

I: What is asexual reproduction?

Ahmet: Asexual reproduction is the production of a new organism through the mitosis.

I: What is sexual reproduction?

Ahmet: sexual reproduction is to produce new organism that is formed by fusion of sperm and egg cell which are products of meiosis'

Ahmet's explanation of asexual reproduction corresponds to scientific explanation, and therefore labelled as sound understanding. Ontological category was process since Ahmet is aware of the mechanism of asexual reproduction. Similarly, his understanding of sexual reproduction concept which is 'sexual reproduction is to produce new organism that is formed by fusion of sperm and egg cell which are products of meiosis' found as sound. Since he could explain the fertilization process and connect the sexual reproduction to meiosis, thus, categorized whitin the ontological category of process.

I: What is somatic cell?

Ahmet: Somatic cells are body cells which are different from gamete [cell]

Ahmet defined somatic cell as "somatic cells are body cells which are different from gamete [cell]." included lack of knowledge. For example, he neither refer that somatic cells are diploid nor explain how somatic cell is produced. According to this information, he was labelled as partial understanding about somatic cell concept. Ontological category of Ahmet with respect to somatic cell was in matter because Ahmet defined the somatic cell basically as a type of cell and did not mention how it is differed from other type of cell.

I: What is gamete?

Ahmet: The common name of germ cell. Egg cell, sperm cell and pollen cell can be example of gamete

Ahmet's explanation of gamete "the common name of germ cell. Egg cell, sperm cell and pollen cell can be example of gamete."found as inadequate. Although provided specific examples, which is missing in the previous question, he again failed to mentioned that gametes are haploid and did not make any attempt to explain how gametes form and how they fuse to produce zygote. Therefore, his understanding categorized as partial.

In his definition, Ahmet focused only different gamet types; however,he did not explain the processes about how gametes are produced and fuse to produce zygote. Because of Ahmet did not mention how gametes are produced and how they fuse to to produce zygote, Ahmet's ontological category of gamete was in matter.

I: What is zygote?

Ahmet: Zygote is the structure that is formed after the fertilization of egg and sperm.

Ahmet's explanation of zygote "zygote is the structure that is formed after the fertilization of egg and sperm." corresponds to scientific definition of zygote. Therefore, Ahmet had sound understanding in zygote concept. Ontological category of Ahmet regarding zygote was process since Ahmet could stress the fertilization process to form zygote.

Unfortunately, Ahmet could not answer the questions regarding centromere and kinetochore, his conception was labelled as no understanding. His ontological category, however, was not identified. He could not be classified within the any one of the ontological categories.

To summarize, Ahmet had sound understanding in the concepts of centrosome, asexual reproduction, sexual reproduction, zygote that basic terms of cell division. Similarly, ontological category of Ahmet was in matter in general, despite his ontological category was process in four concepts (centrosome, asexual reproduction, sexual reproduction, zygote). Ahmet's basic concepts of knowledge shows that he was both lack of understanding conceptual knowledge and his ontological category was in matter. A grasp understanding of knowledge is prerequisite to teach it (Magnusson et al., 1999) however, Ahmet has not this conceptual understanding about basic terms. Moreover, ontological category of Ahmet was matter in general. Because of Ahmet mostly focused on structure of the concepts ignoring their roles in cell divisions, he could not pass to process category. It should have been in process category to teach science successfully (Chi et al., 1994). Next section reports the Ahmet's understanding of Cell Cycle concept.

4.3.1.2.2. Knowledge of Cell Cycle

Question regarding cell cycle which is what is a cell cycle? Can you identify the stages of cell cycle and describe the principle events characteristic of each was asked to Ahmet to reveal his understanding of cell cycle.

Table 4.56

Ahmet's Knowledge of Cell Cycle

		Conceptual understanding			Ontological categorization	
Concept	**Response**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Cell Cycle definition	The events occurred between formation of a cell and its division resulted with two cell are cell cycle. Interphase, karyokinesis and cytokinesis are the events. Firstly, interphase occurs. Karyokinesis follows interphase and then cytokinesis occur. After that, a new interphase starts when first division is completed.		❖		❖	

I: What is cell cycle?

Ahmet: The events occurred between formation of a cell and its division resulted with two cells are cell cycle.

I: What are the stages of cell cycle?

Ahmet: Interphase, karyokinesis and cytokinesis [are stages of cell cycle].

I: What is the direction of cell cycle?

Ahmet: Firstly, interphase occurs. Karyokinesis follows interphase and then cytokinesis occurs. After that, a new interphase starts when first division is completed.

Although Ahmet could mention the cell cycle, he could not expand his views on the stages of cell cycle. For example, Ahmet was not aware of the S and M stages. On the other hand, he could correctly identify the direction of cell cycle that firstly interphase occurs and karyokinesis and cytokinesis follows interphase. Because of Ahmet did not expand his views about stages of interphase which are G1, S and G2, Ahmet was put under partial understanding regarding cell cycle. Regarding Ahmet's ontological category, he failed to mention what happens in each district stages of cell cycle although he explained the cell cycle process as a sequence of different events which are interphase, karyokinesis and cytokinesis. Because of Ahmet did not consider what happens in each stage, Ahmet was put under matter category about cell cycle.

4.3.1.2.3. Knowledge of Mitosis

To grasp Ahmet's understanding of mitosis, he was invited to define mitosis and then explain the events that occur in each stage of mitosis through drawing. Then, he was asked to mitosis of plants and the differences between mitosis of plant cell and animal cell.

I: What is mitosis?

> Ahmet: Type of cell division that provides asexual reproduction. The function of mitosis is the growth and regeneration in multicellular organisms whereas mitosis provides reproduction of unicellular organisms… Each cell including nucleus can undergo mitosis.

Ahmet was able to recognize that mitosis is the mechanism of asexual reproduction. Ahmet knew the functional differences of mitosis on uni-cellular organisms and multicellular organisms. Moreover, Ahmet claimed that cells need to have nucleus for mitotic division. However, Ahmet did not mention whether cells undergoing mitosis are diploid or haploid. Ahmet also held misconceptions and lack of knowledge about the process of mitosis. Hence, his conceptual understanding was partial and his ontological category was in matter.

> I: Assume that an animal has a diploid chromosome number of four (2n=4). Could you please explain and diagram the mitosis process?

Ahmet explained stages of the mitosis that he drew as follows:

> Nuclear envelope disappears in the first stage prophase and *chromosomes are most visible in this stage* [prophase]… Genetic material is diffused in cell in this [prophase] stage because nuclear envelope disappears…We have two DNA strands that need to be segregated… The aim is to break down nuclear envelope in this stage [prophase]. Centrosomes moves to the poles to pull chromosomes and started to produce spindle fibers… There was one chromosome and there are two chromosomes anymore… Chromosomes were duplicated in interphase. Chromosomes arrive at the equatorial plate in metaphase. Spindle fibers have apparent view in this stage [metaphase]. Spindle fibers pull chromosomes to the poles… The most important characteristic of anaphase is that chromosomes are separated moving to the poles. Nuclei reform in telophase. We show (chromosomes) in X shape. Two new cells are seen like telescope before cytokinesis. The last part is cytokinesis. Amount and number of organelles may be different in new cells but new cells are genetically identical with each other.

Although Ahmet's speech was close to what happens in mitosis, his drawings showed that Ahmet had some erroneous mistakes. Ahmet showed two duplicated chromosomes instead of drawing four unduplicated chromosomes in his drawings. Moreover, Ahmet did not recognize the concept of sister chromatids that is essential for mitosis. Thus, he could not duplicate and segregate sister chromatids in his drawings and explanations. In conclusion, Ahmet could not identfiy the mechanism of mitosis or explanation of process. Although Ahmet could explain the static information found in different stges of mitosis, he was not able to explain whole process, hence he was labelled under matter category regarding mitosis.

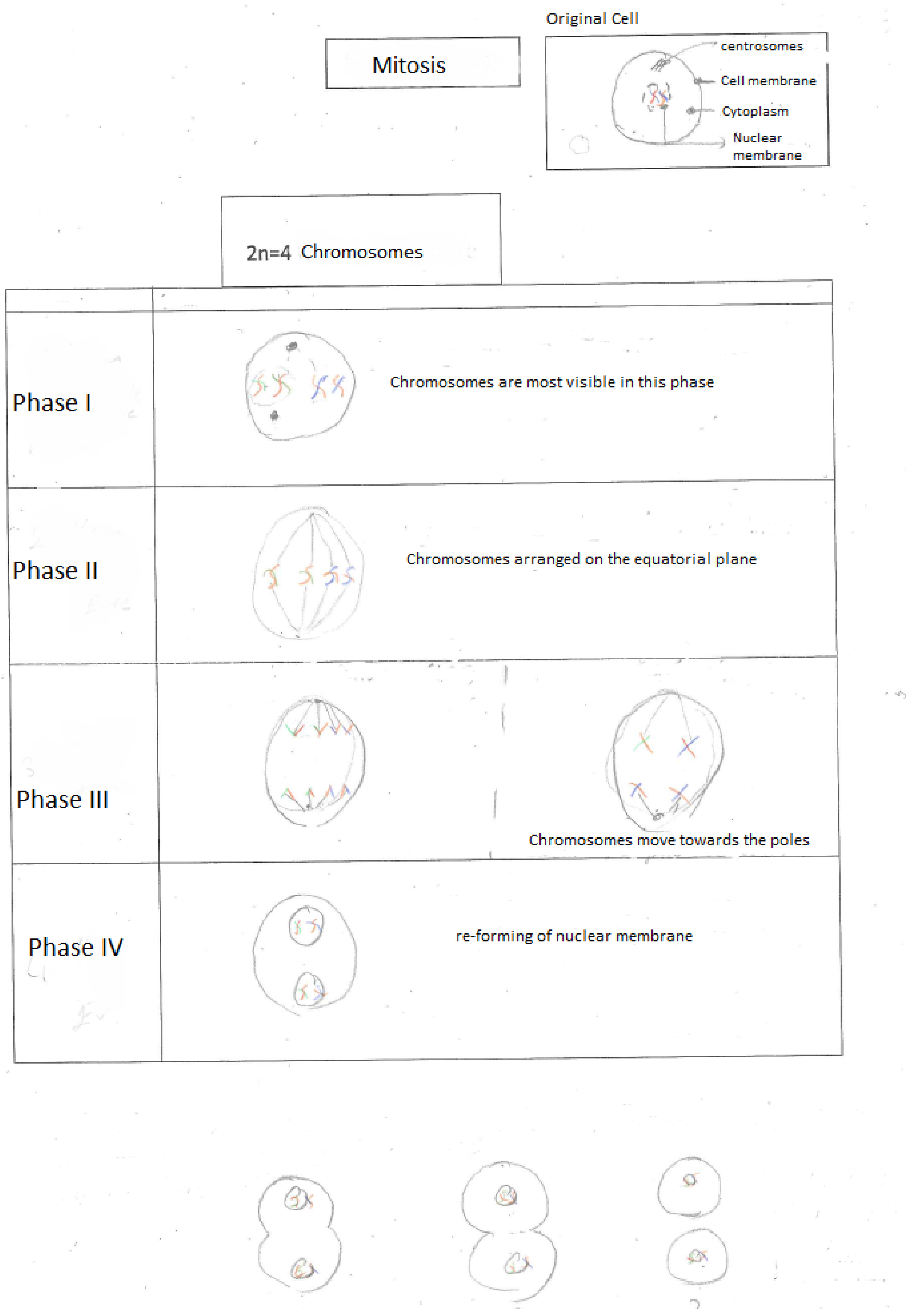

Figure 4.22 Ahmet’s Drawings of Mitosis

Although Ahmet had partial understanding and could not define the mitosis process, he was able to contrasts the mitotic events that occur in plant cells and animal cells:

> I: Do you think that mitosis in plant cells similar to that of animal cell?
>
> Ahmet: If it was plant cell, I needed to draw cell wall. In addition, I need to remove centrosomes for plant cell. Finally, cell plates form in plant cell instead of furrowing in cytokinesis. In plant cell, spindle fibers still exists, but another structure forms it in cytoplasm because plant cell does not include centrosome that produces spindle fibers.

Ahmet could recognize the differences in mitosis between plant cell and animal cell. The differences that Ahmet mentioned were the lack of centrosome in plant cells and existence of cell wall which do not let plant cell to furrow in cytokinesis. Because of Ahmet mentioned the different structures and cause and effect relationship between these structures (thick cell wall do not permit to furrowing), his ontological category was determined as process and he had sound understanding regarding the comparison of mitosis in plant cell and animal cell.

Table 4.57

Ahmet's Knowledge of Mitosis

		Conceptual Understanding			Ontological categorization	
Concept	**Answer of Ahmet**	**Naive**	**Partial**	**Sound**	**Matter**	**Process**
Mitosis Definition and process	Type of cell division that provides asexual reproduction. The function of mitosis is the growth and regeneration in multicellular organisms whereas mitosis provides reproduction of unicellular organisms… Each cell including nucleus can undergo mitosis		❖		❖	
Plant cell's mitosis	If it was plant cell, I needed to draw cell wall. In addition, I need to remove centrosomes for plant cell. Finally, cell plates form in plant cell instead of furrowing in cytokinesis. In plant cell, spindle fibers still exists, but another structure forms it in cytoplasm because plant cell does not include centrosome.			❖		❖

4.3.1.2.4. Knowledge of Meiosis

To clarify his understanding of meiosis, he was expected to define meiosis and then explain the events that occur in each stage of meiosis through drawing. Subsequently, he was asked to meiosis of a plant cell and its differences with meiosis of animal cell.

> I: What is meiosis?
>
> Ahmet: Meiosis is a cell division that aims to produce gametes…Meiosis does not always happen unlike to mitosis… Chromosome number reduces in meiosis and then products of gametes fuse to form zygote… Meiosis finishes with menopause in women and andropause in men. Testicle and ovarian cells undergo meiosis.

Ahmet’s definition of meiosis included lack of knowledge because Ahmet did not mention that meiosis causes genetic diversity. Although his definition had some insufficient knowledge, Ahmet was able to identify gametes are meiosis products and chromosome number reduce in meiosis. Morevoer, he was able to recognize that chromosome number reduce in meiosis. Ahmet also mentioned meiosis role in sexual reproduction and cells that undergo meiosis.

> I: Assume that an animal has a diploid chromosome number of four (2n=4). Could you please explain and diagram the meiosis process?

Ahmet explained his views during her drawing of meiosis diagram as follows:

> This is first stage [prophase-1]. All differences are in this step [prophase-1]. Chromosome number is reduced at the end of meiosis-1. Crossing over occurs in [prophase-1]. Crossing over occurs between two chromosomes. Chromosomes arrange in equatorial plane and spindle fibers are visible in [metaphase-1]. Actually there is no so much difference with mitosis’ metaphase. The main difference occurs in crossing over. Number of chromosomes halve in third stage [anaphase-1]. *Sister chromatids are separated from each other in* [anaphase-1. *I may wrong, I am not sure.* Number of chromosomes reduced from 2n to n. Karyokinesis ends and two cells are formed and then, cytokinesis occurs at the end of meiosis-1. Daughter cells are smaller than original cell [in size]. *Mitosis starts but I don’t know what happens exactly* [mentioning interkinesis]. Nuclear membrane disappeared like mitosis [prophase-2]. *I can say that these chromosomes are homologous* [in meiosis 2].Chromosomes arrange in equatorial plane and spindle fibers form. Chromosomes are pulled to poles.

> Nuclear envelope reformed and two new cells formed after starting of cytokinesis. Two new cells formed from other cell that formed after meiosis-1 which I did not draw. As a result four cells formed. Each of the new cells contains n chromosome.

Similar to his mitosis drawings, Ahmet’s meiosis drawings and explanation of this process included both lack of knowledge and false knowledge. First of all, Ahmet showed two duplicated chromosomes instead of showing four unduplicated chromosomes. Ahmet did not mention sister chromatids, chromatin fiber, homolog chromosomes in his meiosis drawings. The unique concept he mentioned regarding meiosis was ‘crossing over’. Moreover, Ahmet drew two chromosomes at the beginning whereas he was supposed to draw four chromosomes and showed that sister chromatids are not identical. Furthermore, Ahmet did not say that crossing over occurs between homolog chromosomes non-sister chromatids. Later, Ahmet expressed that chromosomes are duplicated and they are named as homolog chromosomes in meiosis-2. Ahmet reported that sister chromatids, crossing over and reduction of chromosome are unique to meiosis ignoring tetrade, synapsis and chiasmata. Moreover, Ahmet did not mention the interkinesis. To sum up, although Ahmet define the meiosis in general he was lack of understanding the meiosis process, hence he had partial understanding and he did not pass to process category.

Although Ahmet could not identify the meiosis process, he was able to contrasts the meiotic events that occur in plant cells and animal cells:

> I: Do you think that meiosis in plant cells similar to that of animal cell?
>
> Ahmet: Plant cells undergo meiosis because it [plant cell] has to produce pollen and egg cell. Similar to mitosis differences, plant cell includes cell wall and it [plant cell] produces cell plate during cytokinesis.

Ahmet was able to clarify that plant cells reproduce sexually and they produce gametes serving to sexual reproduction. Similar to his meiosis response, Ahmet was aware the differences of meiosis between plant cell and animal cell. In conclusion, Ahmet had sound understanding and was in process category regarding meiosis in plants.

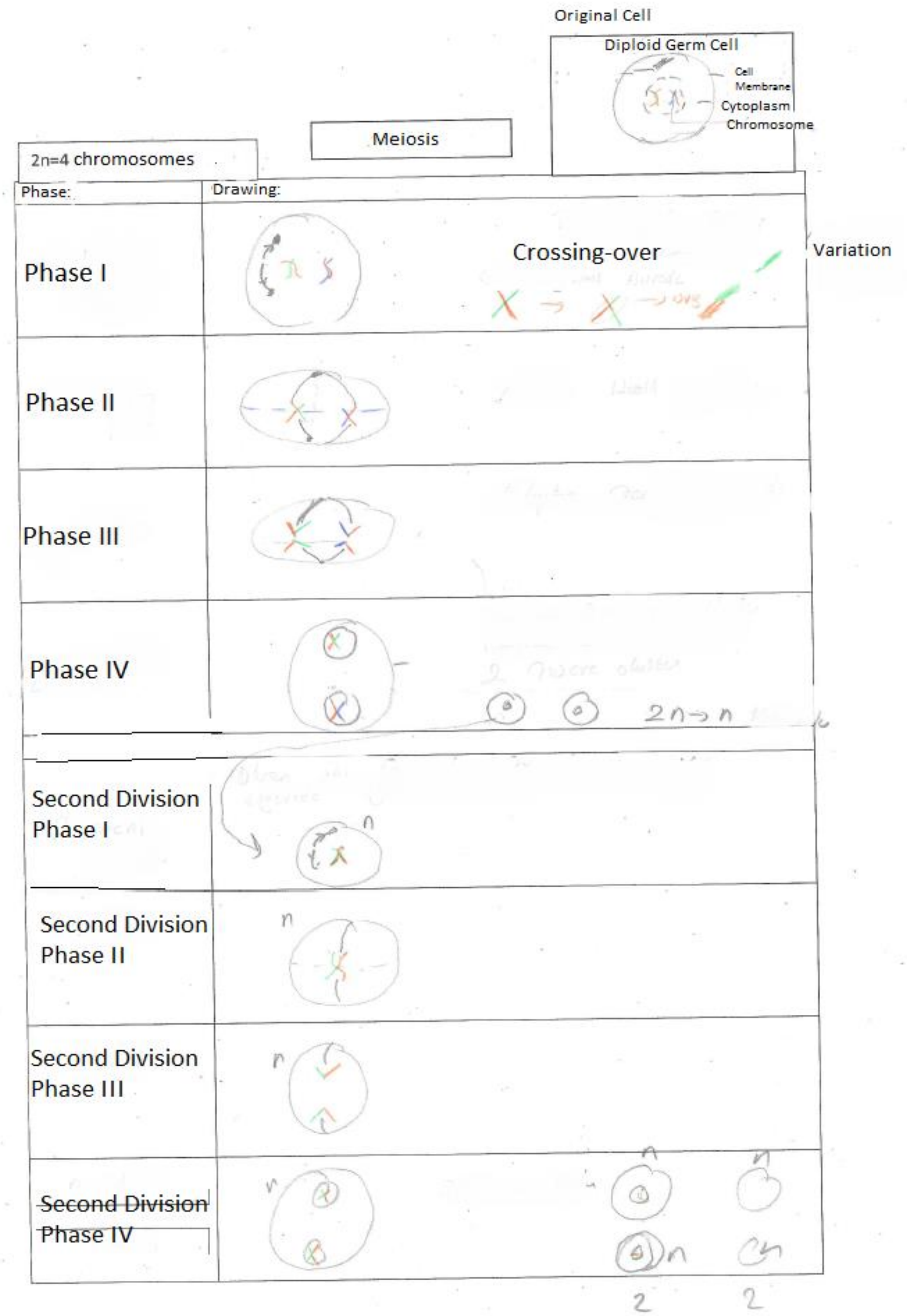

Figure 4.23 Ahmet's Drawings of Meiosis

Ahmet also was able to contrast the differences between mitosis and meiosis in general and he had sound understanding.

> I: What are the differences/similarities between the meiosis and mitosis? Could you explain your answer?
>
> Ahmet: Differences [in meiosis] are crossing over and reduce in number of chromosome. Four cells form at the end of meiosis, but two cells form at the end of mitosis. Because of crossing over, genetic traits change [in meiosis]. However, genetic traits do not change in mitosis. After fertilization of gametes, chromosome number doubles and total number of chromosome for living organisms remain constant. All the cells apart from neurons and erythrocytes can undergo mitosis. Only diploid germ cells undergo meiosis. These diploid germ cells are found in testicle in males and ovarian in females.

Unfortunately, Ahmet did not explain the law of independent assortment that happens in anaphase-1 explaining the relationship between genetics and meiosis when he was asked to draw anaphase-1. Because of he did not respond this question his understanding about the law independent assortment was not categorized for conceptual understanding and ontological category. Table 4.58 summarizes Ahmet's substantive content knowledge regarding meiosis.

In this section, Ahmet's meiosis knowledge was resulted and presented as a part of his substantive content knowledge. Ahmet's pedagogical content knowledge regarding cell division will be presented in next section.

Table 4.58

Ahmet's Knowledge of Meiosis

Concept	Ahmet's Response	Conceptual Understanding			Ontological categorization	
		Naive	**Partial**	**Sound**	**Matter**	**Process**
Meiosis	Meiosis is a cell division that aims to produce gametes…Meiosis does not always happen unlike to mitosis… Chromosome number reduces in meiosis and then products of gametes fuse to form zygote… Meiosis finishes with menopause in women and andropause in men. Testicle and ovarian cells undergo meiosis.		❖		❖	
Meiosis in Plant Cell	Plant cells undergo meiosis because it has to produce pollen and egg cell. Similar to mitosis differences, plant cell includes cell wall and it [plant cell] produces cell plate during cytokinesis.			❖		❖
Meiosis and Mitosis Differences	Differences [in meiosis] are crossing over and reduce in number of chromosome. Four cells form at the end of meiosis, but two cells form at the end of mitosis. Because of crossing over, genetic traits change [in meiosis]. However, genetic traits do not change in mitosis. After fertilization of gametes, chromosome number doubles and total number of chromosome for living organisms remain constant. All the cells apart from neurons and erythrocytes can undergo mitosis. Only diploid germ cells undergo meiosis. These diploid germ cells are found in testicle in males and ovarian in females.			❖		❖

Table 4.58 (cont'd)

Concept	Ahmet's Response	Conceptual Understanding			Ontological categorization	
		Naive	**Partial**	**Sound**	**Matter**	**Process**
Principle that connect genetics and cell division	No idea	-	-	-	-	-

4.3.2. Ahmet's PCK Regarding Cell Division

Ahmet's PCK regarding cell division was gathered by use of PCK pre-interviews, observations, teacher documents such as written exams and post-interview questions. Ahmet's findings about orientation towards science, knowledge of curriculum, knowledge of students' understanding of science, knowledge of assessment, and knowledge of instructional strategies which are five components of Magnusson et al. (1999) model and their subcomponents were presented.

4.3.2.1. Ahmet's Orientation towards Science

Ahmet's beliefs about goals of science teaching were gathered by pre-interview questions, observations and post-interview questions. Ahmet's beliefs about goals of science teaching were presented as central and peripheral goals in general and then these goals were classified as schooling goals, affective goals and subject matter goals.

4.3.2.1.1. Ahmet's Beliefs about Goals of Science Teaching

There were four pre-interview questions asked to reveal Ahmet's beliefs about goals of science teaching in this study. Table 4.59 given below presents Ahmet's beliefs about goals of science teaching based on pre-interviews.

Table 4.59

Beliefs about Goals of Science Teaching (Pre-interviews)

Question	Response	Central Goals	Peripheral Goals
What do you understand about the term “science teaching”?	[Science teaching is] to provide students to understand what happens in their surroundings. [For example] Why do people wear jersey in winter? Students thought that jersey heats up people, however, our body temperature heats up us, jersey does not heat up… Jersey provides heat insulation. At least [students] need to know this information.	Schooling Goals	-
What are the goals of science teaching in your opinion?	By learning their own [students] and their surroundings, students’ life standards increase that is aim of the science teaching.	Schooling Goals	-
As a science teacher, what is the meaning of teaching cell division topics for you?	Teaching cell division is both enjoyable and difficult for me. We teach cell division in macro level.	Affective Goals	-
	When students understand cell division, they [students] understand what growth is, what development is, what recovering is, and understand what living organism is.	Schooling Goals	-

Table 4.59 (cont'd)

Question	**Response**	**Central Goals**	**Peripheral Goals**
Why do you teach cell division topics as a science teacher?	I will give same answer. To recognize living organism and to increase life standards. [Students] know which food they [students] take, what causes them [students] to grow, and what stops growing. Students know that cause of cancer is not a foreign organism coming from out of body, students know that cause of cancer is her/him own cells [dividing unrestrainedly]. Thus, students protect themselves from bad habits such as smoking and drinking alcohols.	Schooling Goals	-

I: What do you understand about the term “science teaching”?

Ahmet: [Science teaching is] to provide students to understand what happens in their surroundings. [For example] Why do people wear jersey in winter? Students thought that jersey heats up people, however, our body temperature heats up us, jersey does not heat up… Jersey provides heat insulation. At least [students] need to know this information.

Ahmet’s understanding to “science teaching” showed that his goal is to make students to understand the connection between science and daily life. Making connection between science and daily life let students be informed citizens according to Ahmet, hence Ahmet emphasized that his central goal was related schooling goals that consider students to prepare life.

I: What are the goals of science teaching in your opinion?

Ahmet: By learning their own [students] and their surroundings, students’ life standards increase that is aim of the science teaching.

Similar to previous question, Ahmet emphasized the importance of schooling goals which prepares students to life. Owing to Ahmet just mentioned one goal as central goal, there was no peripheral goals revealed in his first two answers.

I: As a science teacher, what is the meaning of teaching cell division topics for you?

Ahmet: Teaching cell division is both enjoyable and difficult for me. We teach cell division in macro level. When students understand cell division, they [students] understand what growth is, what development is, what recovering is, and understand what living organism is.

In this question, Ahmet’s beliefs about goals of science teaching were explored based on cell division topics. Ahmet’s beliefs were both affective goals and schooling goals in this question. Because of Ahmet thought that teaching cell division is both enjoyable and difficult, Ahmet had affective goals. On the other hand, Ahmet also tried to connect science and daily life and mentioned learn to think logically which are schooling goals. Ahmet gave priority neither affective goals nor schooling goals, so each of the goals were determined as central goals.

I: Why do you teach cell division topics as a science teacher?

Ahmet: I will give same answer. To recognize living organism and to increase life standard…

I: How do life standards increase?

Ahmet: [Students] know which food they [students] take, what causes them [students] to grow, and what stops growing. Students know that cause of cancer is not a foreign organism coming from out of body, students know that cause of cancer is her/him own cells [dividing unrestrainedly]. Thus, students protect themselves from bad habits such as smoking and drinking alcohols.

In this question, Ahmet's reasons of teaching cell division were questioned. Similar to previous questions, Ahmet's beliefs about goals focused on schooling goals because Ahmet wanted his students to be aware of what happens in their surroundings. To sum up, pre-interviews pointed out that Ahmet's beliefs about goals of science teaching were mostly schooling goals which he wanted to connect daily life and science, and prepare students to life. Ahmet also expected his students to think logically that is another schooling goal. Moreover, Ahmet had affective goals because he believed that teaching cell division is both enjoyable and difficult for him. Because of Ahmet did not sort these goals based on their importance. Each of the beliefs gathered through pre-interviews were assumed as central goals which directly affect teaching decision and practice.

Regarding Ahmet's beliefs about goals of science teaching, further information was gathered through the observations. Moreover, Ahmet's peripheral goals were revealed during observations whilst there was no obvious peripheral goal in pre-interviews. Ahmet focused on High School Entrance Exam in observations, thus he gave priority to preparation of students in High School Entrance Exam. Because of this reason, Ahmet's central goal was schooling goals which he prepared students to high school. On the other hand, Ahmet's peripheral goal was transmitting objectives that are subject matter goal which has little effect on Ahmet's teaching practice and decision.

Although Ahmet focused on connecting daily life and science as schooling goals in pre-interviews, he did not mention connection of science and daily life in observations. This discrepancy was explained by Ahmet during post-interviews.

Ahmet thought that his teaching was sufficient for preparation of high school and so, he implied that the degree of connection between science and daily life in his teaching was enough for this grade level. Table 4.60 given below presents the Ahmet's beliefs about goals of science teaching based on observations.

Table 4.60

Beliefs about Goals of Science Teaching Based on Observations

Observation	**Central Goals**	**Peripheral Goals**
To prepare students to High School	Schooling Goals	-
To transmits curricular Objectives	-	Subject Matter Goals

In conclusion, Ahmet's beliefs about goals of science teaching focused on schooling goals as central goals both in pre-interviews and observations. However, Ahmet's schooling goals differed between interviews and observations. Although his schooling goals were to link science education and real life in pre-interviews, his schooling goals were to prepare students to high school exam in observations. Moreover, Ahmet's peripheral goals were subject matter goals based on the transmission of objectives in observations. Ahmet's knowledge of curriculum is reported in the next section.

4.3.2.2. Ahmet's Knowledge of Curriculum

Knowledge of goals and objectives and knowledge of materials which are two dimensions of knowledge of curriculum were presented. Ahmet's knowledge of curriculum was gathered through the pre-interviews, and observation records.

4.3.2.2.1. Ahmet's Knowledge of Goals and Objectives about Cell Division

Ahmet could explain the place of cell division in curriculum, vertical and horizontal relations in curriculum, cell division objectives, limitations in objectives, and misconceptions cautions in objectives. Moreover, Ahmet could sort the objectives based on their importance. Ahmet also modified textbooks and objectives regarding knowledge of goals and objectives. On the other hand, Ahmet could not explain the reason why cell division place in curriculum. Ahmet was also dependent to curricular materials when he answered student questions. Moreover, Ahmet exceeded the degree of knowledge that is offerred by curriculum.

> I: Why do cell division topics place in curriculum?
>
> Ahmet: Life starts with cell. Cell is the smallest part; the aim is to teach it… Cell division is taught by inductive learning. (Cell division leads) to think human being as whole. Small parts integrate and big parts form (pre-interviews).

First of all, Ahmet answered the question asked in pre-interviews "Why do cell division topics place in curriculum?" This question was asked to understand whether Ahmet knows the reason why cell division place in curriculum. Ahmet thought that this unit is taught due to students' understanding of complex systems such as human body. Ahmet advocated that complex systems are learnt after learning basic units such as cell division because learning occurs inductively in his views. However, Ahmet did not mention that cell division topic place in curriculum to prepare students high school biology topics as an aim of spiral education. Thus, Ahmet was not aware of the reason why cell division placed in curriculum.

I: Do you know the place of cell division in curriculum? In which grade level is cell division taught and what are the topics taught before and after this unit?

Ahmet: Cell division is taught in only 8th grade and this topic is first unit. There is no unit before this unit and force and motion unit follows this unit (pre-interviews).

Secondly, place of cell division unit in curriculum was asked to Ahmet during pre-interviews by the question "Do you know the place of cell division in curriculum? In which grade level is cell division taught and what are the topics taught before and after this unit?" Ahmet answered these questions correctly. He was aware that cell division is taught in 8th grade level and it is the first unit that is taught before force and motion unit.

I: Is there any science topic taught in earlier grades related with cell division?

Ahmet: Reproduction covered in 6th grade and nutrition covered in 5th grade are related with cell division (pre-interviews).

Thirdly, vertical curriculum of cell division was asked to Ahmet during pre-interviews by the question "Is there any science topic taught in earlier grades related with cell division?" Ahmet pointed out reproduction unit in 6th grade level and nutrition unit in 5th grade level as vertical curriculum.

I: Is there any science topic taught in 8th grade level related with cell division?

Ahmet: It could be related with genetics. The concept of cell division gives insight about why eyes and nose are different from each other. It is related with genetic material found in nucleus (pre-interviews).

Next, horizontal curriculum of cell division was asked to Ahmet during pre-interviews by the question "Is there any science topic taught in 8th grade level related with cell division?" Ahmet emphasized on inheritance topics as horizontal relationship with cell division. However, not only inheritance but also evolution topics taught in 8th grade level were related with cell division as horizontal curriculum. Ahmet did not imply evolution topics in his explanation of horizontal relations.

As well as other dimensions of knowledge of goals and objectives, Ahmet's knowledge about objectives of cell division was asked by the question "What are the objectives with respect to cell division found in curriculum?" Ahmet just mention that growth and development of an organism occur through the mitosis and indicated the importance of mitosis during pre-interviews regarding mitosis objectives. On the other hand, Ahmet just noted that gametes are produced by meiosis regarding meiosis objectives. Conversely, Ahmet covered all the objectives regarding cell division during the observations. Hence, he was aware of the objectives about cell division. Ahmet's knowledge about the objectives on cell division is presented in Table 4.61.

Table 4.61

Ahmet's Understanding of Cell Division Objectives

2006 Objectives Stated in Science Curriculum for Cell Division Topic	**Does teacher answer meet the curriculum objective? (Interviews)**		**Does teacher answer meet the curriculum objective? (Observations)**	
	Yes	No	Yes	No
Explain that growth and development occurs through the cell division.	❖		❖	
Define Mitosis as process starting with karyokinesis and including stages following each other.		❖	❖	
Be aware the importance of chromosomes in mitosis and refer that different species can have different number of chromosomes.		❖	❖	
Indicate the importance of mitosis for living organisms and relate mitosis with growth and reproduction.	❖		❖	
Deduce that gametes are produced in meiosis.	❖		❖	
Be Aware of the importance of meiosis for living organisms.		❖	❖	
List the differences between meiosis and mitosis.		❖	❖	

> I: Could you sort the objectives based on their importance?
>
> Ahmet: If I want my students to be successful in High School Entrance Exam, objectives about showing the events from a visual, recognizing the cell division type form a model, and description of cell divisions are more important than others. These three steps are important. (pre-interviews).

Sorting the objectives was another dimension of knowledge of goals and objectives. Thus, Ahmet was asked whether he sorts the objectives based on their importance during pre-interviews. Ahmet emphasized that showing the events of cell division from drawn figure, recognizing the events from models and objectives about the definition of processes are more important than other objectives because these objectives are asked in High School Entrance Exam more than other objectives. As a result, Ahmet sorted the objectives and justified his answer based on students' High School Entrance Exam achievement.

> I: Is there any important points to be emphasized for you apart from existing objectives?
>
> Ahmet: As a teacher, I want my students to understand how and why mitosis occurs and what the functions of cell division are. Student needs to ask himself why and how questions… Although meiosis should immediately come after mitosis in curricula, Mendel's genetics and DNA is taught after mitosis. Students forget what happens in mitosis when we teach inheritance. When we return to another cell division, meiosis, I have to teach mitosis one more time to compare mitosis and meiosis (pre-interviews).

Further, modifications of textbook and objectives are another aspect of knowledge of goals and objectives. Ahmet was asked in pre-interviews that "Is there any important points to be emphasized for you apart from existing objectives?" Ahmet focused on the processes and reasons of events for cell division as important points. For example; Ahmet thought that it should be emphasized that why cell divides, and how DNA replicates itself. Ahmet also added some modifications on the textbook that meiosis should be taught just after mitosis and inheritance should be removed from between mitosis and meiosis because students forget the mitosis after inheritance and Ahmet has to tell mitosis one more time before he passes to meiosis to compare mitosis and meiosis. In conclusion, Ahmet offered alternative objectives and modify textbooks.

Then, Ahmet's understanding about the limitations mentioned in curriculum regarding cell division was assessed through the question "Is there any limitations implied in curriculum regarding cell division?" during pre-interviews. Moreover, this knowledge was questioned through the observations. Ahmet was aware that names of the stages are not mentioned in their teaching based on pre-interviews. However, he did not mention crossing over limitation. Moreover, he did not mention the limitation that "Differences of the stages of meiosis and stages of the mitosis are not mentioned" during pre-interviews. On the other hand, Ahmet noticed all the limitations stated in curriculum during observations. In fact, his presentation included the names of the stages when he taught the stages of cell division. Ahmet said that: "These are the names of stages, but you don't need to know these stages." He also said his students that they would use Turkish name of the "crossing over" and wanted his students not to use this word. To sum up, Ahmet was aware in understanding about the limitations mentioned in curriculum regarding cell division. Table 4.62 summarizes Ahmet's understanding about the limitations mentioned in curriculum regarding cell division.

Table 4.62

Ahmet's Understanding of Cell Division Limitations

2006 Limitations Stated in Science Curriculum for Cell Division Topics	**Does teacher answer meet limitation? (Interviews)**		**Does teacher answer meet limitation? (Observations)**	
	Yes	No	Yes	No
Names and properties of stages of mitosis are not mentioned.	❖		❖	
Names of the stages of meiosis are not mentioned and Turkish name of crossing over (Parça Değişimi) is used.		❖	❖	
Differences of the stages of meiosis and stages of the mitosis are not mentioned.		❖	❖	

Later, Ahmet’s understanding about the misconception mentioned in curriculum regarding cell division was assessed through the question “Is there any misconception implied in curriculum regarding cell division?” during pre-interviews. Researcher also considered whether Ahmet knows the misconception warning found in curriculum through the observations. Although Ahmet did not mention the misconception that “There is a direct proportion between the number of chromosomes of an organism and organism’s size or organism’s complexity.”, he gave an example that different species may have same number of chromosomes and this does not mean species are same in his presentation. To sum up, Ahmet could know that the misconception mentioned in curriculum regarding cell division. Table 4.63 summarizes Ahmet’s understanding about the misconception mentioned in curriculum regarding cell division.

Table 4.63

Ahmet’s Understanding of Cell Division Misconception

2006 Misconception Stated in Science Curriculum for Cell Division Topics	**Does teacher answer the misconception? (Interviews)**		**Does teacher answer the misconception? (Observations)**	
	Yes	No	Yes	No
There is a direct proportion between the size and complexity of organism and the number of chromosome.		❖	❖	

Afterwards, dependence to curricular material is another aspect of knowledge of goals and objectives. Ahmet’s dependence to curricular materials was gathered through the observations. Ahmet was dependent to his presentation that he prepared during his teaching. When students asked questions, he got assistance from related slide. He also used the information found in presentation without any change.

Finally, Ahmet’s understanding about the degree of knowledge that is offered by curriculum was gathered through the observations. Ahmet exceeded the degree of knowledge regarding cell division many times and he gave advance knowledge in his teaching. Some examples that Ahmet exceeded the degree of knowledge as presented below:

> When strawberry touches the ground, a new strawberry plant is produced. Therefore, strawberry plant is not cultivated in straight ground. If strawberry is planted in straight ground, it consumes energy to form root of new plant. However, we want plant to consume its energy to produce fruit, not to produce root. (Observation: Advance knowledge on asexual reproduction).

> Flat worms reproduce by regeneration however, you should cut it proportionally. If you cut randomly, it does not reproduce… Earth worms have red nodule. If you cut from this nodule earth warm reproduces. All worms' heads and ends can replace. (Observation: Advance knowledge on asexual reproduction).

> Ahmet taught the terms tetrad and chiasmata which are topics of high-school biology curriculum. Ahmet showed synapsis as chiasmata that are wrong, similarly Ahmet showed centromere as synapsis that was also wrong information. (Observer Comment)

4.3.2.2.2. Ahmet's Knowledge of Materials

Ahmet mentioned two sources specifically that he uses in cell division teaching which internet and science magazines are. Other sources that he mentioned were generalizable to all science topics and they were not specific to cell division. Moreover, he used the high school biology textbook during observations. Table 4.64 represents Ahmet's knowledge of materials.

Table 4.64

Knowledge of Materials

Sources that teacher use that make teaching easier	**Aim of using selected sources**
Internet	I use internet, but I confirm this information found in internet with books. I collect photos from foreign websites.
Science Magazines	I read national science magazines such as Bilim- Teknik (Science &Technique) regarding cell division. I learned about cell division from Bilim Teknik, but I do not transfer this knowledge to the students because this knowledge can be advance level.
High School Biology Textbook	I have a high school biology textbook old edition. Meiosis is covered in this book, and I mentioned genetic engineering based on the information in this book… When I teach meiosis using this book, I can easily show that meiosis and mitosis are different from each other

I: What are the sources that you use in cell division topics?

Ahmet: I use teacher guidebook very much because I learn constraints of what I teach. I use test books to prepare students to exam. We ask similar questions to exam questions. I use internet, but I confirm this information found in internet with books. I collect photos from foreign websites. I read national science magazines such as Bilim Teknik (Science &Technique) regarding cell division. I learned about cell division from Bilim Teknik, but I do not transfer this knowledge to the students because this knowledge can be advance level. I use course books to prepare myself before lesson. I use exercise book to recall new learning. I use university book when I forget knowledge or learn new things or advance knowledge (pre-interviews).

Sources that Ahmet used in his teaching about cell division were university biology textbook, course textbook, exercise textbook, test book, teacher guide book, internet, science magazines. Although Ahmet mentioned seven sources that he used, he gave specific examples about cell division just in two sources which are internet and science magazines. Ahmet said that he uses internet to get photo about cell division from foreign websites. In addition, Ahmet said that he reads science magazines to inform about cell division and he does not transfer this knowledge to his students because this knowledge is advance level for students.

Then, Ahmet explained aim of the use of sources. Why he uses university book is to learn for himself. He also uses course book to prepare him for teaching. Ahmet uses exercises book that teacher recall their understandings. Because of there is a High School Entrance Exam in Turkey, he gets students to solve multiple choice tests to prepare students to exam. He uses teacher guide books to understand limitations and the degree of content in curriculum. He uses internet to collect photos about cell division from foreign websites. Also, he used science magazines to understand the content for his own learning.

During observations Ahmet used high school biology textbook and he taught the concepts from this book. The concepts were synapsis, kinetochore and tetrade which exceed the curriculum. Researcher asked Ahmet why he used high school biology book in his teaching. Ahmet answered that he used the biology books to show different concepts found in meiosis. He claimed that students would understand the differences between meiosis and mitosis easier. Some excerpt about why he used high school biology text book was presented below:

> I have a high school biology textbook old edition. Meiosis is covered in this book, and I mentioned genetic engineering based on the information in this book… When I teach meiosis using this book, I can easily show that meiosis and mitosis are different from each other (post-interviews).

In conclusion, Ahmet did not recognize why cell division placed in curriculum. Ahmet also gave advance level knowledge violating curriculum. Moreover, he was dependent to sources in his teaching. Regarding knowledge of materials Ahmet used high-school biology book and did not use textbook or exercise book actively. On the other hand, Ahmet was aware the place of cell division in curriculum. Ahmet could connect verticular and horizontal relations about cell division. Ahmet was also aware the curricular objectives, limitation objective and misconception warning objectives regarding cell division. In the next section, Ahmet's knowledge of students' understandings is reported.

4.3.2.3. Ahmet's Knowledge of Students' Understanding of Science

Ahmet's understanding of this component was revealed by analysis of two sub-components which are knowledge of requirements for learning and knowledge of students' difficulties.

4.3.2.3.1. Ahmet's Knowledge of Requirements for Learning regarding Cell Division

> I: What prior knowledge should students have to understand cell division topic?
>
> Ahmet: [Students need to know] cytoplasm, mitochondria, ribosome, and nucleus to learn cell division. Students who can draw cell model can easily comprehend cell division (pre-interviews).

Ahmet pointed out organelles and cell topic as necessary to understand cell division. However, Ahmet did not refer chromosomal structure and chromosome movement as prerequisite knowledge to understand cell division. Moreover, Ahmet did not mention basic genetics terms as prerequisite knowledge to understand cell division.

4.3.2.3.2. Ahmet's Knowledge of Students' Difficulties regarding Cell Division

Ahmet was aware that the misconceptions which students hold about cell division, sources of misconceptions, the points that students have difficulty and reasons of students' difficulties. On the other hand, Ahmet had inadequate understanding about the identification and remediation of misconceptions regarding cell division.

> I: Which points do your students have difficulty in understanding cell division topics, in your opinion?
>
> Ahmet: Cell division of plants are not understood because textbook did not mention this, we cover this based on animal cell division. They have difficulty on understanding cytokinesis because they compare cytokinesis to mitosis and they think cytokinesis has different stages. They have also difficulties on the understanding of formation of cell plate (pre-interviews).

Firstly, points that students have difficulty were assessed by the question asked in pre-interviews "Which points do your students have difficulty in understanding cell division topics, in your opinion?" In his answer, Ahmet mentioned cell division of plants, cytokinesis and formation of cell plate in plants' cell division. Ahmet did not mention any students' difficulties regarding mechanisms such as mechanism of genetic transferring and concepts related with cell divisions such as homolog chromosomes, and alleles. Ahmet focused on the examples of processes that occur in cell division as difficult points.

> I: What are the reasons of students' difficulties regarding cell division?
>
> Ahmet: Reasons are that: there are very few numbers of Turkish sources regarding cell division and original sources are foreign sources… National Education should send us audiovisual materials. For example, there can be a pool and we get these materials from these pools. In addition, I want to show reproduction of yeast experiment but I have no tool to show this or students

are noisy during experiment. Moreover, students think that making experiment is very difficult and complex procedure (pre-interviews).

Secondly, reasons of the students' difficulties were asked to Ahmet by the question "What are the reasons of students' difficulties regarding cell division?" in pre-interviews. Ahmet underscored lack of availability of Turkish sources, the lack of material, classroom management problems and students' bias towards science. Ahmet did not mention the reasons of students' difficulties about nature of cell division such as abstract nature of cell division, its difficult terminology, detailed procedure of cell division and unseen structure of cell division (micro level).

I: What are the students' misconceptions regarding cell division?

Ahmet: Students think that cell always divides, and cell division takes a long time. They understand that after a cell divides, two new cells forms but they could not understand that these new cells can divides too after they become mature. They think that new cells share content of cytoplasm equally after division. They think that original cell exists after mitosis and there are 3 cells anymore. They think that number of chromosome reduces at the end of meiosis-2. They think that DNA is duplicated after division starts (pre-interviews).

Ahmet revealed many students' misconceptions regarding cell division most of which overlaps the misconceptions in literature during interviews.

During observations, Ahmet found two additional misconceptions which are related with different asexual reproduction types and fertilization. To sum up, Ahmet was knowledgeable about students' misconceptions regarding cell division. Two additional misconceptions that Ahmet mentioned in observations are presented below.

Ahmet: You think that yeast reproduce by dividing; however it reproduces by budding (Asexual reproduction misconception- Observation)

One of the students thought that she was the egg cell produced after meiosis, and then Ahmet told her that she was the integration of sperm and egg cell not the egg cell (fertilization misconception- Observer comment)

I: What are the sources of students' misconceptions regarding cell division?

> Ahmet: They are learning cell division first time, they are not familiar with terms and they are afraid of learning these topics… Figures are too small; for example, centrosomes are not seen in textbook figure. Similarly, DNA seems like line in textbook's figure. They may not infer DNA in that figure. Sometimes, teacher can be source, we make speech defect. Daily life also affects; when I say division word, some students think it like to break something (pre-interviews).

Later, Ahmet expressed that students are not familiar with cell division topics, so they develop misconceptions. Figures in textbook are not visible so students can not learn meaningfully according to Ahmet. Ahmet also mentioned that teacher can be source of misconception because he sometimes gives false knowledge unwittingly. Ahmet also referred to use of daily life language as causing misconception such as 'division' words. All the sources of misconceptions are congruent with the sources of misconceptions found in literature that Ahmet mentioned.

> I: How do you identify students' misconceptions regarding cell division?
>
> Ahmet: I want them to draw figures in exams. The words and figures they used in exam make me aware of their misconceptions. I also compare student's answers to different questions that measure the same objectives. For example, student gives correct answer to true false, but he gives different answers to test question. I also want students to make presentation, but their parents react negatively to this situation. They think that I am expected to teach topic. In addition, time is limited to let students make presentations… I also get students to write question and answer. You can understand misconception when you look what they write… I make quizzes (pre-interviews).

Afterwards, Ahmet's understanding of identification and remediation of misconception was assessed by two questions asked in pre-interviews "How do you identify students' misconceptions regarding cell division?" and "What are the teaching strategies that you used to eliminate students misconceptions?". Moreover, field notes of observations were used to understand how Ahmet identify and eliminate misconceptions. Ahmet claimed that he identifies students' misconceptions by quizzes, exams and assignments as drawing figure or writing assignment. Ahmet did not mention concept mapping, discussions, short tests and two tier diagnostic tests. On the other hand, Ahmet did not make quizzes in his teaching and he said that he did not test quizzes because it was the first unit and he did not want to frighten students (post interviews).

> I: What are the teaching strategies that you used to eliminate students misconceptions?
>
> Ahmet: I call students to my room after exam and ask them what they want to write in their exam sheet. If misconception is common, I repeat the topic again in class. I warn the students who answer wrongly one by one (pre-interviews).

Ahmet explained that he eliminates students' misconceptions by face to face interaction and explaining the topic. Ahmet did not point out conceptual change approach, analogy, refutational texts, and concept map during interviews and observations as a way of eliminating misconceptions. To sum up, Ahmet was not aware the way of identifying and eliminating misconceptions regarding cell division based on interviews and observations.

In conclusion, Ahmet mentioned cell topic is prerequisite for students' to understand cell division topics and Ahmet did not mention the chromosomal movement and the basic genetic concept as pre-requisite to learn cell division. Ahmet focused on processes which are difficult to understand, however he ignored the mechanisms of cell division and the concepts of cell division as difficulties for students. Ahmet did not mention abstract nature, terminology and complex structure of cell division as sources of difficulty. On the other hand, Ahmet recognized the misconceptions and their sources about cell division whereas he did not identify and remediate students' misconceptions. Ahmet's knowledge of assessment are reported in next section.

4.3.2.4. Ahmet's Knowledge of Assessment

Ahmet's knowledge of assessment was gathered through the pre-interview questions, observation records, post-interview questions and teacher documents which are written exams. Sub-components of knowledge of assessment which are knowledge of dimensions of science learning to assess and knowledge of methods of assessment were resulted and presented in this section.

4.3.2.4.1. Ahmet's Knowledge of Dimensions of Science Learning to Assess

> I: What do you want to assess in depth when you assess your students' knowledge in terms of cell division topics?
>
> Ahmet: Our priority is to assess National Education objectives and High School Entrance Exam because students' parents want their children to be successful in High School Entrance Exam (pre-interviews).

Ahmet underscored the objectives found in curriculum as what he assesses in cell division because of his concerns about High School Entrance Exam. Ahmet ignored the assessment of interdisciplinary themes such as genetics and cell division relation, nature of science knowledge about cell division, science process skills about students' lab performance, and problem solving skills in terms of cell division.

Similar to his pre-interview results analysis of exam questions expressed that Ahmet just focus on curricular objectives. Some examples that Ahmet assessed students' conceptual understanding in exam are presented.

- 5^{th} multiple choice item question assess students' knowledge about the misconception found in curriculum.
- 2^{nd} multiple choice item question assess the objective regarding the relationship between asexual reproduction and mitosis.

To sum up, Ahmet just assessed students' conceptual understandings and ignore other knowledge types which are interdisciplinary themes, nature of science, problem solving skills, and science process skills. Table 4.65 summarizes Ahmet's knowledge of dimensions of science learning to assess.

Table 4.65

Ahmet's Knowledge of Dimensions of Science Learning to Assess

Dimension	**Response**
What to Assess?	Our priority is to assess National Education objectives and High School Entrance Exam because students' parents want their children to be successful in High School Entrance Exam

4.3.2.4.2. Ahmet's Knowledge of Methods of Assessment

Ahmet used only traditional assessment techniques and did not use alternative assessment techniques. Similarly, Ahmet's formative assessment was fragmented because he preferred ask questions at the beginning of the lesson just for informing students. On the other hand, he ignored formative assessments during the lesson and at the end of the lesson. Thus, Ahmet could not identify, eliminate misconceptions and he did not provide sufficient feedbacks to students. Table 4.66 summarizes Ahmet's knowledge of methods of assessment.

Table 4.66

Ahmet's Knowledge of Methods of Assessment

Dimension	
How to assess?	Only traditional assessment techniques such as multiple choice questions, questioning (closed ended). He did not use drama as alternative assessment because of limited time caused by High school Entrance Exam.
When to assess?	Summative assessment at the end of the unit Formative assessment at the beginning of the lesson

> I: Which assessment techniques do you use when you assess your students regarding cell division?
>
> Ahmet: Written exams, observations in class that students' participation…Multiple-choice, short answer, figure drawing, true-false, and short essay questions are part of written exam… They present their performance; each group of students told me different stages of cell division and they modeled this. Each of the students became an organelle in cell division and they acted like theatre (role playing)… I don't prefer project assessment because this is first unit and student get anxiety if I give them project assignment in first unit. Even I give this assignment; there is no worthwhile project that students do. I don't use peer assessment because they are affected by their friends. I have never used self-evaluation. I do quizzes after chapter including 5-6 questions (pre-interviews).

Ahmet mentioned written exams including multiple choice questions, short answer, figure drawing, true-false, and short essay questions, class observations, drama and quizzes regarding cell division. According to his answer he mostly used traditional assessment techniques which are written exams, observations and quizzes. The only alternative assessment technique he referred was drama.

During observations, Ahmet did not use drama technique as an assessment technique although he mentioned this technique during pre-interviews. He just used traditional techniques during observations. Ahmet pointed out change of schedule of High School Entrance Exam, private school pressure and parent pressure to explain why he did not get students to perform drama. Sample excerpt about Ahmet's explanation of why he removed drama activity is presented below.

> I did not [get students perform drama] because High School Entrance Exam was on June last year. I had so much time to compensate time loss; however, this year exam was conducted on 28-29 November. We focused on content in first unit; it gradually turns to activity base anymore. Parents made pressure on us that they asked whether topics would be covered until the exam and private education centers covered the topic very fast. In addition, some schools finished the topics and they repeated the topic. So, I needed to be fast in my teaching. Moreover, parent pressure and administer pressure cause to pass the activities. The most important factor is parents. They compare their own education in past and today's education. They think that transmission of knowledge is the best way for their kids to learn. They think activities as waste of time (post-interviews).

It was also asked Ahmet why he did not prefer other assessment techniques in his teaching during post interviews. Ahmet underlined the deficiency of his knowledge to apply alternative assessment techniques. Sample excerpt that Ahmet's explanation of why he did not use alternative assessment techniques are presented below.

> I don't know how to use them. I use others that I know better. If National Education informs and teaches us about alternative ways of assessment, it will be better. They taught us to hold an examination, but they didn't teach us about how to asses and grade these exams (pre-interviews).

To sum up, Ahmet only used traditional assessment techniques and did not use alternative assessment techniques.

> I: When do you assess your students regarding cell division?
>
> Ahmet: I hold exam after unit... I ask 3-4 questions at the beginning of the lesson to inform students about topics. (Pre-interviews).

Regarding formative and summative assessment techniques, Ahmet focused on exams at the end of unit as summative assessment and questioning at the beginning of the lesson as formative assessment to provoke students learning. During observations, Ahmet used questioning as formative assessment at the beginning of the lesson. However, questions that he asked were closed ended (assessed factual knowledge) and questions assessing higher cognitive level were not used. Stated differently, Ahmet questions assessed knowledge level which recalls the knowledge according to Bloom's Taxonomy. Moreover, he did not use formative assessments in the middle of the lesson, so he did not identify students' misconceptions and did not eliminate them during lesson. Similarly he did not give emergent feedback. Some examples of Ahmet's questioning as formative assessment are presented below.

> Ahmet: What is the name of diploid germ cell that produces sperms?
>
> Student: Testicle cell
>
> Ahmet: What is the aim of the mitosis?

> Student: Growth and developments, it provides reproduction in uni-cellular organisms (Observation- at the beginning of the lesson).

Ahmet also claimed that he does not prefer to ask questions at the end of the lesson in cell division unit because this is the first unit and students feel exam pressure in first unit if questions are asked in cell division unit lessons' ends. Because of this reason, Ahmet said that he was the supporter of asking provoking questions at the beginning of the topic in first units.

Regarding summative assessments, Ahmet held an examination at the end of the unit. This exam included traditional techniques which are Multiple-Choice items (First part of the exam including fifteen questions), True-False questions (Second part of the exam including fifteen questions), Short Answer (Third part of the exam including five questions), and Short Essay questions (Fourth part of the exam including two questions).

In conclusion, Ahmet had some problems in knowledge of assessments because Ahmet only preferred to assess students' conceptual understanding regarding the knowledge of dimension of science learning ignoring the assessment of interdisciplinary themes, nature of science, science process skills. Moreover, Ahmet preferred to use traditional assessment technics because of his lack of knowledge in alternative assessment technics. Similarly, he had problems in time of assessments. His formative assessments were fragmented because he did not assess students' learning in the middle of the lesson and at the end of the course. Ahmet's knowledge of instructional strategies is reported in next section.

4.3.2.5. Ahmet's Knowledge of Instructional Strategies

Ahmet's Knowledge of instructional strategies was gathered through pre-interviews, observations and post-interviews. Results of the sub-components of knowledge of instructional strategies which are knowledge of subject specific strategies and knowledge of topics specific strategies (knowledge of activities and knowledge of representations) were presented in this section.

4.3.2.5.1. Ahmet's Knowledge of Subject Specific Strategies

Ahmet preferred to use teacher centered approaches such as lecturing and he did not use student centered strategies in terms of learning cycle, argumentation, and conceptual change approach. Table 4.67 summarizes Ahmet's knowledge of subject specific strategies.

Table 4.67

Ahmet's Knowledge of Subject Specific Strategies

Dimension	
Subject Specific Strategies	Lecturing, watching video and reading book which are didactic strategies
The reason of why Ahmet chose these strategies	Lack of knowledge about student centered strategies Limited time for High School Entrance Exam

> I: When you teach science concept in general, which teaching method, strategy and technic do you prefer to use?
>
> Ahmet: Students are active at the beginning of the lesson. They say their own ideas which can be correct or wrong. I listen to them, then I tell the lesson and make an order in topic. I get them watch video and read book in the first unit. I get them to read book because there are some new students and old students. By reading book, they become friends (pre-interviews).

Ahmet explained the subject specific strategies that he teaches as lecturing, watching video and reading book which are didactic strategies during pre-interviews. Similar to his pre-interviews, Ahmet adopted direct instruction strategies during observations.

> I: Why do you prefer to choose these methods, strategy and technics?
>
> Ahmet: I do not know how to use 5E Learning Cycle and Conceptual change approach… It is related with High School Entrance Exam, we do direct instruction in this year because of exam… Exam time was close, so we passed activity (post-interviews).

Then, Ahmet clarified why he just used direct instruction in his teaching. There were mainly two reasons why he preferred to use direct instruction. First reason was he did not know the alternative methods for teaching. Second reason was the change of High School Entrance Exam schedules in an earlier time that shape Ahmet's subject specific strategies.

4.3.2.5.2. Ahmet's Knowledge of Topic Specific Strategies

Knowledge of topic specific strategies was reported under two dimensions in terms of Ahmet's knowledge of representations and Ahmet's knowledge of activities. Firstly, Ahmet's knowledge of representations regarding cell division was reported and then results of Ahmet's knowledge of activities about cell division are presented.

4.3.2.5.2.1. Ahmet's Knowledge of Representations

Ahmet used visuals as illustrations, but he did not draw figures for cell division topics. Ahmet did some comparisons in his teaching and he gave many examples during his teaching. Table 4.68 summarizes Ahmet's knowledge of representations regarding cell division.

Table 4.68

Ahmet's Knowledge of Representation

Representation Types	**Specific Examples**
Illustrations Showing visuals (photo, video etc.)	Ahmet showed many visuals when he taught asexual reproduction, genetics terms, differences of plant mitosis and animal mitosis, stages of mitosis, and life cycle of an organism.
Examples	Ahmet gave several examples about mitosis and its daily life interaction. Ahmet gave examples of different organisms that produce by different types of asexual reproductions. Ahmet also exemplified which cells undergo meiosis in his teaching.
Comparisons/Metaphor/Analogy	Ahmet used these comparisons when he taught asexual reproduction about budding. Moreover, Ahmet mentioned that he makes comparison regarding duplication of chromosomes in interphase.

> I: Do you use illustrations, examples, models, drawings, and analogues to assist students' learning cell division topics and concepts? If yes, what are these representations and can you give examples of these representations? If no, why do not you use illustrations, examples, models, drawings, and analogues?
>
> Ahmet: I use visuals and presentations actively through the smart board. I find some videos from internet showing that cell is dividing. I show the photos that are taken from electron microscope about different stages of cell division (pre-interviews).

During pre-interviews, Ahmet focused on illustrations as representation of cell division topics. Ahmet clarified that presentations, videos taken from internet and slides of cell division's different stages were the representations that Ahmet used.

Similar to pre-interview results Ahmet showed many visuals when he taught asexual reproduction, genetics terms, differences of plant mitosis and animal mitosis, stages of mitosis, and life cycle of an organism. Ahmet did not draw any figures regarding cell division topics during observations.

- ❖ Ahmet showed the genetics terms' visuals which are chromosome, DNA, sister chromatids and homologues chromosomes.
- ❖ Ahmet showed the visual about differences of animal mitosis and plant mitosis
- ❖ Ahmet showed the stages of mitosis as visuals (observation reports)

Apart from illustrations, Ahmet used some comparisons to increase students' understandings in his teaching. However, the analogies he used were simple analogy, and he did not consider the breaking points, similarities and difference. Moreover, Ahmet mentioned that he makes comparison regarding duplication of chromosomes in interphase during pre-interviews. Examples of Ahmet's comparisons regarding asexual reproduction and duplication of chromosomes are presented below:

- Ahmet: Asexual reproduction by budding compares to fractals that you learnt in math. For example, corals reproduce asexually by budding (observation).

Target Concept	Familiar Concept
Budding	Fractals

- Ahmet: I make a comparison to teach duplication of chromosomes saying that duplication of chromosomes is similar that your mother gets cake recipe from your neighbor. Then, she makes cake based on this recipe. At the end there are two cakes, one of them made by neighbor, and one of them made by your mother. (pre-interviews)

Target Concept	Familiar Concept
Chromosome	Cake
Duplication of chromosome	Making same cake using same recipe

Ahmet's representations were not limited with illustrations and analogies; Ahmet gave several examples about mitosis and its daily life interaction. Some of the examples that Ahmet explained in his lesson is provided below.

- For example; Ahmet said that food adulteration means that there are many bacteria that produce by mitosis causing bad odor.
- Ahmet also gave examples of different organisms that produce by different types of asexual reproductions such as corals and sea stars. Ahmet also exemplified which cells undergo meiosis in his teaching.
- Examples of organisms which are reproduce by binary fission; amebae, euglena, paramecium.
- Examples of organisms that reproduce by vegetative reproduction; strawberry, mandarin, orange, melon and rose.

In the next section, Ahmet's knowledge of activities are reported.

4.3.2.5.2.2. Ahmet’s Knowledge of Activities

Ahmet claimed that he has not so many activities in cell division topics because of exam pressure on. On the other hand, Ahmet preferred or planned to conduct some activities regarding subtopics of cell division. Specifically, Ahmet preferred problem solving about mitosis. Ahmet preferred to use direct instruction in teaching the role of chromosomes in cell division. Ahmet focused on problem solving and experimenting to teach asexual reproduction; however, he just conducted problem solving activity and he passed experiment activity due to exam pressure. Ahmet preferred to use direct instruction and read the slides that he prepared for teaching meiosis and sexual reproduction. Ahmet also used direct instruction to show differences between mitosis and meiosis. Ahmet’s knowledge of activities regarding cell division is presented in the table 4.69.

Table 4.69

Knowledge of Activities

Types of Activity	**Specific Examples**
Problem Solving Activity	I ask them bread is molding, how can you decrease the mold? (pre-interviews). Ahmet: Suppose that a bacterium divides one time per each 20 minutes. How many divisions does a bacterium divide in a day? (Observations).
Experiments	(Not conducted) I assign them to experiment germination of potato in mitosis. We could not do this experiment. Exam time was close, so we passed that activity (post-interviews).
Role playing Activity	(Not conducted) I let students present their performance in crossing over in previous years. Girls would go to one side and boys would go to other side, then they would cross each other that represent crossing over… We did direct instruction this year because of exam (pre-interviews).

I: Do you conduct activities in class regarding cell division? If you conduct, what are these activities?

Ahmet: I have not so many activities because of this is the first unit. However, if I have time, I let students do activities. I let them to do activities such as matching exercises found in exercise book (pre-interviews).

I: What are the activities that you conduct when you specifically teach mitosis?

Ahmet: I assign them problem solving activity as homework at the end of topic. For example; I ask them bread is molding, how can you decrease the mold? (Pre-interviews).

I: What are the activities that you conduct when you specifically teach the role of chromosomes in cell division?

Ahmet: It is the most difficult part. I do not give them assignment about chromosome. I tell them what chromosome and its structures are. It is easier to teach chromosomes in genetics, rather than teaching chromosomes in cell division. I say the concept of chromosome in mitosis and I teach chromosomes in genetics one more time (pre-interviews).

I: What are the activities that you conduct when you specifically teach asexual reproduction?

Ahmet: I explain the definition of asexual reproduction after I teach mitosis.

I: What are the activities that you conduct when you specifically teach meiosis?

Ahmet: I pointed out the reproduction in 6th grade level. I usually prefer to use direct instruction and questioning. However, this situation may change depending on the reaction of students and events in class. If they do not understand by questioning, I prefer to use visuals. If illustrations do not work, I prefer to use metaphors.

I: What are the activities that you conduct when you specifically teach crossing over?

Ahmet: Again, it is related with High School Entrance Exam. I let students present their performance in crossing over in previous years. Girls would go to one side and boys would go to other side, then they would cross each other that represent crossing over… We did direct instruction this year because of exam (pre-interviews).

I: What are the activities that you conduct when you specifically teach the differences between mitosis and meiosis?

> Ahmet: I draw figures and show the properties of mitosis and meiosis. Then, I show the similarities and differences (pre-interviews).

Ahmet mentioned that he did not conduct activities in cell division unit. He pointed out limited time, and if there is time he said that he let students to do matching exercise in exercise book. During observations, Ahmet did not conduct activities in cell division topics. Then, researcher asked Ahmet why he did not conduct activities. Ahmet mentioned limited time, High School Entrance Exam pressure, and students' expectations about the lesson when he answered why he did not conduct activities. Owing to both students, parents and school principals focus on the High School Entrance Exam; these people thought that activities are unnecessary to learn according to Ahmet's narration in post interviews. Thus, Ahmet removed the activities which he planned to do. Sample excerpts about why Ahmet did not conduct activities are presented below.

> I just focused on direct instruction and test. Time is limited. In addition, students may think that they could not learn the topic when we focus on activities. Everyone says them to solve questions. Students get boring in doing activities found in activity book. Students adopted multiple choice questions. For example; I asked the reason why contractile ring does not form in plant cell. Students answered this question just saying cell wall. They did not explain the answer. They did not say that cell wall is thick and this thickness did not let the formation of contractile ring, thus cell plate occurs (post-interviews).

After Ahmet's general knowledge of activities in cell division, his knowledge of activities was specifically examined in terms of mitosis, role of chromosome in cell division, asexual reproduction, meiosis, sexual reproduction, crossing over and the differences between mitosis and meiosis. For example; Ahmet explained the activity that he conducted about mitosis at first. Ahmet mentioned an assignment about molding of bread when he teaches mitosis which is a real life problem and thus Ahmet revealed a problem solving activity regarding mitosis. Similarly, Ahmet focused on problem solving activity and experimenting regarding asexual reproduction during observations although he said that he preferred to do direct instruction in pre-interviews in asexual reproduction topic. Problem solving activity was based on a mathematical calculations regarding asexual reproduction of bacteria. This problem is presented below.

> Ahmet: Suppose that a bacterium divides one time per each 20 minutes. How many divisions does a bacterium divide in a day? (Observations).

Apart from problem solving activity, Ahmet planned to conduct an experiment regarding asexual reproduction of potato in observations. In this experiment, students were supposed to observe and take photo of vegetative reproduction of potato. However, they did not conduct this experiment in class. Then, Ahmet explained why they did not conduct this experiment in class during post interviews. Ahmet again noted change of schedule of High School Entrance Exam and thought that they had limited time and thus they passed this experiment.

> I assign them to experiment germination of potato in mitosis. We could not do this experiment. Exam time was close, so we passed that activity (post-interviews).

Although Ahmet said that he conducted role playing activity to teach crossing over in previous year, Ahmet just showed crossing over from the presentation during observations. When he explained why he did not conduct this activity was related with limited time due to change on High School Entrance Exam schedule.

In conclusion, Ahmet used teacher centered strategies as subject specific strategies because of his lack of knowledge on student centered approaches. Ahmet used illustrations, analogies and examples to facilitate students' understandings as representations. On the other hand, Ahmet did not conduct the activities found in textbook. Although he mentioned the experiment of asexual reproduction, role playing activity, and problem solving activity, he only got students to do problem solving and passed the other activities because of limited time due to High School Entrance Exam. In the next section, each of the participants' findings about content knowledge and pedagogical knowledge are summarized.

4.4. Summary of the Findings

In this section, participants results which were presented above one by one are compared and presented based on research questions. First, participants' content knowledge which are syntactic knowledge and substantive knowledge are compared and resulted. Second, participants' pedagogical content knowledge about cell division are compared and resulted.

4.4.1. Science Teachers' Content Knowledge

4.4.1.1. Science Teachers' Syntactic Content Knowledge

Nature of science knowledge refers to participants' syntactic knowledge in this study. Seven tenets of Nature of Science was used which are tentative NOS, empirical NOS, inferential NOS, imaginative and creative NOS, socio-cultural NOS, the functions of and differences between theory and law, and subjective NOS.

All of the participants had inadequate views on tentative NOS. Participants thought that scientific knowledge can change until it becomes law. All the participants thought that laws are certain and they never changes. Only one teacher had informed views regarding empirical NOS. This teacher mentioned role of experiment and observations in science to get evidence. On the other hand, other two teachers had adequate views in empirical NOS. Although these teachers mentioned experiments and observations, they did not emphasize that experiments are used to get direct evidence and observations are used to get indirect evidence. Similar to previous NOS tenet, only one of the teachers had informed views regarding inferential NOS. This teacher could explain observations, inferences and their differences. On the other hand, other two teachers had adequate views on inferential NOS because they had lack of knowledge in observation, inference and their differences. Similarly, only one teacher had informed views on imaginative and creative NOS. Only one teacher had informed views on imaginative and creative NOS. This teacher claimed that scientists use their creativity and imagination in all stages of scientific investigations. On the other hand, other two participants thought that scientists use their imagination and creativity only in planning or designing stage. All the participants had inadequate understanding about socio-cultural NOS. Participants thought that science is not affected by socio-cultural values. They thought that science is universal. All three participants had inadequate understanding about the functions of and differences between theory and law. Participants thought that there is an hierarchical relationship between theory and laws. Participants had common misconception that scientific method myth. According to this misconception, participants thought that scientists follow a step by step procedure. They validate hypothesis, theories and reach the laws which are proven. One of the teachers had informed views about subjectivity. She thought that scientists' background and expertise affect their point of view in scientific studies. On the other hand, other two teachers had inadequate views on subjective NOS. They thought that scientist are objective. They claimed that if scientists interpret same data differently, there is a lack of evidence.

To sum up, participants' syntactic knowledge was gathered in this study. Teachers had either adequate or informed category in three tenets of NOS which are empirical NOS (two adequate, one informed), inferential NOS (two adequate, one informed), and creative and imaginative NOS (two adequate, one informed). On the other hand one of the teachers had informed views on subjective NOS and two others had iadequate knowledge. Furthermore, science teachers were found in inadequate in socio-cultural NOS, functions and differences of theories and laws, and tentative NOS. In the next section participants' findings of substantive content knowledge are summarized.

4.4.1.2. Science Teachers' Substantive Content Knowledge

Science teachers' substantive content knowledge was gathered by pre-interview questions that researcher prepared. Substantive content knowledge regarding cell division included four dimensions which are basic cell division terms, cell cycle, mitosis, and meiosis.

None of the participants sorted the size of cell division concepts correctly. They sorted the concepts as Organism > Cell > Nucleus > Chromosome > DNA > Allele > Gene. All the participants had misconception that allele is bigger than gene hence they all had naïve conceptual understanding about size sequence.

All the participants' conceptual understanding about chromosome concept was partial. Participants had lack of knowledge the formation of chromosome, its structure, or role of chromosome in cell division. Participants have difficulty in process category about the role of chromosome because only one of the participants reached the process category.

Participants included lack of knowledge about homolog chromosomes. Two of them were aware of the homolog chromosome; however they gave lack of knowledge such as how homolog chromosomes form. On the other hand, one of them had misconception that homolog chromosomes are identical. Although one of them explained the whole process and passed to process category about homolog chromosome, two of the teachers considered on structure and they were in matter category on homolog chromosome.

One of the teachers had sound understanding about DNA whereas two of them had partial understanding. The teacher who had sound understanding considered both structure and role of DNA in cell division. On the other hand, two teachers just mentioned the structure of DNA. These two teachers explanation of DNA included lack of knowledge such as absence of double stranded structure of

DNA. Two of the teachers' ontological category was matter; however, teacher who had sound understanding was in process category because only this teacher explained the role of DNA in cell division.

Similar to DNA concept, only one teacher had sound understanding about gene. Two of them had partial understanding about gene. The teacher having sound understanding was aware that gene is the information sequence that affects our body. On the other hand, other two teachers had lack of information in gene concept. For example, they did not mention how gene affects our body. Ontological category of the teacher having sound understanding was process because she mentioned how genes affect our body. On the other hand, other two teachers did not consider role of genes, hence they wer in matter category.

All the participants had misconception about alleles. They thought that allele is bigger than genes or allele is two genes that transfer from parents. Hence, participants had naïve understanding about allele. Two of them focused on structure of allele, so they were in matter category. On the other hand, one of the teacher explained the mechanism that how alleles transfer from parents and put under process category, although she had misconception about allele concept.

Two of them were aware what sister chromatids are and how they forms. These teachers had sound understanding about sister chromatids whereas one of them was naïve in this concepts. Similarly, teachers who had sound understanding was in process category whereas teacher who was naïve about sister chromatids was in matter category.

Two of the teachers had sound understanding about centrosome. They both explained the centrosome as an organelle and explained its function in cell division specifically. On the other hand, one teacher just considered centrosome as an organelle. Because of two teachers considered the function of centrosome specifically, they were put under process about ontological category. One teacher did not explain the function of centrosome and he was in matter about ontological category.

All the participants had partial understanding on centriole concept because they included lack of knowledge about centriole. They either did not mention perpendicular tubes that shape centriole or they did not mention the role of centriole. One of the teachers explained the role of centriole; on the other hand, two of them did not explain the role of centriole.

One of the teachers did not answer the centromere concept; on the other hand two of the teachers had sound understanding about centromere. Teachers who had sound understanding about centromere concept focused on the nodule that connects sister chromatids each other. They did not mention the events about how centromere occurs and disappears. Hence, these two teachers were in matter category.

None of the participants answered the kinetochore question. Hence, their conceptual understanding and ontological category about this concept was not identified. Although participants could not answer the kinetochore concept they had sound understanding about asexual reproduction. All the participants could explain how asexual reproduction occurs, so they reached the process category.

Two teachers had sound understanding whereas one teacher had partial understanding regarding sexual reproduction. The teacher who had partial understanding explained sexual reproduction including lack of knowledge because this teacher did not mention fertilization that is mechanism of sexual reproduction. Because of this teacher did not explain the mechanism of sexual reproduction he was in matter category. On the other hand, two teachers mentioned fertilization and passed the process category.

Participants differed in somatic cell concepts. One teacher could not explain the somatic cell, and his categories were not identified about this concept. On the other hand, one teacher had partial understanding.this teacher ignored how somatic cells form and their chromosome number. Ontological category of this teacher about somatic cell was matter because this teacher focused on the cellular structure On the other hand; one teacher had sound understanding about somatic cell. This teacher was in process category because she explained the mitosis process that somatic cell undergoes.

Two of the teachers had sound understanding about gamete whilst one of the teachershad partial understanding. Teacher having partial understanding included lack of knowledge that gametes have ‘n’ chromosome. Ontological category of one teacher was process because she explained the event that gametes are the products of meiosis. On the other hand, other two teachers ignored this event and they placed in matter category.

All the participants had sound understanding about structure and formation of zygote. Their ontological category of this concept was process because they all mentioned the fusion of egg cell and sperm cell.

In conclusion, participants of this study had sound understanding in two concepts which are asexual reproduction and zygote. On the other hand, none of the participants answer the question that ‘what is kinetochore?’. All the participants had misconception regarding the sorting size of cell division and allele concept. Their misconception was caused by their false knowledge about allele for both of the questions. Because of participants thought that allele is bigger than gene or allele is two genes, they did not explain correct definition of allele that is ‘alternative forms of gene’. Regarding ontological category of concepts, participants had process category in asexual reproduction and zygote whereas they were in matter category for the sorting size of cell division question.

When specifically examined participants’ conceptual understanding, teachers differed with each other. One of them had sound understanding in ten concepts which are DNA, gene, sister chromatids, centrosome, centromere, asexual reproduction, sexual reproduction, somatic cell, gamete and zygote. On the other hand, one teacher had sound understanding in five concepts which are sister chromatids, centromere, asexual reproduction, gamete and zygote. Another teacher had sound understanding on centrosome, asexual reproduction, sexual reproduction and zygote concepts. Regarding ontological category, teacher who had sound understanding in ten concepts was in process category about eleven concepts which are homolog chromosome, DNA, gene, allele, sister chromatids, centrosome, asexual reproduction, sexual reproduction, somatic cell, gamete, zygote. The teacher having sound understanding about five concepts was in process category about five concepts which are chromosome, sister chromatid, centriole, asexual reproduction and zygote. The teacher having sound understanding about four concepts was in process category about four concepts which are centrosome, asexual reproduction, sexual reproduction and zygote.

Cell cycle is second dimension of cell division's substantive content knowledge. Two of the participants did not answer the cell cycle knowledge. Hence, neither their conceptual understanding nor ontological category regarding cell cycle was identified and categorized. On the other hand, one teacher defined the cell cycle. His explanation of cell cycle was partial because he could not identify the stages of the cell cycle which are G1, S, G2 and M. Regarding his ontological category, he was in matter category because he did not have a grasp of whole cell cycle process.

Third dimension of substantive content knowledge regarding cell division was mitosis in this study. Regarding mitosis definition and its process, only one teacher had sound understanding. She defined the term and her drawings of mitosis were scientifically correct too. Although other two teachers defined the mitosis, their drawing of mitosis processes included either lack of knowledge or false knowledge. Hence, they had partial understanding regarding mitosis. Ontological category of two teachers' mitosis knowledge was process because they could explain the stages of mitosis. On the other hand, ontological category of other teacher was matter because he could not explain mitosis and his drawings included false knowledge regarding mitosis. Regarding plant cells' mitosis, all the participants had sound understandings. Moreover, they mentioned different events between mitosis of animal cell and plant cell. Hence, ontological category of the participants regarding plant cell meiosis was process.

When data examined specifically, teachers differed with each other. One teacher acted as content specialist because she had sound understanding in mitosis process and definition. Although another one of the teacher drew mitosis correctly in general, he had some mistakes in his drawings such as absence of centromere, so he had partial understandings. On the other hand, another teacher could define mitosis; but his mitosis drawings included erroneous mistakes such as wrong separation of sister chromatids. Hence, he had partial understanding in mitosis. All the participants had sound understanding about plant cell’s mitosis. Regarding ontological category, two of them were in process category in definition and process of mitosis. One teacher was in matter category regarding definition and process of mitosis because his drawings of the mitosis were wrong. All the participants were in process category regarding mitosis of plant cell.

Last dimension of substantive content knowledge was meiosis. Only one teacher had sound understanding regarding meiosis definition and process. This teacher’s explanation and drawing of meiosis was scientifically correct. Other two teachers had partial understanding, their definition or drawings of meiosis included lack of knowledge or false knowledge. Two of the teachers were in process category regarding ontology because they could explain the meiosis process in their drawings. One teacher could not draw meiosis process, so he could not pass to process category. Regarding basic terms unique to meiosis, all participants had partial understanding because they did not mention synapsis, tetrade and chiasmata regarding meiosis. Participants’ ontological category was matter because they focused on the structures of what they mentioned. All participants had sound understanding about meiosis of plant cell. Their ontological category was in process, they could explain the differences and different events between meiosis of animal cell and meiosis of plant cell. Participants had sound understanding regarding the differences between mitosis and meiosis. Their ontological category was process because they could explain different structures and different events between mitosis and meiosis. Unfortunately, participants could not make a relationship between meiosis and genetics in their drawings of meiosis during anaphase-1. In another word they could not explain the law of independent assortment that connects genetics and meiosis. Hence their conceptual understanding and ontological category was not identified in this relationship between cell division and genetics. To sum up, participants had sound understandings in plant cell's meiosis and the differences between meiosis and mitosis. Participants did not respond to the question about the relationship between genetics and meiosis. Participants were in process category regarding plant cell's meiosis and the differences between mitosis and meiosis.

When specifically examined, one teacher had sound understanding in three concepts which are meiosis definition and process, plant cell's meiosis and the differences between mitosis and meiosis. Other two teachers had sound understanding in two concepts which are plant cell's meiosis and the differences between mitosis and meiosis. Regarding their ontologies, two teachers were in process category about three concepts which are meiosis definition and process, plant cell's meiosis and the differences between mitosis and meiosis. One teacher was in process category about two concepts which are plant cell's meiosis and the differences between mitosis and meiosis. In the next section, participants' pedagogical content knowledge regarding cell division is summarized.

4.4.2. Science Teachers' PCK regarding Cell Division

Five components of PCK which are orientation towards science, knowledge of curriculum, knowledge of students' understandings, knowledge of assessments and knowledge of instructional strategies were used to understand science teachers' PCK about cell division. Data were gathered by means of pre-interviews, observation records, post-interviews and teacher documents such as written tests.

4.4.2.1. Science Teachers' Orientation towards Science

In this study, science teachers' beliefs about goals of science teaching refer their orientation towards science. Science teachers' beliefs about goals of science teaching were categorized as central goals and peripheral goals. There was a discrepancy between interviews and observations about science teachers' central goals which directly affect their teaching decision and practice. During pre-interviews, participants' central goals were mostly schooling goals. Participants claimed that they wanted to prepare students to life, and they wanted students to use scientific knowledge in daily life. Apart from schooling goals, two of the teachers pointed out the importance of teaching science content. Hence, these two teachers revealed their subject matter goals in pre-interviews. On the other hand, another teacher pointed out affective dimension of science teaching. This teacher also had dualistic views about teaching cell division. He claimed that teaching cell division is both difficult and enjoyable. Participants' peripheral goals were not clear in pre-interviews. However, one of the teachers said that students are curious when they learn how their body grows. Students' curiosity may be peripheral goal which has little impact on teacher decision and practice for this teacher. Moreover, one of the teachers gave priority to subject matter goals and she pushed schooling goals aside. Hence Burcu's schooling goals can be peripheral based on pre-interviews.

Further information was gathered through the observations. Subject matter goals replaced with schooling goals as central goals during observations. Two of the teachers gave priority to teaching objectives in their teaching. Only one of the teachers maintained his schooling goals. Although this teacher's central goals were still schooling goals, he changed his priority. This teacher wanted to prepare students to high school exam during observations whilst he aimed to prepare students to daily life in pre-interviews. Teachers' peripheral goals regarding science teaching were mostly schooling goals in observations. Teachers wanted to connect science and students' real life in their class; however they did not emphasize schooling goals as much as they did in pre-interviews. Moreover, one of the teachers got students' attention and curiosity by board marker models that she used in her teaching. Hence, her peripheral goals can be affective goals in her teaching.

4.4.2.2. Science Teachers' Knowledge of Curriculum

Science teachers' knowledge of curriculum included knowledge of goals and objectives and knowledge of materials. Science teachers' knowledge of goals and objectives are summarized at first.

Participants' knowledge about why cell division placed in curriculum was asked. Only one of the teachers could pointed out spiral curriculum. She pointed out that cell division topics place in curriculum to prepare students to high school biology. All the participants could recognize the place of cell division unit, so they were knowledgeable about cell division's place in curriculum. Participants answered that cell division is the first unit taught in 8th level which is placed before force and motion unit. Similarly, participants could connect the vertical relationships between cell division concepts and reproduction, development and growth unit taught in 6th grade level. Participants connected cell division topics with inheritance and connected mitosis and meiosis with each other as horizontal relations. However, they ignored the evolution topic that is related with cell division unit. Although participants did not mention some of the cell division objectives in pre-interviews, they all mentioned these objectives in their teaching. Hence, they were knowledgeable about objectives regarding cell divisions.

Two of the teachers sorted the objectives based on their importance. One of the teachers who sorted the objectives thought that objectives which emphasize on ‘how and why cell division occurs’ are more important. Another teacher sorted the objectives thought that mitosis objectives are more important because mitosis knowledge is prerequisite knowledge for meiosis. On the other hand, one teacher did not sort the objectives and thought that all objectives have equal importance.

Two of the teachers modified textbooks or objectives. These teachers thought that inheritance should be taught before mitosis. However, their justifications were different. One of the teachers wanted to teach inheritance before mitosis because students forget mitosis until they start to learn meiosis. So, he has to repeat mitosis one more time when they compare mitosis and meiosis. On the other hand, another teacher wanted to place inheritance before mitosis because chromosome that is vital for cell division is taught in inheritance according to this teacher. She claimed that students cannot understand mitosis without chromosome knowledge. On the other hand one of the teachers stressed that he is the supporter of curriculum and did not modify textbooks or objectives.

Two of the teachers applied limitations of cell division in curriculum. However, one of the teachers ignored the limitation about the Latin names of the stages although she applied other limitations in her class. All the participants emphasized on the misconception regarding with cell division that is ‘There is a direct proportion between the size and complexity of organism and the number of chromosome.’ during observations, so all of the teachers had adequate understanding regarding cell division.

One of the teachers could answer students’ needs without use of material or she could adjust textbook sentences with what students can understand related to dependence to curricular materials component of curricular knowledge. On the other hand, one teacher got assistance from his presentation when he answered students’ questions and another teacher used notebook in his teaching that assisted him. Hence, Ahmet and Selim were dependent to curricular materials in their studies.

Only one of the teachers did not exceed the cell division content that is the degree of knowledge supported by curriculum. On the other hand, two teachers gave advance level knowledge in their teaching, so they violated the degree of knowledge suggested by the curriculum.

In conclusion, participants were knowledgeable about four aspects which are the place of cell division in curriculum, vertical relationship, curricular objectives and misconceptions found in curriculum

Sources that teachers used in their teaching and the reasons of why teachers selected these sources are presented in this section as second component of knowledge of curriculum. One of the teachers used many materials in his teaching which are textbooks, exercise book, videos, posters, and notebook. Aims of the using these sources were directly related with cell division teaching. On the other hand, other two teachers used either few sources or wrong sources. For example; one of these teachers who used few sources did not use textbook and exercise book actively because of contextual factors. She used only internet and her presentation. Similarly, another teacher used wrong source that high school textbook which is not suitable for 8th level. All teachers commonly used in their teaching internet to show visuals for abstract nature of cell division. By this way, teachers aimed to facilitate students' understandings.

4.4.2.3. Science Teachers' Knowledge of Students' Understanding of Science

Science teachers' knowledge of students' understanding in science included two sub dimensions which are knowledge of requirements for learning regarding cell division and knowledge of students' difficulties

None of the participants claimed that knowledge of basic genetics terms and their relationship such as sister chromatids as pre-requisite knowledge. On the other hand, they pointed out cell and organelles knowledge is pre-requisite knowledge for cell division. Different from other two science teacher, one of the teachers considered the chromosomal structures as pre-requisite knowledge for cell division.

To understand science teachers' knowledge of students' difficulties; the points that students had difficulty, the reasons of these difficulties, students' misconceptions in cell division, sources of students misconceptions and the ways of identifying and eliminating misconceptions were explored.

Science teachers mentioned either concepts or processes regarding cell division as difficulties, however; they did not consider on mechanisms of cell divisions as students' difficulties.

None of the participants stressed the abstract nature of cell division, cell division own terminology, cell division as a micro level process, assimilation of knowledge, complex and detailed structure of cell division all together regarding the reasons of students' difficulty about cell divisions. On the other hand, participants emphasized some of the reasons of difficulties such as complex nature of cell division and cell division own terminology.

Participants of this study were knowledgeable about students' misconceptions. Science teachers explained many misconceptions about cell division such as 'Gametes undergo meiosis.' Two of the teachers indicated teachers, textbooks, daily life language, and students' background can be source of students' misconceptions. On the other hand, Burcuone of the teachers just indicated textbook and students' lack of knowledge as source of misconceptions.Two of the teachers considered on questioning, written exams, explanation of topic one to identify and eliminate misconceptions. They did not prefer constructivist based strategies such as concept maps to identify misconception or conceptual change approach to remediate misconception. On the other hand, one of the teachers used concept maps to identify and remediate students' misconceptions although he did not use other constructivist based strategies.

4.4.2.4. Science Teachers' Knowledge of Assessments

Science teachers' knowledge of assessment was summarized. Knowledge of dimensions of science learning to assess and knowledge of methods of science teaching which two sub-components of knowledge of assessment are presented to understand science teachers' knowledge of assessments.

Science teachers' knowledge of dimensions of science learning to assess refers what science teachers assess in science teaching. Science teachers preferred to assess only students' conceptual understandings which are related with cell division objectives. Teachers did not prefer to assess interdisciplinary themes, nature of science knowledge and students' problem solving skills.

Science teachers' knowledge of methods of assessments refers how to assess and when to asses students' learning. Only one of the teachers assessed his students' understandings using both traditional assessment technics which are matching, questioning, short answer and alternative assessment technics which are concept mapping and poster. On the other hand, other two teachers preferred to use only traditional assessment technics.

Two of the teachers used both summative assessment and formative assessment regarding when science teachers assess their students. Formative assessments that teachers used included whole teaching process. These two teachers used questioning to understand students' learning at the beginning of the lesson, in the middle of the lesson, at the end of the lesson. On the other hand, one of the teachers' formative assessments were fragmented. He just assessed his students at the beginning of the lesson by questioning during observations. All teachers in this study used summative assessments at the end of the unit.

4.4.2.5. Science Teachers' Knowledge of Instructional Strategies

Knowledge of instructional strategies included two sub-dimensions which are subject specific strategies and topic specific strategies. Science teachers' knowledge of subject specific strategies was summarized at first in this section. Science teachers preferred to use teacher centered strategies which are direct instruction and questioning in their teaching. Hence, science teachers were inadequate regarding subject specific strategies. Two of the teachers addressed same reasons for using teacher centered strategies. Lack of knowledge of student centered strategies and limited time caused science teachers to use teacher centered strategies. On the other hand, one teacher was aware of the student centered strategies which are based on constructivism whereas she did not use student centered approaches such as drama because she thought that this strategy appeals to lower grade levels. Moreover, she did not conduct experiment because of lack of equipment.

Next, science teachers' knowledge of topic specific strategies included two sub dimensions which are knowledge of representations and knowledge of activities. Science teachers' knowledge of representations is included in this part. All the participants used visuals, photo and videos to facilitate students' understanding about cell division as illustrations. Two of the teachers used actively board to draw different stages of the process. These two teachers drew crossing over, homolog chromosomes, DNA, sister chromatids separately to show their significance in cell division. On the other hand, one teacher did not draw figures in his teaching.

Furthermore science teachers gave many examples in cell division topics such as examples of organisms that reproduce by different asexual reproduction types, or examples of different cell types which are produced after meiosis such as pollen, sperm, and egg cell as part of knowledge of representation. Moreover, teachers mentioned daily life examples to connect science and students' life such as recovery of injuries and mitosis relation regarding examples.

One of the teachers actively used board marker models to facilitate students' learning as models to represent cell division.On the other hand, other two teachers did not mention models regarding cell division nor they used models.

All teachers used comparisons and make simple analogies as kinds of representations to make students to understand cell division topics. However, teachers did not extend their explanation so steps of the analogy were not achieved by science teachers. Stated differently, science teachers did not consider constructing analogy between two concepts, they only wanted to do basic comparisons between familiar concept and target concept.

When specifically examined, one of the teachers used four aspects of representations which are illustrations, drawings, models and examples. On the other hand, another one of the teachers used three aspects of representations which are illustrations, drawings, and examples. Contrary, one teacher used two aspects of representations which are illustrations and examples.

Science teachers' knowledge of activities including problem solving activity, simulations, experiments, role playing activity, play dough activity are summarized too in this study. None of the participants use simulations which are computer assisted programs that students actively engaged. On the other hand teachers showed videos found in internet as representations. Only, one teacher used problem solving activities in his teaching. This teacher used daily life problems such as molding of bread. Two of the teachers did not conduct experiment in cell division teaching but, one teacher conducted experiment about asexual reproduction although he did not consider science process skills. One of the teachers mentioned both role playing activity and play dough activity and this teacher could also modify these activities. He removed play dough activity because it takes so much time, and used poster activity instead of play dough activity. Moreover, this teacher passed the role playing activity because he thought that this activity is childish and unnecessary for this grade level.

When specifically examined, one teacher was knowledgeable in two of the activities which are role playing and play dough activity. On the other hand, one teacher used problem solving activity. One teacher in this study had no use of activities related cell division. The teacher who used most representation did not use any activity regarding cell division. Hence, her knowledge of representations may substitute with her knowledge of activities regarding topic specific strategies.

CHAPTER 5

DISCUSSIONS, CONCLUSIONS AND IMPLICATIONS

5.1. Science Teachers' Content Knowledge and PCK about Cell Division

Science teachers' content knowledge including substantive and syntactic structures and pedagogical content knowledge including components' of Magnusson et al. (1999) model were studied. In general, science teachers' nature of science knowledge referring syntactic knowledge (Khalick & BouJaoude, 1997; Schwab, 1964) included lack of knowledge in current study. Science teachers especially had naive ideas about tentative NOS, subjective NOS, socio-cultural NOS, nature of theories and laws. Science teachers thought that scientific knowledge is tentative until it becomes theory. However, they added that tentativeness ends when knowledge reaches the law status. This situation shows that science teachers had naive views in tentativeness. Moreover, science teachers thought that science is an isolated phenomenon that is not affected by society. Furthermore, science teachers implied that scientists are objective people who do not reflect their background or expertise to the field what they work on. Next, science teachers had common problems that there is a hierarchical relationship between hypothesis, theory and law. This hierarchy also could let participants to think that there is a one single scientific methodology that scientists follow. Science teachers' naïve views about scientific method myth may impede their understanding about the inferential NOS, empirical NOS and imaginative and creative NOS which are the three NOS tenets that science teachers had adequate or informed understanding in this study. Although science teachers reported that scientists use their creativity in scientific investigations, science teachers were aware the differences between observation and inferences and they thought that scientists conduct experiments and make observations to get empirical evidence; scientific method myth may lead them to ignore importance of creativity, imagination, observation and inference. Therefore, science teachers NOS tenets which are adequate or informed are at risk because of their lack of NOS tenets. This situation may indicate that NOS tenets are not independent from each other, and they are in interaction. Thus, it cannot be asserted that science teachers are good at some of the NOS tenets, until they have well understanding about the all NOS tenets. Science teachers' lack of understanding about the NOS tenets were also reported in previous reports (Aslan et al., 2009; Doğan & Khalick, 2008; Iqbal et al., 2009; Lederman & Lederman, 2004).

Similar to their lack of knowledge about NOS, science teachers did not cover NOS tenets in their lessons because science teachers aimed at transmitting curricular objectives. However, aim of the curricular program is not to transmit scientific knowledge. Curricular program expresses that aim of it is to make students as scientific literate people (MoNE, 2006). Moreover, one of the aspects of being scientific literate is to be aware of Nature of Science knowledge. Hence, NOS should be emphasized in science classes. However, none of the teachers observed in this study focused on experiments or observations as empirical NOS. Although one of them conducted an experiment about vegetative reproduction, the teacher ignored scientific process skills that are another aspect of scientific literacy. Similarly, teachers mentioned the cell topics before they taught the cell division topics as prerequisite knowledge, however; none of the teacher mentioned the cell theory or its historical development as tentative NOS. Similarly, laws about cell division were not mentioned. None of the teachers mentioned in which conditions scientists developed their study about cell division. So, students were not informed about how social factors shaped scientists' works. Later on, science teachers did not mention what was known before cell division studies and what are the alternative views of cell division proposed by scientists based on their creativity. Furthermore, all the teachers taught biologic dimensions of cell division and they intended to teach cell division from biologist perspective, so students had no chance to think cell division from different point of view. For example; no one focused on the chemicals take role in cell division unlike to chemists, therefore students had no chance to understand subjective aspect of NOS. To sum up, science teachers could not teach NOS tenets in their lesson. It is possible to say that science teachers' lack of understanding about NOS cause them not to integrate it into their lessons. As Shulman (1986, 1987) claimed, insufficient syntactic content knowledge does not permit robust PCK for NOS. Science teachers' lack of understanding and teaching NOS is consistent with previous studies (Hanuscin et al., 2010; Posnanski, 2010).

There could be some reasons why science teachers could not understand and teach NOS in their classrooms. First problem is related with science teachers' undergraduate educations. NOS education has recently been covered in Turkish undergraduate programs, thus experienced science teachers in current study might not learn NOS when they were enrolled in undergraduate programs. Hence, it is meaningful that science teachers are not familiar to NOS and teaching it. Studies held with pre-service teachers who had been taught NOS support this view. These pre-service teachers were found to be familiar to NOS tenets (Mıhlandız, 2010). Second reason why science teachers do not teach NOS in their lesson can be related with curricular problems. Because of there is no specific curricular objective about cell division topics, science teachers feel that they do not have to teach NOS. Similar to this view, Hanuscin et al. (2010) claimed that there is no material and activity to teach NOS in science courses. This lack of specific objectives, materials, and activities do not permit science teachers to have curricular knowledge about teaching or integrating NOS in science courses. Another problem is related with assessment issues. Hanuscin et al. (2010) reported that science teachers do not assess students' understandings about NOS because teachers thought that NOS is related with affective domain more that cognitive domain, so it is difficult to assess. Moreover, Hanuscin et al. (2010) reported that science teachers had no idea about how to assess students' NOS understandings. Similar to this findings science teachers in this study did not assess students' NOS understanding too. Because of science teachers did not assess students' understandings; they could not develop their knowledge of learner about NOS. Similarly, there was no clue for explicit or implicit NOS instruction in the classes which were observed. Hanuscin et al. (2010) claimed that science teachers use kids friendly terms, use operational definitions and make some analogies to make NOS tenets to be understandable for students. On the other hand, science teachers in current study did not use these approaches to teach NOS. Moreover, science teachers do not give importance to the NOS in their orientations because their orientations were limited to transmitting curricular objectives. In conclusion, science teachers had insufficient NOS understandings as syntactic structures. They do not think teaching NOS in their orientations, there is no specific curricular programs for them to apply it, they have no idea about the assessment of NOS and students' views about NOS, and they did not use any explicit or implicit strategy to teach NOS in their classes. In another word, science teachers had neither NOS understandings nor PCK for NOS.

Another type of content knowledge used in this study was the substantive structures (Schwab, 1964). Substantive content knowledge included four components which are basic terms, cell cycle knowledge, mitosis knowledge and meiosis knowledge. Allele is an important term connecting cell division and genetics. Science teachers had misconception about allele. However, science teachers thought that allele is bigger than gene. They did not think that allele is the alternate form of gene. This misconception was common in previous research on cell division (Lewis et al., 2000; Williams et al., 2012). Because of their naive views about allele, science teachers could not sort the physical relationship between basic cell division concepts. Although science teachers could sort the concepts correctly from gene to organism unlike to Lewis et. al. (2000) study's results, science teachers placed allele concept between gene and DNA. Similarly, teachers in this study were not aware the relationship between genetics and cell division related to the law of independent assortment. While they were drawing anaphase-1, science teachers could not explain the law of independent assortment that connects genetics and meiosis. Science teachers' naive views about allele and the law of independent assortment support the view that science teachers had problem in connecting genetic and cell division. Brown (1990) and Appleton and Kindt (1999) claimed that the lack of understanding about the relationship between genetics and cell division can be caused by the textbooks. Fragmented textbooks may lead teachers not to connect cell division and genetics. Therefore, Brown (1990) suggested that textbooks should integrate biology topics. Science teachers' lack of knowledge about this connection can be related with fragmented textbook.

Moreover, science teachers were mostly found in matter category regarding basic cell division terms. However, Chi et al. (1994) claimed that teachers should be in process category to be able to teach science topics. Science teachers' understandings of mechanisms about cell division confirm their ontological status. For example; scientists did not explicitly explain the mechanism of genetic transferring and science teachers did not reach the process category about kinetochore and centromere concepts which are related with the mechanism of genetic transferring. Similarly, science teachers did not explain the mechanism of asexual reproduction because they did not know the cell cycle that provides the asexual reproduction (Koç & Turan, 2012). Or, science teachers could know the mechanism of sexual reproduction in plants because they were aware that plants undergo meiosis.

The reason why science teachers have difficulty in understanding cell division concepts could be related with terminology (Lankford, 2010; Lewis et al., 2000; Öztaş et al., 2003). For example; Researcher asked the term 'somatic cell' and only one of the teachers could explain it. However, all teachers could know this term when it is identified as 'body cell'. Moreover, participants had more difficulty in meiosis rather than mitosis. This could be related with meiosis's more complex and lengthier structure. For example; meiosis has its own terminology and structures which are tetrade, synapsis, chiasmata and crossing over. Participants could not explain this terms when they were requested to draw important meiosis terms. Furthermore, curriculum supports that science teachers' ignorance to meiosis terms. 8^{th} grade textbook does not include these terms and teachers feel them responsible for acting curricular objectives. Hence, science teachers might forget these terms because of not teaching them. Similar to other meiosis terms, science teachers do not know the interkinesis what happens between meiosis-1 and meiosis-2.

Science teachers' orientations are multi-dimensional and complex, so it is difficult to change science teachers' orientations according to Luft and Roehring (2007). Science teachers' orientation towards science or beliefs about science teaching had discrepancy between interviews and observations. Although science teachers aimed to make students to connect science and daily life in pre-interviews, they attempted to transmit curricular objectives during observations. This orientation corresponds to subject matter goals according to Friedrichsen and Dana (2005). However, this orientation is limited and problematic for PCK because PCK is the overarching component that shapes other components. Transmitting curricular objectives recalls the teacher led orientations such as lecturing and academic rigor. These orientations are not student led which do not address student needs. Hence, it is possible that teachers in teacher led orientation do not improve their knowledge of learner (Miranda, 2010). Similar to current study, Miranda (2010) found that teachers focus on cognitive skills ignoring their prior knowledge and difficulties. Moreover, teachers should not ignore student interest and motivation. Miranda (2010) added that science teachers' beliefs about students determine their knowledge of instructional strategies. Similarly, Drechsler and Van Driel (2008) claim that teacher led orientations underestimate students. These teachers conduct activities which are easier than original activities that decrease the efficacy of course.

There are some possible reasons that why science teachers only preferred to transmit curricular objectives. Firstly, it is thought that science teachers are affected by contextual factors such as High School Entrance Exam (TEOG). Teachers in this study focused on transmission of knowledge regarding objectives because these objectives are asked in High School Entrance Exam. Moreover, context of the current study was held with private schools which aim academic achievements. Secondly, why science teachers in this study adopted subject matter goals could be their background or previous experiences (Friedrichsen & Dana, 2005). Teachers had worked in cram school in the past. Teachers reported that they were familiar to transmission of content knowledge. Hence, they may carry their orientation from cram school to private schools. Third factor shaping science teachers' orientation could be selected topic (Avraamidou, 2012; Feierabend et al., 2011; Friedrichsen & Dana, 2005; Friedrichsen et al., 2010). Science teachers' orientation was transmission of objectives in this study; however, if selected topic was climate change, teachers' orientations towards science could be make students to inquiry about socio-scientific issues. The last factor shaping science teachers' orientation can be related with time (Friedrichsen & Dana, 2005). Teachers in this study had limited time to teach science content because schedule of High School Entrance Exam was moved in earlier time. Hence, teachers had to remove some of the activities which might mask teachers other beliefs regarding goals of science teaching.

Science teachers were aware of the curricular objectives, misconception warning in objectives, and limitations in objectives. Science teachers could also know the place of cell division topics in curriculum. Moreover, science teachers could link verticular and horizontal relations. The relationships that were suggested by teachers as curricular knolwedge was also related with science teachers' knowledge of students' understandings because these relations can be seen as example of prerequisite knowledge to learn cell division. On the other hand, science teachers had some deficiency about the activities suggested by textbook because science teachers generally tended to ignore the activities found in curriculum. Science teacher's lack of knowledge about the activities also affected their knowledge of instructional strategies because they did not teach these activities. The interaction between knowledge of instructional strategies and curricular knowledge were reported in Hanuscin et al. (2010) and Falk (2012)'s study. Science teachers claimed that they removed these activities because of High School Entrance Exam (TEOG) and limited time. Effects of contextual factors on science teachers' curricular knowledge was also reported in previous study (Mıhlandız & Timur, 2011).

It is thought that science teachers' knowledge about the curricular objectives and place of the topic in curriculum is the result of their experience. Because of science teachers have been teaching since ten years, these teachers are familiar to curricular objectives and place of the topic. PCK studies held with pre-service or novice teachers showed that science teachers were not aware of the curricular objectives and place of the topic (Graf et al., 2011; Hanuscin et al., 2010; Lankford, 2010; Karakulak & Tekkaya, 2010; Mıhlandız, 2010; Mıhlandız & Timur, 2011;Özcan & Tekkaya, 2011; Tekkaya & Kılıç; 2012; Uşak, 2009) and confirmed this argument. Moreover, there was no clue for current study that orientation towards science directly shapes science teachers' knowledge of curriculum. Therefore, science teachers' knowledge of curriculum can be related with teacher experience rather than orientation towards science. However, it could be interaction between orientation towards science and knowledge of curriculum thanks to the mediators such as knowledge of learner. For example; science teachers having teacher led orientations have lack of knowledge about students' understandings. If science teachers are lack of understanding about their students, they can not modify the textbooks as response to students' needs (Miranda, 2010) and curricular sources adress students needs in general context and appeal to a wide audience without specific characteristics of students (Bayer & Davis, 2012).

Science teachers also violated the curriculum in this study. Similar violations of curriculum were also reported in previous studies (Graf et al., 2011; Lankford, 2010; Tekkaya & Kılıç, 2012). These studies reporting science teachers violated the curriculum seem to be related with science teachers' lack of experience. However, science teachers of current study had sufficient experience in their career. So, these teachers should have violated the curriculum, but they did. There could be three possible reasons that science teachers violated the curriculum. First of all, science teachers tended to talk more on what they are interested or what they are familiar. For example; one of the teachers explained that he had grown in a village and worked as farmer in his childhood. Hence, this science teacher mentioned advance level knowledge about asexual reproduction and allocated much time for teaching this topic. He mentioned how different types of plants reproduce asexually, and he mentioned how students should plant vegetables and fruits to the earth. Secondly; science teachers' teaching beliefs or pedagogical concerns may lead them to exceed curricular knowledge. One of the science teachers wanted to make connection between daily life and cell division to get students attention or to show students this topic is closely related with their daily life. When teacher explained the sexual reproduction, she mentioned that women have two ovaries and she exceeded the curriculum by saying "Each month, one of the ovaries undergo meiosis and produce eggs.". Similarly, she added that meiosis ends in women in menapause and meiosis ends in men in andropause. This knowledge was also violation of curriculum caused by teacher's connection between meiosis and daily life. Third reason of exceeding curriculum could be related with science teachers' lack of knowledge in selected topic. One of the teachers used meiosis terms in his teaching which are tetrade, synapsis, and chiasmata using high school biology textbook. Moreover, teacher confused these terms during teaching. Similarly, this teacher could not reflect correct explanation of this term in his drawing during pre-interviews. Hence, he might want to compensate his lack of knowledge by giving large amount of knowledge in the class.

Curricular dependence to materials is another issue to be discussed. Science teachers in this mainly needed course textbook and they frequently refer textbook when they answer the students' needs or questions. On the other hand; science teachers should use wide range of sources when they answer the students' needs. Although curricular materials are designed for students' needs, they are not specific to students in teachers' classes (Bayer & Davis, 2012). Therefore, teachers should adjust the information given in textbook when students have problems about it. Moreover, textbooks sometimes do not answer the students' need or they include lack of knowledge that is subject to different interpretations (DeJong & Van Driel, 2004). For example; textbook did not inlude meiosis of plant cells in textbook, hence science teachers are alone when students have problems in meiosis of plants. Similarly, one of the activities in exercise book included a photo and asked that whether this photo belongs to mitosis or meiosis. The answer was not clear because students and teachers looked for crossing over for meiosis, but photo did not include crossing over. Moreover, two chromosomes were attaching each other, but these chromosomes were not homolog chromosomes. This lack of knowledge in activity found in exercise book may let students to confuse their minds. As a result, science teachers should have capability for adjusting curricular based on students needs and they should use wide range of curricular materials to help students' needs.

Another dimension of the PCK is knowledge of students' understanding. Science teachers could adress the cell, development and growth topics as pre-requisite knowledge to understand cell division. Moreover, science teachers could sort the concepts and proceses as students' difficulty on cell division topics. Similarly, science teachers were aware of students' misconceptions about cell division. The best way to get students' understanding is to assess them. However, Park and Oliver (2008) claimed that it is not always possible to assess students. Therefore, science teachers should already have students' common difficulties and misconceptions. Teachers in current study seem to have sufficient knowledge for students' misconceptions and difficulties. This could be related with their experience level (Cochran et al., 1993; Veal et al., 1999). Their understanding about students' knowledge may lead them to adjust their teaching strategies to make their teaching more efficient (Akerson, 2008;Aydın et al., 2010; Boz & Boz, 2008; Brown et al., 2013; Demirdöğen, 2012; Hanuscin et al., 2010).

Science teachers' orientations towards science also assist for understanding their knowledge of learner. Miranda (2010) and Drechsler and Van Driel (2008) suggested that teacher led oreintations does not permit teachers to understand students needs. Science teachers in this study adopted the teacher led orientations as 'transmission of objectives'. It can be expected that science teachers should have insufficient knowledge of students' understandings because of their teacher led orientations. However, science teachers were knowledgeable about students' understandings in this study. First reason for their sufficient knowledge can be their experience level as mentioned before although they had teacher led orientations. Second reason was science teachers' past work might also increase science teachers' knowledge of students' understandings. Science teachers worked in cram schools that prepare students to high school exam in the past. Because of high school exam includes questions which are multiple choice items, all science teachers actively used test books including multiple choice questions. Distracters in multiple choice questions mainly include misconceptions; hence science teachers might develop their knowledge of misconceptions using test books.

Science teachers' knowledge of assessment was another component of PCK revealed in this study. Science teachers focused on assessing students' conceptual understanding. This result is similar to previous research (Lankford, 2010; Tekkaya & Kılıç, 2012). It is belived that most important factor that shape what teachers assess is their orientation towards science. Because of science teachers aimed to transmit curricular objectives, they focused on assessing curricular objectives. On the other hand, science teachers did not assess nature of science, science process skills and science, technology and society knowledge. Therefore, it is difficult to understand and improve students' STS, SPS and NOS views for teachers because they do not assess and understand what students think about these issues which are the components of scientific literacy.

Another reason why science teachers only assess students' cognitive understanding can be related with their curricular knowledge. Park and Oliver (2008) claimed that curricular objectives determine what teachers assess. Our National Curriculum for 8th grade level focuses on the objectives which aim to let students understand cell division topics. There is no specific objectives regarding other components of scientific literacy, hence teachers do not need to assess these dimensions. Moreover, science teachers may not be aware of scientific literacy because they either did not mention scientific literacy or they talked about little on scientific literacy during observations and interviews. Only one of the teachers mention scientific literacy, but her understanding about scientific litercy is limited with conceptual understanding and its application on daily life. In another word, science teachers did not know that scientific literacy consists of conceptual understnding, SPS, STS and NOS. In conclusion, science teachers' ignorance of scientific literacy in their orientation towards science might become an obstacle for their knowledge of assessment.

Moreover, contextual factors may affect science teachers' assessment (Uşak et al., 2011; Yarden & Cohen, 2009). High School Entrance Exam is accepted as contextual factors. This exam focuses on assessing curricular objectives and curricular objectives are based on conceptual understandings. Therefore, science teachers might focus on assessing conceptual understanding.

Science teachers also tended to use traditional assessment techniques and they mainly did not use alternative assessment techniques. This result is similar with previous reports (Canbazoğlu et al., 2010; Graf et al., 2011; Taşdere & Özsevgeç, 2012; Uşak et al., 2011; Yarden & Cohen, 2009). Science teachers' orientation again could be related with science teachers' use of assessment technics. Science teachers' orientation towards science is teacher led orientation as it mentioned before. On the other hand, alternative assessment technics such as performance assessment and portfolio are student centered assessment technics. Therefore, as it is expected science teachers preferred to use traditional assessment technics which are consistent with their orientation. Moreover, science teachers' lack of knowledge about alternative assessment technics might force them to use traditional assessment technics. Science teachers' lack of knowledge about alternative assessment technics evokes us to think about Kaya (2009) discussion about the knowledge of assessment. Kaya (2009) complained the ignorance of assessment courses in undergraduate education of Turkey. Number of limited assessment courses forced pre-service teachers not to learn alternative assessment technics and they tend to use traditional assessment techincs which they are familiar from their K-16 education. The lack of assessment technics might be the reason of why science teachers do not know the alternative assessment technics.

Another concern related this component is the time of assessment. Time of assessment includes both formative assessment (assessment for learning) and summative assessment (assessment of learning) as suggested by Earle (2014). It is expected that science teachers should always assess their students' understandings to help their needs, to elicit their misconceptions, to provoke them towards further learning and to recall their prior knowledge. However, it is not possible to always assessing students. Hence, knowledge of assessment does not guarantee to release students' understandings (Park & Oliver, 2008). Although, it is not possible always assessing students, two of the teachers in this study aimed to use both formative assessment and summative assessment during their teaching by questioning and whole class interaction. Formative assessment seems to be more important than summative asssessment in PCK studies because formative assessment improve science teachers' PCK (Folk, 2012). Thanks to formative assessments, science teachers develop their knowledge of assessments. After they develop knowledge of assessments, their understanding about knowledge of learner increases. Similarly, teachers assessments are based on curricular goals (Park & Oliver, 2008), and their curricular knowledge also increases regarding goals and objectives consistent with their assessments. When science teachers increase their knowledge of curriculum, their understanding about curriculum will increase and they have capability of conducting curricular activities in their class. When in-service teachers integrate curricular activities in their classes, their instructional strategies will increase too. For example; they could adjust the activities as an example of improvement of instructional strategies. Either science teachers could remove unnecessary activities. Science teachers' formative assessment might also be related with orientation towards science. Science teachers' orientation should be student centered to use formative assessments. Student centered orientations such as conceptual change approach elicit students' understandings and this inquiry process occured between students and teacher is provided by formative assessment technics. In conclusion, science teachers' formative assessments are crucial for their professional development when components of PCK are thought in holistic way.

The last component of the PCK is the knowledge of instructional strategies. Science teachers preferred to use teacher led instructions which are lecturing and direct instruction. Science teachers did not use student centered or constructivist approaches which are conceptual change approach, 5E Learning etc. Findings of this study about knowledge of instructional strategies are consistent with previous research (Brown et al., 2013; Kapyla et al., 2009; Karakulak & Tekkaya; 2010; Mıhlandız, 2010; Mıhlandız & Timur, 2011; Tekin, 2006; Uşak, 2009; Uşak et al., 2011). First reason why science teachers preferred to use teacher led strategies could be related with science teachers' lack of knowledge about student centered instructions (Brown et al., 2013). Second reason, why they did not prefer to use student centered instructions could be related with their orientations. Because of science teachers focus on transmitting curricular objectives, they preferred to use instructional strategies which are consistent with their orientation at most. Hence, they preferred direct instructions. Although science teachers' orientation was based on transmitting objectives, they were also knowledgeable about their students' understandings thanks to their experiences as Park and Oliver (2008) suggested. So, science teachers' knowledge about learner may affect their teaching instructions. Science teachers reported that they preferred to use teacher led strategies in older grade levels such as 8th grade and they used student centered instructions in earlier grades. Their preference for instructional strategy based on students' grade level is consistent with previous report (Aydın et al., 2010; Boz & Boz, 2008). Moreover, contextual factors have great impact on science teachers' choice of instructional strategy (Aydın et al., 2010). First contextual factors that shaped science teachers' instructional strategy was limited time. Because of High School Entrance Exam (TEOG) moved to an earlier time, science teachers preferred to use direct instruction to cover all the content found in objectives. Second reason was lack of equipment that shape science teachers' instructional strategies. For example; one of the teachers aimed to conduct an experiment about asexual reproduction by budding. However, she did not conduct this experiment because their microscope did not reach the school in cell division unit. Parents' expectations and administrative policies also determine science teachers' instructional preference. Both parents and school administartors thought that teachers are the subject transmitters. So, teachers take their social role that is expected by the people who they are in interaction.

Most of the PCK studies claim that science teachers set their knowledge of instructional strategies based on their knowledge of students' understandings (Akerson, 2008; Boz & Boz, 2008; Brown et al., 2013; Demirdoğan, 2012; Hanuscin et al., 2010). On the other hand; science teachers in this study were aware of pre-requisite knowledge for cell division, students' misconceptions about cell division and students' difficulties. So, it was expected that science teachers use constructivist approaches to understand students' misconceptions and difficulties. However, they did not use these approaches because of the reasons that were mentioned above and science teachers' subject specific knowledge of instructional strategies were limited with teacher centered instructions.

On the other hand, science teachers used representations and some activities regarding cell division unit as their topic-specific instructional strategies. These activities that science teachers used were found also related literature. Science teachers used problem solving activities (Clark, 2000; Kindfield, 1994; Williams et al., 2012); however, science teachers ignored the integration of cell division and genetics unlike to previous studies. One of the science teachers also conducted an experiment (Appleton & Kindt, 1999; Aydın et al., 2010; Kapyla et al., 2009) ignoring the role of science process skills. One of the science teachers mentioned play dough activity (Bogiages & Hitt, 2008) found in also curriculum, but change this activity with poster activity because he thought that students are not interested in play dough activity and they found this activity childish. The ability of modifying activities based on students' needs is indicator of good science teachers (Magnusson et al., 1999). Science teachers also addressed role playing activity (Clark, 2000). None of the teachers used role playing activity in their lesson. Science teachers explained that they did not conduct this activity because of their knowledge of learner. Science teachers thought that students found this activity childish and they removed this activity too from their lessons. Science teachers also used visuals and drawings as illustrations to visualize abstract cell division topics (Cho et al., 1985). Similarly science teachers used examples to link abstract ideas and concrete things (Hume & Berry, 2011). Moreover, one of the teachers used model to represent chromosomal activity in mitosis and meiosis. The use of model to teach cell division topics are also common in literature (Clark, 2000; Kılınç, 2008; Mickle, 1990). Finally, science teachers used analogies to facilitate students' understandings. Analogies are usually used as types of representations for topic specific PCK studies (Hanuscin et al., 2010; Hume & Berry, 2011; Van Driel et al., 1998). However, science teachers used simple analogies. In another word, science teachers did not consider mapping, analogue concept, target concept, and breaking points. However, these concepts are important for good application of analogy technic (Brown & Salter, 2010; Mastrilli, 1997). Science teachers' lack of understanding about analogy technic can be related with their undergraduate method courses. If undergraduate method courses include analogy technic with its components, science teachers could better adapt analogy technic in their lessons.

Until now science teachers' syntactic content knowledge, substantive content knowledge and pedagogical content knowledge about cell division were discussed. Anymore, science teachers' content knowledge's impacts on their PCK are discussed. Because of PCK is the transformed version of other knowledge domains which are pedagogical knowledge, content knowledge and contextual knowledge, it is wondered how PCK is affected by other knowledge domains (Grossman, 1990; Magnusson et al., 1999). A good content knowledge is compulsive for PCK; however, good content knowledge does not guarantee well PCK (Magnusson et al., 1999). Hence, researchers examined the impact of content knowledge on PCK within different science topics (Akerson, 2005; Demirdöğen, 2012; Hanuscin et al., 2010; Kapyla et al., 2009; Kaya, 2009; Özden, 2008). Firstly, syntactic knowledge impact on science teachers' PCK can be discussed. Science teachers' nature of science knowledge showed that science teachers have insufficient knowledge about NOS. Because of science teachers have little knowledge on NOS, science teachers could not develop PCK for NOS in this study. Or science teachers did not show any indication of NOS teaching in their courses. However, this does not mean that if science teachers had adequate NOS knowledge, they could have well PCK for NOS. Because of understanding the content is pre-condition and science teachers had little knowledge about NOS, the only interpretation that can be done about science teachers PCK for NOS in cell division topics is that science teachers had no PCK for NOS. Stated differently, science teachers could not transform their limited NOS knowledge into the way that students can understand in cell division lessons. Second type of content knowledge that was investigated in this study is science teachers' substantive content knowledge about cell division.

Firstly, science teachers' content knowledge impact on their knowledge of curriculum is addressed. Horizontal relations are part of science teachers' knowledge of goals and objectives. Although science teachers claimed that genetics and cell division topics are related with each other, they did not claim that there are horizontal relations between evolution topics and cell divisions. For example; science teachers did not know that meiosis and genetic diversity provide raw material for natural selection which is the mechanism of evolution (Sadava et al., 2011). Similarly, modification of textbook and sorting objectives based on their importance can be related with teachers' content knowledge. One of the science teachers claimed that inheritance topic should be thought before mitosis because inheritance topic includes chromosome and chromosome related issues which are pre-requisite knowledge. When science teachers explained and drew cell division processes, it was seen that the teacher who claimed that inheritance should be taught before mitosis performed better in explanation of cell division processes. Moreover, this teacher was in process category in most of the basic cell division terms whilst other two teachers mostly placed in matter category. Science teachers' content knowledge may give insight about their dependence to curricular materials which is related with knowledge of curriculum too (Cochran et al., 1993). The teacher who was mostly in process category and had sound understanding did not depend on specific curricular sources when she answered students' needs and addressed students' difficulty in observations. On the other hand, other two teachers used prepared materials such as their notebook and power point presentations without making any changes and teachers were dependent to these materials in their teaching when they answer students' questions. These teachers who depend on the curricular materials had lack of knowledge on cell division processes.

Science teachers' content knowledge might be directly related with their knowledge of students' understandings (Magnusson et al., 1999; Veal & MaKinster, 1998). Science teachers claimed that cell topics and chromosome related structures are pre-requisite knowledge for cell division. However, they did not assert that basic genetic terms and their relationships are pre-requisite knowledge to understand cell division topics. Regarding their content knowledge science teachers could not have sound understanding about allele concept that is important for both cell division and genetics. Similarly, none of the participants could claim the law of independent assortment what happens in metaphase-1 and anaphase-1 connects cell division and genetics. This situation shows that science teachers had lack of understanding about the basic genetic terms and their relationships. Similarly, they did not assert that basic genetic terms and their relationships are pre-requisite knowledge to understand cell division. Therefore, science teachers' lack of knowledge about cell division and genetics relations might impede their knowledge of students' understandings too.

Content knowledge may also affect science teachers' knowledge of instructional strategies (Akerson, 2005; Appleton & Kindt, 1999; Aydın et al., 2010; Boz & Boz, 2008; Van Driel et al., 1998). Previous studies reported that science teachers who are content specialist are open to discussion and they are in more interaction with students. On the other hand, teachers who know less tend to use teacher led instructions such as direct instruction (Kind, 2009). Science teachers used direct instructions and questioning technics as subject specific strategies and this situation can be related with their lack of content knowledge in this study. Moreover, quality and quantity of the questions asked by teachers differed in current study. The teacher who knows more asked more questions than other teachers asked. Moreover, science teacher who know more asked procedural questions that include explanations whereas other teachers tended to use factual questions that have short answer and based on memory. These findings are consistent with Kapyla et al. (2009) and Yarden and Cohen (2009)'s study.

Activities are important component of knowledge of topic specific strategies. One of the teachers preferred to use problem solving activity in cell division topics. Problem solving activities found in literature mainly connect cell division and genetics each other (Clark, 2000; Kindfield, 1994; Williams et al., 2012). However, this teacher had lack of understanding the connection of cell division and genetics. This teacher led problem solving activities based on mathematical calculations and formulas such as the number of bacteria that produced in certain time. Or this teacher preferred to use problem solving activities about asexual reproduction that connect his teaching and students' daily life. In conclusion, science teacher's lack of understanding about genetics and cell division might be an obstacle for him to ask problem solving activity including genetics and cell division together.

Knowledge of representations is also important for knowledge of topic specific strategies. Drawing figure on board is part of illustrations that teacher used in their teaching. Two of the teachers could draw the events and processes about mitosis and meiosis in general. However, one of the teachers could not draw the meiosis and mitosis during pre-interviews. Two teachers who could draw the mitosis and meiosis correctly in pre-interviews also preferred to draw cell division events and concepts in their lecture. On the other hand, other teacher who cannot draw cell division stages correctly did not prefer to use drawings in his lessons. On the other hand, this teacher preferred to use visuals showing the processes of mitosis and meiosis. Hence, science teachers' knowledge about mitosis and meiosis might affect their drawings or illustrations that are part of knowledge of instructional strategies.

Similarly, science teachers preferred to use analogies to make abstract topics to be understandable for learners (Mastrilli, 1997). The teacher who performed better in substantive content knowledge pre-interview used more analogies than other teachers used. Hence, science teachers' substantive content knowledge can be related with the analogies that they used to make students become familiar to the concept. Another representation type that can be affected by teachers' content knowledge could be models. The teacher who knows more on chromosome, homolog chromosome, DNA, sister chromatids and chromatin fiber used a model where each of the board markers represent chromosome. On the other hand, other two teachers did not use or mention any models regarding cell division. Therefore, science teachers' use of models can be affected by their content knowledge. To sum up, there are some findings in this study that teachers' knowledge of instructional strategies can be affected by their content knowledge similar to previous research (Akerson, 2005; Boz & Boz, 2008; Van Driel et al., 1998).

In this chapter, science teachers' findings regarding content knowledge and PCK about cell division were discussed. Figure 5.1 summarized the findings of this study based on what was discussed in this chapter from a holistic way:

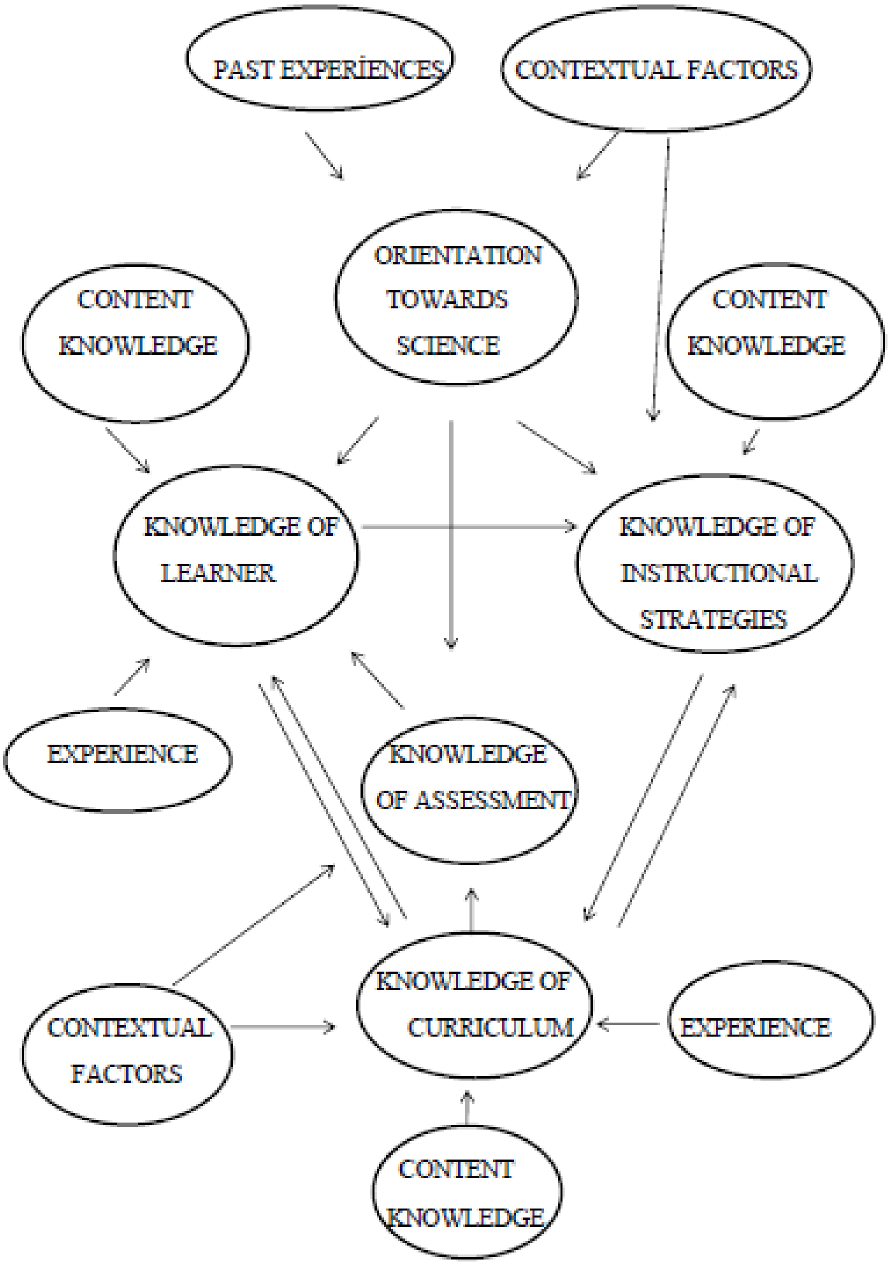

Figure 5.1. Summary of the Science Teachers' PCK and Content Knowledge about Cell Division

5.2. Implication & Recommendations

These results have important implications for science teachers, researchers and curriculum developers about PCK and content knowledge about cell division. This study revealed that science teachers have inadequate knowledge about syntactic knowledge and they have some problems in understanding cell division and connecting it with genetics. Moreover, science teachers have important deficiency about their orientation towards science, knowledge of instructional strategies and knowledge of assessments.

Depending on the findings of this study, it was shed light on science teachers need a professional development program including NOS, and substantive content knowledge about cell division. Firstly, this program should aim to increase science teachers' NOS knowledge. Moreover, NOS integration in cell division topics is essential. Therefore, professional development programs might start with historical development of cell division. For example; McComas (2012)'s study can guide to NOS part of the planned professional program. According to this plan, firstly different views about the mechanism of reproduction in the past can be presented to the teachers such as pangenesis. These different views about reproduction can be used to show that scientists use their creativity and imagination in their study. Moreover, when teachers learn the conditions of the time that scientists live, they can understand how scientists are affected by the society referring socio-cultural aspect of science. Later on, when teachers see the Watson's experiment that refutes the pangenesis, the idea which is supported by Darwin, they would appreciate the role of experiment and observations in science. Furthermore, teachers will understand that science is tentative after they learned the history of mitosis, chromosome and meiosis that follow pangenesis views. Moreover, historical development of cell division might inform teachers to understand the role of theories in science.

Science teachers' syntactic knowledge collaborates with substantive knowledge. Therefore, science teachers could have chance to improve their substantive content knowledge in planned professional development programs.

These programs should focus not only what cell division is but also what the function of cell division to increase teachers' understandings of cell division. Moreover, these programs should connect genetics and cell division. Emphasize on two points can be beneficial for teachers to understand the relation between cell division and genetics. These two points that should be pointed out are allele and the law of independent assortment. If teachers understand these two points, it is believed that they have the capability of connecting cell division and genetics.

Improvements of science teachers' content knowledge are not sufficient and there are some problems identified in this study that curriculum developers should cope with. First of all, curriculum developers should place specific NOS objectives in cell division topics such as: "Students will be able to comprehend that knowledge about mitosis and meiosis are the product of scientists' experiments and observations" to represent science is empirical based. Moreover, curriculum developers should focus on integration of cell division and genetics which are the different explanation of same phenomenon. If these suggestions are not adapted to the curriculum, science teachers may not be voluntarily to teach integration of NOS and connection between cell division and genetics because science teachers tend to teach what curricular objectives mention as it is understood by the findings of the current study.

Learning the content knowledge and curricular adaptations are not sufficient for teachers to teach NOS integrated cell division topics. Therefore, theoretical framework of this study, topic specific PCK, can be used in planned development program to increase how well science teachers teach NOS integrated cell division topics. Firstly, science teachers' orientation towards science needs to be changed based on the findings in these programs. However, orientation towards science is multidimensional and resistant to change (Luft & Roehring, 2007). Therefore, planned PD program should be long standing to change teachers' orientations. Otherwise, program could be unsuccessful for changing orientation towards science as shaping component of PCK. Science teachers' orientation towards science can be changed by conceptual change approach from teacher as knowledge transmitter to teacher adopting scientific literacy. It is believed that what scientific literacy is should be explained to teachers because findings of the study showed that teachers have insufficient knowledge about scientific literacy. Components of the scientific literacy which are NOS, STS, SPS and conceptual understanding should be recognized to the teachers. After teachers understand what scientific literacy is, it is advised that why science teachers give up their current orientation ‘knowledge transmission’ in this case. Science teachers should comprehend that knowledge transmission is teacher led and students are not included to teaching process actively when teachers use teacher led instructions. After teachers are persuaded that teacher led instructions are useless, the use of student centered or constructivist approcaches such as 5E Learning or argumentation can be taught to teachers. Before using constructivist approaches, science teachers should accept that constructivist approaches are understandable, acceptable and useful. Then, teachers should have chance in these programs to use constructivist approaches and these programs should expand to real science classes because it is usually observed that science teachers work on well performance in PD programs whilst they do not reflect this performance to actual classrooms (Guerra-Ramos, Ryder & Leach, 2009). Increase on science teachers’ knowledge about constructivist approaches results with the improvement of science teachers’ knowledge of instructional strategies.

Contextualized and explicit NOS instruction is advised in planned PD program (Michel & Neumann, 2014); moreover, constructivist approaches should accompany with contextualized and explicit NOS instruction. Science teachers could teach NOS embedded cell division courses by use of kid friendly terms, analogies and operational definitions because NOS instruction in cell division can be problematic when it is thought based on philosophical perspectives. In addition, pedagogical perspective should be focused (Guerra-Ramos et al., 2009). When science teachers’ knowledge of instructional strategies increase and they can understand students’ misconceptions about NOS and cell division more; hence their knowledge of students’ understanding can improve.

Teacher orientation based on scientific literacy takes his or her attention into SPS, STS, and NOS as an addition to attention towards conceptual understanding. If teachers care these scientific literacy components, they need to assess these components; hence their knowledge of assessment may increase. Increasing knowledge of assessment triggers to knowledge of students' understandings and science teachers could modify the curriculum based on students' needs as increasing of knowledge of curriculum. Similarly; science teachers could use the suitable instructional strategies after they increase their knowledge of students' understandings. To support this interaction between components of PCK and development of PCK, science teachers need to learn alternative assessment technics too. If planned PD programs teach alternative assessment technics; science teachers' knowledge of assessment could increase. This increase also could support teachers' PCK. Increase on teachers' PCK affects the quality of science teaching positively too.

Another implication of the current study is related with science teachers. Findings of this study can be seen as a pool including knowledge about teachers' experience on cell division. Teachers who read this product can benefit without any experiences regarding cell division. For example; a pre-service teacher could be aware of students' misconceptions about cell division reported here and this teacher looks for the ways of eliminating misconceptions referred in the study. Moreover, teachers could be aware of the possible activities and representations about cell division such as board marker model representing chromosomes, experiment of vegetative reproduction of Benjamin plant and poster activity. In conclusion; Bucat (2004)'s suggestion could be realized for the use of experienced teachers' knowledge by other teachers.

Results of the study can also be implemented to pre-service education programs. Science teachers in this study did not know the alternative assessment technics and student centered instructions. Therefore, education faculties should give priority to assessment courses. Similarly, science method courses should focus on teaching student centered instructions such as conceptual change approach, inquiry and argumentations. Moreover, science teachers' orientations were teacher led and science teachers' orientations are shaped by their experiences. Science teachers' instructors in university can be role model for them; therefore their instructors should also adopt student centered instructions in their courses.

Moreover, this study showed that science teachers do not have grasp PCK and content knowledge about cell division. Hence; teacher training programs should focus on specific science topics and care how different science topics could be taught to learners because each topic has its own instructional strategies, assessments, curriculum and difficulties.

There are also some recommendations for further studies in this study. Firstly, it is recommended science educators to study on more specific issues about PCK because PCK is a complex structure and explanation of the broad topics such as cell division could be exhaustive and difficult to interpret. Hence, it is recommended science teachers to study mitosis and meiosis studies separately in PCK studies. Moreover, separate PCK studies results for mitosis and meiosis can be different in future studies showing that PCK could be more topic specific than it is thought.

Moreover, V-NOS C was used to understand science teachers' NOS knowledge in this study. Science educators can develop their own context based NOS tools to understand teachers' NOS knowledge. Context based NOS tools could be more topic specific which support theoretical framework of current study 'topic specific PCK' in this case.

In this study, Magnusson et al. (1999) model was used to understand participants' PCK. According to this model all components of the PCK is interacted with each other. Although there are some insights about the interactions, some components could be independent from each other as claimed in integrative models. For example; transformative models claimed that science teachers' knowledge of assessment feeds their knowledge of learner. However, science teachers did not have the knowledge about alternative assessment technics implying science teachers have limited knowledge of assessment. On the other hand; science teachers were knowledgeable about knowledge of learner. This situation cannot be explained only by use of transformative models as Magnusson et al. (1999) model in this study. Instead of this explanation, explanation of the integrative models for components of PCK can be more useful related science teachers' knowledge of learner. Integrative models suggest that science teachers' knowledge of learner increase by the experience as reported in current study which does not require development of knowledge of assessment. Therefore, it is recommended science educators to use also integrative PCK models such as Veal and MaKinster (1998) model for PCK.

This study gave some insight about the impact of content knowledge on PCK. Hence, the PCK studies could be focus on their relationship by use of qualitative, quantitative and mixed method in the future. Similarly, PCK studies could integrate learning and teaching each other, thus the following studies could be conducted with teachers PCK, student achievement and their relationships. Finally, science teachers' PCK regarding cell division can be replicated with pre-service teachers to show how well experience affects teachers' PCK. Similarly, this study can be replicated in public schools and findings can be compared with current study to show that PCK is context specific. Moreover, cross cultural PCK studies can be conducted to see how different cultures affect teachers' PCK in specific science topics.

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APPENDICES

APPENDIX A

VNOS (C)

1. What, in your view, is science? What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?
2. What is an experiment?

3. Does the development of scientific knowledge **require** experiments?
   •If yes, explain why. Give an example to defend your position.
   • If no, explain why. Give an example to defend your position.

4. Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom? What specific evidence, or types of evidence, **do you think** scientists used to determine what an atom looks like?

5. Is there a difference between a scientific theory and a scientific law? Illustrate your answer with an example.

6. After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
   If you believe that scientific theories do not change, explain why. Defend your answer with examples. If you believe that scientific theories do change: (a) Explain why theories change? (b) Explain why we bother to learn scientific theories. Defend your answer with examples.

7. Science textbooks often define a species as a group of organisms that share similar characteristics and can interbreed with one another to produce fertile offspring. How certain are scientists about their characterization of what a species is? What specific evidence **do you think** scientists used to determine what a species is?

8. Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?

• If yes, then at which stages of the investigations do you believe that scientists use their imagination and creativity: planning and design; data collection; after data collection? Please explain why scientists use imagination and creativity. Provide examples if appropriate.

• If you believe that scientists do not use imagination and creativity, please explain why. Provide examples if appropriate.

9. It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy wide support. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these **different conclusions** possible if scientists in both groups have access to and **use the same set of data** to derive their conclusions?

10. Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced.

• If you believe that science reflects social and cultural values, explain why and how. Defend your answer with examples.

• If you believe that science is universal, explain why and how. Defend your answer with examples.

11. What is observation? What is difference? What is the difference between observation and inference?

APPENDIX B

VNOS-C

1-a) Sizce, bilim nedir?

1-b) Bilimi (ya da fizik, kimya, biyoloji gibi bilimsel alanları) din ve felsefe gibi disiplinlerden ayıran nedir? Açıklayınız.

2- Deney sizce nedir?
3-a) Bilimsel bilginin gelişmesi için her zaman deney gerekli midir?

- Eğer gerekli olduğunu düşünüyorsanız, niçin olduğunu örneklerle açıklayınız.
- Eğer deneylerin her zaman gerekli olmadığını düşünüyorsanız niçin olduğunu örneklerle açıklayınız.

3-b) Bilimsel bilgi sadece deney yapılarak mı gelişir? (Bu soru 3-a sorusunda katılımcı bilimsel metot ile ilgili cevap vermediği takdirde sorulacaktır.)

- Eğer bilimsel bilginin sadece deney yoluyla gelişeceğini düşünüyorsanız nedeninizi açıklayınız.
- Eğer bilimsel bilginin gelişiminde deneyden başka yöntemlerinde olduğunu düşünüyorsanız, bu yöntemlere örnek verir misiniz?

4- Fen kitapları atomu genellikle protonlar (pozitif yüklü parçacıklar) ve nötronlardan (yüksüz parçacıklar) oluşan bir çekirdek ve çekirdeğin etrafında dönen elektronlar (negatif yüklü parçacıklar) olarak anlatır.Size göre bilim insanları atomun yapısı hakkında ne kadar emin olabilirler? Bilim insanlarının atomun yapısına karar verirken ne gibi kanıtlardan yararlanmış olabileceklerini düşünüyorsunuz?

5-Bilimsel teoriler ve bilimsel kanunlar arasında bir fark varmıdır? Cevabınızı örnek vererek açıklayınız.

6-Bilim insanlarının geliştirdikleri teoriler (örneğin atom teorisi, evrim teorisi, hücre teorisi) zamanla değişirler mi?

- Eğer bilimsel teorilerin değişeceğine inanıyorsanız, niçin olduğunu açıklayınız. Sizce bu durumda niçin bilimsel teorileri öğreniyoruz? Görüşlerinizi örneklerle açıklayınız.

- Eğer bilimsel teorilerin değismeyeceğine inanıyorsanız, niçin olduğunu açıklayınız. Görüşlerinizi örneklerle açıklayınız.

7-Fen kitapları genellikle tür kavramını “ortak özellikleri paylaşan ve birbirleriyle çifleştiklerinde verimli döller verebilen organizma grupları” olarak tanımlar. Bilim insanları “tür” kavramını tanımlarken ne kadar emin olabilirler ve ne gibi kanıtlardan yararlanmışlardır?

8-Bilim insanları ortaya attıkları sorulara cevap bulmaya çalışırken deneyler/araştırmalar yaparlar. Size göre bilim insanları bu araştırmalar/deneyler sırasında hayal güçlerini ve yaratıcılıklarını kullanırlar mı?

- Eğer kullandıklarını düşünüyorsanız, hayal gücü ve yaratıcılıklarını araştırmalarının hangi aşamalarında (planlama ve tasarım, veri toplama, verileri inceleme-değerlendirme vb.) kullanır? Cevabınızı uygun örneklerle açıklayınız.
- Eğer kullanmadıklarını düşünüyorsanız nedenini uygun örneklerle açıklayınız.

9-Dinazorların 65 milyon yıl önce nesillerinin tükendiğine inanılmaktadır. Bu yokoluşu açıklayan kabul görmüş iki farklı hipotez ileri sürülmüştür. Bir grup bilim insanı tarafından öne sürülen hipotez, 65 milyon yıl önce dünyaya büyük bir meteorun çarptığı ve bu çarpmanın yokoluşa neden olan olaylar zincirini başlattığı şeklindedir. Diğer bir grup bilim insanı ise büyük ve şiddetli volkanik patlamaların bu yokoluşa sebep olduğu şeklindeki ikinci hipotezi ileri sürmüştür. Size göre aynı verilere ulaşan ve aynı verileri kullanan bilim insanlarının farklı sonuçlara ulaşması nasıl mümkün olabilmiştir? (Gerektiği takdirde katılımcılara veri olarak iridyum örneği verilecektir.)

10-Bazı iddialara göre bilim oluşturulduğu toplumun değerlerinden etkilenir-sosyal, kültürel değerler, felsefik varsayımlar ve entellektüel normlar gibi. Bazı iddialara göre ise bilim evrenseldir, sosyal, kültürel değerler, felsefik varsayımlar ve entellektüel normlar gibi kavramlardan bağımsızdır.

- Eğer bilimin sosyal, kültürel değerlere bağımlı olduğunu düşünüyorsanız, nedenini uygun örneklerle açıklayınız.
- Eğer bilimin sosyal, kültürel değerlerden bağımsız olduğunu düşünüyorsanız nedenini uygun örneklerle açıklayınız.

11- a) Gözlem nedir?

11-b) Çıkarım nedir?

11-c) Gözlem ile çıkarım arasında fark var mıdır? Lütfen cevabınızı açıklayınız.

APPENDIX C

Cell Division Substantive Content Knowledge Questions

a)

1. A) Cell

B) Chromosome

C) Gene

D) Allele

E) DNA

F) Organism

G) Nucleus

Some basic terms regarding cell division were given above. Write the items in order of size. Start with the largest.

Basic Terms: Please answer basic concepts related with cell division.

2. What is chromosome? Could you explain your answer?

a. What is the function of chromosome?

3. What is homologous chromosome? Could you explain your answer?

4. What is DNA? Could you explain your answer?

5. What is gene? Could you explain your answer?

6. What is allele? Could you explain your answer?

7. What is sister chromatids? When are they formed?

8. What is centrosome? Could you explain your answer?

9. What is centriole? Could you explain your answer?

10. What is centromere? Could you explain your answer?

11. What is kinetochore? Could you explain your answer?

12. What is asexual reproduction? Could you explain your answer?

13. What is sexual reproduction? Could you explain your answer?

14. What is somatic cell? Could you explain your answer?

15. What is gamete? Could you explain your answer?

16. What is zygote? Could you explain your answer?

b) ***Cell Cycle***

17. What is cell cycle? Could you draw it?

- Could you explain your drawings? Please indicate the direction of the cell cycle on your drawings.

c) ***Mitosis***

18. a) What is mitosis?

b) Which cells do undergo mitosis?

c) Could you draw mitosis of an animal cell (2n=4 chromosomes) that undergo mitosis?

Explain the stages of the mitosis.

a. Could you explain what happens in prophase?
b. Could you explain what happens in metaphase?
c. Could you explain what happens in anaphase?
d. Could you explain what happens in telophase?

19. If this cell was a plant cell, what would be the differences of stages and events occurred in mitosis?

- If yes, what are the differences?
- If no, please explain your answer.

d) ***Meiosis***

20. a) What is meiosis in your opinion? Could you explain your answer?

b) What is the importance of meiosis in your opinion? Could you explain your answer?

c) Could you draw meiosis of an animal cell (2n=4 chromosomes) that undergo meiosis?

Explain the stages of the meiosis.

a. Could you explain what happens in prophase-1?

b. Could you explain what happens in metaphase-1?

c. Could you explain what happens in anaphase-1?
d. Could you explain what happens in telophase-1?
e. What happens after telophase-1?
f. Could you explain what happens in prophase-2?
g. Could you explain what happens in metaphase-2?
h. Could you explain what happens in anaphase-2?
i. Could you explain what happens in telophase-2?

21. What are basic terms unique to meiosis in your opinion? Can you explain these concepts?

22. If this cell was a plant cell, what would you want to add?

- Does plant cell undergo meiosis?
- If yes, does it undergo meiosis similar to animal cell?
- If no, please explain your answer.
- Is there a difference between animal cell and plant cell regarding meiosis?
- If yes, what are the differences?
- If no, please explain your answer.

23. Is there a relationship between meiosis and anyone of the genetics principle?

- If yes, what is this principle? Can you explain this principle and its relationship with meiosis?
- If no, please explain your answer.

24. What are the differences/similarities between the meiosis and mitosis? Could you explain your answer?

APPENDIX D

Hücre Bölünmesi Konu Kavrama Soruları

a)

1. A) Hücre

B) Kromozom

C) Gen

D) Allel

E) DNA

F) Organizma

G) Çekirdek

Yukarıda hücre bölünmesi ile ilgili bir dizi temel kavram verilmiştir. Bu kavramları büyükten küçüğe doğru sıralayınız.

Temel Kavramlar: Hücre bölünmesi ile ilgili temel kavramları lütfen yanıtlayınız.

2. Kromozom nedir? Cevabınızı açıklar mısınız?
   a. Kromozomun görevi nedir?
3. Homolog kromozom nedir? Cevabınızı açıklar mısınız?
4. DNA nedir? Cevabınızı açıklar mısınız?
5. Gen ne demektir? Cevabınızı açıklar mısınız?
6. Allel ne demektir? Cevabınızı açıklar mısınız?
7. Kardeş kromatit nedir? Ne zaman oluşur?
8. Sentrozom nedir? Cevabınızı açıklar mısınız?
9. Sentriol nedir? Cevabınızı açıklar mısınız?
10. Sentromer nedir? Cevabınızı açıklar mısınız?
11. Kinetokor nedir? Cevabınızı açıklar mısınız?
12. Eşeysiz üreme nedir? Cevabınızı açıklar mısınız?
13. Eşeyli üreme nedir? Cevabınızı açıklar mısınız?
14. Somatik hücre nedir? Cevabınızı açıklar mısınız?
15. Gamet nedir? Cevabınızı açıklar mısınız?
16. Zigot nedir? Cevabınızı açıklar mısınız?

b)Hücre döngüsü

17. Hücre döngüsü nedir? Çizer misiniz? (Bu aşamada araştırmacı çalışmaya katılan öğretmenlere hücre döngüsünü gösteren şekiller çizmeleri için boş kağıt verecektir.)

- Çiziminizi açıklar mısınız? Çiziminizde hücre döngüsünün yönünü belirtiniz.

c) Mitoz

18. a) Mitoz bölünme nedir?

b) Mitoz bölünme hangi hücrelerde gerçekleşir?

c) Mitoz bölünme geçirmekte olan 2n=4 kromozomlu hayvan hücresini çizermisiniz? (Bu aşamada araştırmacı, çalışmaya katılan öğretmenlerin mitoz bölünme ile ilgili çizimler yapabilmesi için öğretmenlere daha önce hazırlamış olduğu mitoz bölünme şablonlarını verecektir.)

Çizdiğiniz şekillerde önemli olduğunu düşündüğünüz yerleri ok çıkartarak gösteriniz.(Eksik ve yanlış gösterimler araştırmacı tarafından tekrar sorulacaktır.)

Mitoz bölünmenin fazlarını açıklayınız.

a. Mitoz bölünmenin profaz aşamasında meydana gelen olaylar nelerdir açıklar mısınız?

b. Mitoz bölünmenin metafaz aşamasında meydana gelen olaylar nelerdir açıklar mısınız?

c. Mitoz bölünmenin anafaz aşamasında meydana gelen olaylar nelerdir açıklar mısınız?

d. Mitoz bölünmenin telofaz aşamasında meydana gelen olaylar nelerdir açıklar mısınız?

19. Eğer mitoz bölünme geçiren bir bitki hücresi olsaydı mitoz bölünme fazlarında ve gerçekleşen olaylarda farklılıklar olur muydu?

- Varsa, bu farklılıklar nelerdir? Cevabınızı açıklar mısınız?
- Yoksa, neden böyle düşündüğünüzü açıklar mısınız?

d) Mayoz

20. a) Size göre, Mayoz bölünme nedir? Cevabınızı açıklar mısınız?

b) Sizce, Mayoz bölünmenin önemi nedir? Cevabınızı açıklar mısınız?

c) 2n=4 kromozomlu bir hayvan hücresindeki mayoz bölünmeyi fazları ile beraber çiziniz. Her bir fazda önemli gördüğünüz yerleri ok çıkartarak gösteriniz.

(Bu aşamada araştırmacı, çalışmaya katılan öğretmenlerin mayoz bölünme ile ilgili çizimler yapabilmesi için öğretmenlere daha önce hazırlamış olduğu mayoz bölünme şablonlarını verecektir.)

a. Mayoz bölünmenin profaz-1 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

b. Mayoz bölünmenin metafaz-1 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

c. Mayoz bölünmenin anafaz-1 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

d. Mayoz bölünmenin telofaz-1 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

e. Telofaz-1 den sonra ne olur?

f. Mayoz bölünmenin profaz-2 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

g. Mayoz bölünmenin metafaz-2 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

h. Mayoz bölünmenin anafaz-2 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

ı. Mayoz bölünmenin telofaz-2 aşamasında gerçekleşen olaylar nelerdir? Açıklayınız.

21. Mayoz bölünme deyince aklınıza gelen temel kavramlar nelerdir? Bu kavramları açıklar mısınız?

22. Eğer bu hücre bitki hücresi olsaydı mayoz bölünme hakkında ne söylerdiniz?

- ➢ Bitki hücresi mayoz bölünme geçirir mi?
- ➢ Eğer geçirirse hayvan hücresi gibi mi mayoz bölünme geçirir?
- ➢ Eğer geçirmezse neden böyle düşündüğünüzü açıklayınız.
- ➢ Bitki ve hayvan hücresinin geçirdiği mayoz bölünmeler arasında fark var mıdır?
- ➢ Eğer varsa bu fark/farklar nelerdir?
- ➢ Eğer bitki ve hayvan hücresindeki mayoz bölünmeler arasında herhangi bir fark olmadığını düşünüyorsanız, neden böyle düşündüğünüzü açıklayınız.

23. Mayoz bölünme ile herhangi bir genetik prensibinin ilişkisi var mıdır?

- ➢ Eğer varsa bu yasa nedir? Bu yasayı ve bu yasanın mayoz ile olan ilişkisini açıklar mısınız?

- Eğer yoksa neden böyle düşündüğünüzü açıklayınız.

24. Genel olarak mayoz bölünme ile mitoz bölünme arasında ne gibi farklılıklar/ benzerlikler vardır? Cevabınızı açıklar mısınız?

Hint-1: Mayoz geçiren bir hücre mayoz sırasında kaç defa bölünür?Mitoz geçiren bir hücre mitoz sırasında kaç defa bölünür?

Hint-2: Mayoz bölünme sonucu kaç hücre oluşur? Mitoz bölünme sonucu kaç hücre oluşur?

Hint-3: Mayoz geçiren bir hücrenin taşımış olduğu genetik bilgi değişir mi? Mitoz geçiren bir hücrenin taşımış olduğu genetik bilgi değişir mi?

Hint-4: Her iki hücre bölünmesi sonucunda hücrelerin taşıdıkları kromozom sayısı değişir mi? eğer değişirse nasıl bir değişim olur?

Hint-5: Mayoz ve mitoz bölünmenin hızları arasında fark var mıdır? Eğer varsa hangi bölünme daha hızlıdır? Hücre bölünmelerinin süreleri hakkında bilginiz var mı? cevabınızı açıklar mısınız?

Hint-6: Mitoz ve mayoz bölünmenin hücre döngüsü ile ilgisi var mıdır? Eğer varsa bu ilişki nedir? Cevabınızı açıklar mısınız?

Hint-7: Mayoz bölünmede olan fakat mitoz bölünmede görülmeyen yapı ve olaylar var mıdır? Eğer varsa bu yapılar ve olaylar nelerdir?

Hint-8: İnsan vücudunda hangi hücreler mitoz geçirir, hangi hücreler mayoz bölünme geçirir? Cevabınızı açıklayınız.

APPENDIX E

PCK Pre-Interview Questions

1-Orientation towards science Teaching

1. What do you understand about the term "science teaching"? Can you explain your answer?
2. What are the goals of science teaching in your opinion? Can you explain your answer?
3. As a science teacher, what is the meaning of teaching cell division topics for you?
   a. Why do you teach cell division topics as a science teacher?

2- Knowledge of Science Curriculum

1. Why do cell division topics place in curriculum? Can you explain your answer?

2. Do you know the place of cell division in curriculum?

- In which grade level is cell division taught?
- What is the number of unit that cell division is taught?
- What are the topics taught before and after this unit?

3.Does cell division topics are related with other science topics, units and grades level?

- Is there any science topic taught in earlier grades related with cell division?
  If yes, which science topics are related with cell division in earlier grade?
- Is there any science topic taught in 8^{th} grade level related with cell division?
  If yes, which science topics are related with cell division in 8^{th} grade?
- If no, please explain your answer

4. What are the objectives with respect to cell division found in curriculum?
5. Could you sort the objectives based on their importance?
6. Is there any important point to be emphasized for you apart from existing objectives?
   - If yes what are the important points?
   - If no, please explain your answer
7. Is there any limitations implied in curriculum regarding cell division? Is there any misconception implied in curriculum regarding cell division?
   - If yes, what are these misconceptions and limitations?
   - If no, please explain your answer.
8. What are the sources that you use in cell division topics?
   - If you use, can you explain your aim of use selected source?

- If no, please explain your answer.

3-Knowledge of Students' Understanding of Science

1. What prior knowledge should students have to understand cell division topic? Can you explain your answer?
2. Which points do your students have difficulty in understanding cell division topics, in your opinion?
3. What are the reasons of students' difficulties regarding cell division?
4. Do your students have misconception regarding cell division? If yes, what are the students' misconceptions regarding cell division?
5. What are the sources of students' misconceptions regarding cell division?
6. Do you identify students' misconceptions?
   - If yes, how do you identify students' misconceptions regarding cell division?
   - If no, why do not identify students' misconceptions?
7. Do you remediate students' misconceptions?
   - If yes, how do you remediate students' misconceptions regarding cell division?
   - If no, why do not remediate students' misconceptions?

4.Knowledge of Assessment

1. What do you want to assess in depth when you assess your students' knowledge in terms of cell division topics?
2. Which assessment techniques do you use when you assess your students regarding cell division? Can you explain why did you prefer this technic?
   - Why did not you prefer other assessment technics?
3. When do you assess your students regarding cell division?
   - Why did you prefer to use this period?

5.Knowledge of Instructional Strategies

1. When you teach science concept in general, which teaching method, strategy and technic do you prefer to use? Can you explain the reason that use of selected strategy.

2. Do you conduct activities in class regarding cell division?

   - If you conduct, what are these activities?
   - If no, explain why you do not conduct activity.
3. What are the activities that you conduct when you specifically teach mitosis?
   - Can you explain the reason why you preferred to use this activity?
4. What are the activities that you conduct when you specifically teach the role of chromosomes in cell division?
   - Can you explain the reason why you preferred to use this activity?

5. What are the activities that you conduct when you specifically teach asexual reproduction?

- Can you explain the reason why you preferred to use this activity?

6. What are the activities that you conduct when you specifically teach meiosis?

- Can you explain the reason why you preferred to use this activity?

7. What are the activities that you conduct when you specifically teach sexual reproduction?

- Can you explain the reason why you preferred to use this activity?

8. What are the activities that you conduct when you specifically teach crossing over?

- Can you explain the reason why you preferred to use this activity?

9. What are the activities that you conduct when you specifically teach the differences and similarities between mitosis and meiosis?

- Can you explain the reason why you preferred to use this activity?

10. Do you use illustrations, examples, models, drawings, and analogues to assist students' learning cell division topics and concepts?

- If yes what are the representations that you used in cell division lesson?
- If yes, what are these representations and can you give examples of these representations?
- If no, why do not you use illustrations, examples, models, drawings, and analogues?

APPENDIX F

PAB Ön Görüşme Sorular

1-Fen Öğretimine karşı Yönelimler

1. Size göre "fen öğretmek" ne anlama gelmektedir? Düşüncelerinizi açıklar mısınız?
2. Sizce genel anlamda fen öğretiminin amacı/amaçları nedir? Cevabınızı açıklar mısınız?
3. Özel olarak "Hücre bölünmesi" konusunu ele alırsak bir fen bilgisi öğretmeni olarak bu konuyu öğretmek sizin için ne anlama geliyor? Cevabınızı açıklar mısınız?
   a) Hücre bölünmesi konusunu siz, neden öğretiyorsunuz?

2-Müfredat Bilgisi

1. Sizce hücre bölünmesi konularına öğretim programında neden yer verilmiştir? (Bu konunun öğretmenlerin öğretim programına göre konunun önemine vurgu yapmaları beklenmektedir.)

2. Hücre bölünmesi knoularının müfredattaki yerini biliyor musunuz?
   - Sizce "Hücre Bölünmesi" konusu kaçıncı sınıfta okutulmaktadır?
   - Hücre bölünmesi konusu (8.sınıf ders programında) kaçıncı ünitedir?
   - Bu konulardan önceki ve sonraki üniteler nelerdir? Cevabınızı açıklar mısınız?
3. Öğretim programında hücre bölünmesi konuları diğer konularla, ünitelerle veya sınıflarla ilişkilendirilmiş mi?
   - Eğer ilişkilendirilmişse önceki yıllarda işlenen hangi fen konuları ile ilişkilidir?
   - Eğer ilişkilendirilmişse 8.sınıftaki hangi konularla ilişkilendirilmiştir?
   - Eğer ilişkilendirilmemişse, sizce hangi konularla ilişkilendirilse konunun öğretimi ve öğrenilmesi daha iyi olur? Neden böyle düşündüğünüzü açıklayınız.
4. Fen bilgisi öğretim programında hücre bölünmesi ile ilgili olarak öğretilmesi amaçlanan temel kazanımlar nelerdir?
5. Bu kazanımları önem sırasına göre sıralar mısınız?
6. Bu kazanımlardan farklı olarak sizin hücre bölünmesi konuları ile ilgili önemli gördüğünüz noktalar var mıdır?
   - Eğer varsa nelerdir? Cevabınızı açıklar mısınız?
   - Yoksa neden böyle düşündüğünüzü açıklar mısınız.
7. Fen bilgisi öğretim programında hücre bölünmesi ile ilgili kavram yanılgılarına ve konunun anlatımı sırasında uyulması gereken sınırlamalara yer verilmiş midir?
   - Eğer varsa, belirtilen kavram yanılgıları ve sınırlamalar nelerdir?
     - Yoksa neden böyle düşündüğünüzü açıklar mısınız.

8. Öğrencilerinize hücre bölünmesi konularını anlatırken hangi kaynakları kullanıyor sunuz?

- Eğer kullanıyorsanız, bu kaynakları hangi amaçla kullanıyorsunuz?

Hint: içerik bilgisi öğretmek, öğrenmelerini ölçmek, bilimsel süreç becerilerini geliştirmek...

- Eğer kullanmıyorsanız neden kullanmaya ihtiyaç duymadığınızı açıklar mısınız?

3. Öğrenci Bilgisi

1. Sizce öğrencilerinizin hücre bölünmesi konusunu öğrenebilmeleri için gerekli olan ön bilgiler neler olmalıdır? Neden böyle düşünüyorsunuz? Cevabınızı açıklar mısınız?
2. Öğrencilerinizin hücre bölünmesi ile ilgili olarak, hangi konuları anlamakta zorluk çektiklerini düşünüyorsunuz?
3. Sizce öğrencilerinizin bu konuları anlamakta zorlanmalarının sebepleri nelerdir?
4. Öğrencilerinizin hücre bölünmesi ile ilgili kavram yanılgıları var mıdır? Varsa bu kavram yanılgıları nelerdir? Cevabınızı açıklarmısınız?
5. Öğrencilerinizin hücre bölünmesi ile ilgili sahip oldukları kavram yanılgılarının nedenleri sizce neler olabilir?

Hint: Ders kitabı, öğretmen, günlük hayattaki tecrübeler vs.

6. Öğrencilerinizin hücre bölünmesinde sahip olduğu kavram yanılgılarını nasıl saptarsınız?Kavram yanılgılarını saptamak için hangi yöntemleri kullanıyor sunuz?
- Eğer öğrencilerinizin kavram yanılgılarını saptamıyorsanız nedenini belirtiniz.

7. Saptadığınız bu kavram yanılgılarını gidermeye çalışıyor musunuz?
- Cevabınız evet ise, Kavram yanılgılarını gidermek için hangi yöntemleri kullanıyorsunuz?

Hint: kavram haritası, kavramsal değişim metinleri, iki basamaklı testler vs.

- Kavram yanılgısını gidermek için neden bu yöntemi seçtiğinizi açıklar mısınız?
- Sizce bu yöntem kavram yanılgısını gidermek için yeterli mi?
- Neden yeterli/ neden yeterli değil?
- Cevabınız hayır ise neden kavram yanılgılarını gidermediğinizi açıklar mısınız?

4.Değerlendirme Stratejileri Bilgisi

1. Öğrencilerinizin hücre bölünmesi ile ilgili bilgilerini ölçerken tam olarak neyi ölçmeyi hedefliyorsunuz?

Hint: İçerik bilgisi, bilimsel süreç becerileri, problem çözme yeteneği, bilimin doğası bilgisi

2. Hücre bölünmesi konularınında hangi ölçme ve değerlendirme yöntemlerini kullanıyor sunuz? Neden bu yöntemi seçtiğinizi açıklar mısınız?

Hint: Alternatif yöntemler; performans, portfolyo, proje, akran değerlendirmesi, kendi kendini değerlendirme ve geleneksel yöntemler; çoktan seçmeli, eşleştirmeli, doğru yanlış, boşluk doldurma, yazılı-sözlü sınav.

- Neden diğer ölçme ve değerlendirme yöntemlerini tercih etmediğinizi açıklar mısınız?

3. Öğrencilerinizin öğrenmelerini ne zaman ölçüyorsunuz? (Ünitenin hangi aşamasında ölçüyorsunuz?)

Hint: Dersin sonunda, dersin başında,dersin ortasında vs.

- Neden bu zaman dilimini seçtiğinizi açıklar mısınız?

5.Öğretim Stratejileri Bilgisi

1. Genel olarak fen konularını öğretirken hangi öğretim strateji, metot ya da öğretim yöntemlerini kullanıyorsunuz? Bu strateji, metot yada yöntemi kullanma nedenlerinizi belirtiniz.

Hint: 5E öğrenme halkası, kavramsal değişim yaklaşımı vs.

2. Hücre bölünmesi ile ilgili sınıfta etkinlik yapıyor musunuz?

- Eğer yapıyorsanız bu etkinlikler nelerdir?

Hint: programda belirtilen etkinlikler: hücreler bölünüyor, mitozun evrelerini gösterelim, kontrol altına alınamayan hücreler, mitoz, üreme hücreleri nasıl oluşur, hücre bölünmesi kavram haritası oluşturalım, mayoz neden önemli.

- Eğer hücre bölünmesi ile ilgili etkinlik yapmıyorsanız neden etkinlik yapmadığınızı açıklayınız.

Hint: malzeme eksikliği, imkanlar, süre yetersizliği vs.

3.Özel olarak, Mitoz bölünme konusunu öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyor sunuz?

- ➢ Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

Hint: Gösteri yöntemi, labaratuvar yöntemi, proje yöntemi, modelleme, ders gezileri, argumentasyon, problem çözme, keşif etme vs.

4. Özel olarak, kromozomların hücre bölünmesindeki rolünü öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyor sunuz?
- ➢ Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

5. Özel olarak, eşeysiz üreme konusunu işlerken hangi öğretim yöntemini/ yöntemlerini kullanıyor sunuz?
- ➢ Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

6. Özel olarak, mayoz bölünmeyi öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyor sunuz?
- ➢ Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

7. Özel olarak, eşeyli üreme konusunu öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyor sunuz?
- ➢ Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

8. Özel olarak, parça değişimi konusunu öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyor sunuz?
- ➢ Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

9. Özel olarak, mitoz ve mayoz bölünme arasındaki benzerlikleri ve farklılıkları anlatırken hangi öğretim yöntemini/ yöntemlerini kullanıyor sunuz?
- ➢ Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

10. Öğrencilerinizin hücre bölünmesi konularını öğrenmeleri ve kavramlarını anlamaları için gösterimler, figürler, simülasyonlar, çizimler yada meteforlar kullanıyor musunuz?

- ➢ Eğer gösterimler, figürler, simülasyonlar, çizimler yada meteforlar vs. kullanıyorsanız bunlar nelerdir? Cevabınızı açıklayınız.
- ➢ Eğer gösterimler, figürler, simülasyonlar, çizimler yada meteforlar kullanıyorsanız kullandığınız bu gösterimlere örnek verir misiniz?
- ➢ Eğer gösterimler, figürler, simülasyonlar, çizimler yada meteforlar vs. kullanmıyorsanız, neden bu gösterimleri kullanmadığınızı açıklar mınız?

APPENDIX G

Selim's PCK Post-Interview

1. Although you said that you use test book to prepare students to High School Entrance Exam, you did not use test book during observation. Can you explain the reason for the discrepancy occured between pre-interviews and observations?
2. Can you explain the reason why you used notebook during observations because you did not mention use of notebook in pre-interviews?
3. Although you claimed that students have no misconceptions regarding cell division because it is their first time experience about the topic, you have identified many misconceptions that students hold. What do you think about this situation?
4. What are the sources of students' misconceptions regarding cell division?
5. Why did you only assess students' conceptual understandings during the course?
6. When I asked you the assessment methods that you used regarding cell division, you did not mention the concept map. However, you used this technic in your teaching during observations. What is the reason of this difference?
7. Although you said that you conduct play dough activity in class regarding mitosis, you did not conduct this activity during observations. Can you explain the reason for the discrepancy occured between pre-interviews and observations?
8. Why did you conduct the vegetative reproduction activity even you did not mention it in pre-interviews?
9. When you compared the differences between mitosis and meiosis, argumentation aroused in your class. Some of the students claimed that visual belong to mitosis because homolog chromosomes do not exist together, on the other hand some others thought that this visual belongs to meiosis because different chromosomes attach each other in visual. What do you think about the situation arose in class?

APPENDIX H

Burcu’s Post Interview PCK

1. Although you said that you actively use exercise book and textbook in pre-interviews. You did not use these curricular materials during observations. Can you explain the reason of discrepancy occurred between pre-interviews and observations?

2. Although you said that you conduct experiment related with reproduction of yeast in pre-interviews; however, you did not conduct this experiment during observations. Can you explain the reason of discrepancy occurred between pre-interviews and observations?

APPENDIX I

Ahmet's Post-Interview PCK

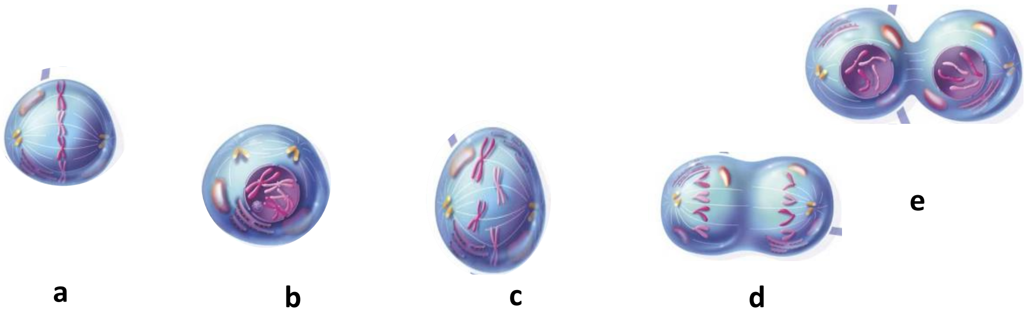
1. Although you mentioned that you wanted students to connect science learnt in class and daily life in pre-interviews, you did not relate science and daily life so much. What is the reason of this discrepancy? Can you explain the reason?
2. During your teaching, I observed that you actively used high-school biology textbook. Can you explain that why did you use high school biology textbook?
3. Although you mentioned that you used drama to assess your students, you did not conduct drama in your teaching. What is the reason of this discrepancy? Can you explain the reason?
4. Why do you prefer to choose teacher centered methods, strategy and technics in your teaching during observations?
5. Although you mentioned that you conduct activities found in exercise book, you did not use exercise book. Can you explain the reason why you did not use exercise book?
6. During observations, you assigned students to conduct an experiment about vegetative reproduction of potato. However, students did not conduct this experiment. Can you explain the reason why students did not conduct experiment?
7. Although you said that you drew figures about cell division in pre-interviews, you did not draw figures during observations. What is the reason of this discrepancy? Can you explain the reason?

APPENDİX J

Burcu’nun Yazılı Sınavı

2013-2014 EĞİTİM ÖĞRETİM YILI 8. SINIF 1. DÖNEM FEN VE TEKNOLOJİ 1. YAZILI SORULARI

1. Aşağıda karışık halde verilen mitoz bölünme aşamalarını verilen boş kutulara oluşum sırasına göre yazınız.(3754)



2. Aşağıdaki ifadelerin doğru olanlarının başına (D) yanlış olanlarının başına (Y) yazınız.(3756)

(…..) Mitoz bölünme tek hücrelilerde büyüme ve gelişmeyi, çok hücrelilerde ise üremeyi sağlar.

(…..) Mitoz bölünmede kromozom sayısı sabit kalır.

(…..) Mitoz bölünme tür içi çeşitliliği sağlar.

(…..) Mitoz bölünme yaraların onarılmasını sağlar.

(…..) Eşeysiz üremenin temelini mitoz bölünme oluşturur.

3. Aşağıdaki tabloda verilen canlıların geçirdikleri üreme çeşidini tablo üzerinde işaretleyiniz.(3756)

	TOPRAK SOLUCANI	HİDRA	AMİP	ÖGLENA	KAVAK
TOMURCUKLANMA İLE ÜREME					

BÖLÜNME İLE ÜREME					
YENİLENME İLE ÜREME					
VEJETATİF (ÇELİKLE) ÜREME					

4. Aşağıdaki ifadelerde boş bırakılan yerleri uygun ifadelerle doldurunuz.

- ……………………………. bölünmede kromozom sayısı yarıya iner.(3769)
- Bira mayası mantarı ………………………………… İle çoğalır.(3756)
- Patateste …………………………………… ile üreme görülür.(3756)
- İnsandaki üreme hücreleri ……………………… ve ………………… hücreleridir.(3767)
- İnsandaki zigot hücresi …………………………… kromozom içerir.(3767)
- Mayoz bölünme ………………………………………………………… hücrelerinde görülür.(3768)
- Herhangi bir karakteri oluşturan alel genler farklı olduğunda oluşan gen çiftine ……………………………………….. denir. (örnek: Aa)(3760)

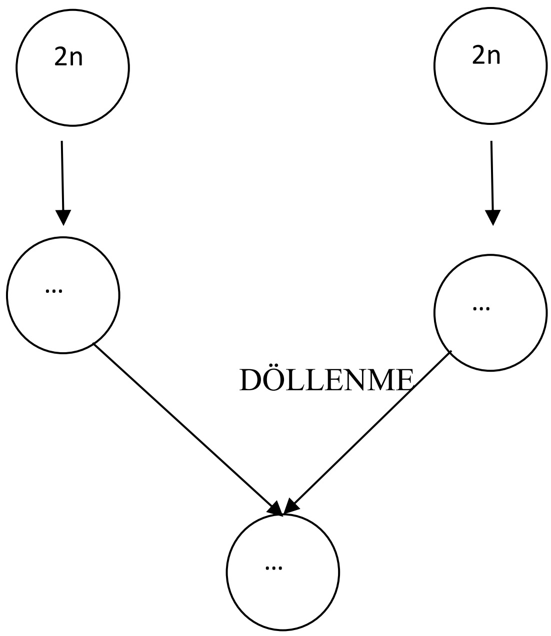
5. Heterozigot kahverengi gözlü bir baba ile mavi gözlü annenin çocuklarının;(3762)

- Homozigot kahverengi gözlü olma ihtimali % ………………………
- Heterozigot kahverengi gözlü olma ihtimali %..........................
- Mavi gözlü olma ihtimali %...............................
- Kahverengi gözlü olma ihtimali % ……………………….
- Çaprazlamasını aşağıdaki boşluğa yapınız.

6. Aşağıdaki bireylerden hangisi Down Sendromlu dişidir?(3763)

A) 44+XX B) 43+XX C) 45+XY D) 45+XX

7. Aşağıda verilen şemada boş bırakılan yerleri uygun kavramlar yazarak doldurunuz. (3767)



8. Mitoz ve mayoz bölünmeler arsındaki farklardan 5 er tane yazınız.(3769)

MİTOZ	MAYOZ
1	1
2	2
3	3
4	4
5	5

APPENDIX K

NOS Categorization Schema (Bilican, 2014, p.54)

Categorization	Inadequate	Adequate	Informed
Tentative NOS	Recognizes scientific knowledge as accumulation of absolute, certain proven facts	Recognition of science as subject to change but this view is supported with lack of extended explanation or examples	Recognizes that all scientific knowledge is subject to change with the new evidence, advancement in technology and reinterpretation of scientific knowledge.
Empirical NOS	Fails to recognize the role of evidence to make scientific claims. Fails to differentiate science from other disciplines by means of recognizing role of the evidence	Refers to “observation” and “experiments” but lack of explanation on role of experiments and observations to get “evidence” and lack of examples to support the claim.	Considers that scientific claims should be supported with empirical – direct/indirect-evidences. Also supports that view with and extended explanation or examples
Inferential NOS	Holds the views that “seeing is believing”, and science is “what we see”, disregards the role of indirect evidence and inferences	Refers to that scientists make inferences, but lack of emphasis on the distinction between observation and inference and lack of emphasize that scientists make inferences based on observations	Recognizes that while making scientific claims, it is not possible to observe all the natural phenomena, but scientists make interpretations based on scientific evidence.supports that view with and extended examples

Table (cont'd)

Categorization	Inadequate	Adequate	Informed
Creative NOS	Recognizes science as step-by-step procedure and disregard the role of creativity	Recognizes the role of imagination and creativity but emphasizes particularly on certain part of the scientific investigation.	Holds the views that scientist's imagination and creativity is crucial part of their any part of investigation and have role in every stage of Scientific investigation. Also supports that view with and extended Explanation examples
Socio Cultural NOS	Consider science as universal and isolated from the values and norm of culture in which it is practiced	Recognition of influence of socio-cultural values on scientific investigation but lack of claim support by extended explanations or examples.	Hold the view that science is a human endeavour and both influence and influenced by the culture in which it was practiced. Also supports that view with and extended explanation or examples
Theory & Law	Holds the view that there is a hierarchical relationship between laws and theories	Consider that theories and laws as distinct form of scientific knowledge not unable to articulate clear and extended definitions or provide examples.	Recognizes theories and laws as distinct form of scientific knowledge as equally valuable. Understands that scientific theories explain natural phenomena, while scientific laws describe observed relationships between scientific phenomena. Also supports that view with and extended explanation or examples

Table (cont'd)

Categorization	Inadequate	Adequate	Informed
Subjective NOS	Recognizes scientists as objective and value free. Views different interpretations of scientist due to the lack of evidence	Understand that scientists' subjectivity influence the development of scientific knowledge but not unable to provide clear and extended explanations or examples to support the claim.	Considers that scientist' preconceptions, values, background influences the way they work and interpret data. Recognizes that the theories that scientists hold guide their scientific investigations, data interpretations etc. Also supports that view with and extended explanation or examples

APPENDİX L
Extended Turkish Summary

Fen Bilgisi Öğretmenlerinin Hücre Bölünmesi Konusundaki Pedagojik Alan Bilgisi ve Konu Alan Bilgisi Üzerine Bir Çalışma

GİRİŞ

Fen öğretiminde öğrenciden sonra en önemli etmen öğretmendir (Kind, 2009). Öğretmenin bir konuyu anlatabilmesi için öncelikli olarak ihtiyacı olan şey ise öğretmenin o konu hakkında yeterli bir alan bilgisine sahip olmasıdır (Shulman, 1986). Fakat fen eğitiminde daha önce yapılan çalışmalar öğretmenlerin davranışlarını gözlemlemek üzerine kurulmuş yada öğretmenlerin pedagoji bilgisi ön planda tutulmuştur. Bir başka deyişle öğretmenlerin konu alan bilgisi daha önceki çalışmalarda ihmal edilmiştir (Shulman, 1986). Bu noktada, Shulman (1986; 1987) pedagoji alan bilgisi ve konu alan bilgisinin bir karışımı olan pedagojik alan bilgisini ortaya atmıştır. Pedagojik alan bilgisi ile hem daha önceki çalışmalarda unutulmaya yüz tutmuş olan konu alan bilgisine yönelik çalışmalar yapılacak hemde öğretmenin sahip olması gereken pedagoji bilgisi ile konu alan bilgisi birbirine bağlanmış olacaktır. Bu sayede pedagojik alan bilgisinin teorik çerçeve olarak fen eğitimi çalışmalarında sıklıkla kullanılmaya başlanmıştır.

PAB çalışmalarının işlevi iki boyutta incelenebilir. Öncelikle PAB teorik bir çerçeve olarak bizlerin öğretim sürecini anlamamızı sağlar, öğretimin kalitesini artırır ve öğretmen yetiştiren kurumların kalitesini artırır (Abell, 2008; Magnusson vd., 1999). PAB' ın ikinci fonksiyonu ise gerçek sınıflar ile öğretmen yetiştiren kurumlar arasında bir köprü vazifesi görmesidir. PAB aracılığıyla fen sınıflarında deneyimli öğretmenlerin konuları nasıl anlattığı ortaya konur ve ilgili öğretme yolları öğretmen yetiştirme programlarına eklenerek öğretmen adaylarının aynı bilgiye daha az tecrübe ile ulaşması sağlanır. Benzer şekilde diğer fen öğretmenleri meslektaşlarının fen konularını hangi yollarla anlattığını görerek kendilerini geliştirme fırsatı bulabilirler. Böylece PAB sayesinde fen öğretmenleri ve öğretmen adayları diğer fen öğretmenlerinin tecrübelerinden yararlanabilirler (Bucat, 2004).

PAB üzerine yapılan çalışmalar, PAB'ın genel özelliklerini ortaya koymaktadır. Buna göre pedagojik alan bilgisi diğer bilgi alanlarının dönüştürülmüş halidir (Grossman, 1990; Magnusson vd., 1999) veya diğer bilgi alanlarının birleşimidir (Cochran vd., 1993; Veal & MaKinster, 1998). PAB öğretmenin tecrübesi ile gelişir (Cochran vd., 1993). PAB fen öğretiminin nasıl yapılması gerektiğini ortaya koyan kavramsal bir çerçeve olduğu için boyutları ile analiz edildiğinde daha iyi sonuç vermektedir bu yüzden PAB boyutları ile tanımlanır (Abell, 2008). PAB; konuya özgü PAB, alana özgü PAB ve genel PAB olarak sınıflandırılır (Veal & MaKinster, 1998) ve bu çalışmada konuya özgü PAB teorik çerçeve olarak ele alınmıştır. Ayrıca, bir öğretmenin PAB'ı konudan konuya farklılık göstermekle birlikte zamana, mekana ve öğrenciye göre de farklılık gösterebilmektedir (Park & Oliver, 2008; Van Driel et al., 2012).

Bu PAB çalışmasında Magnusson ve arkadaşları (1999) tarafından ortaya konulmuş olan PAB modeli kullanılmıştır. Bu modele göre; PAB beş farklı boyuttan oluşmaktadır. Bu boyutlar fene karşı yönelimler, müfredat bilgisi, öğrenci bilgisi, değerlendirme bilgisi ve öğretim yöntemleri bilgisidir. Fene karşı yönelimler öğretmenin fen öğretimine karşı tutumunu ve fen öğretimi ile ilgili inançlarını temsil eder ve diğer dört boyutu şekillendirir (Magnusson vd., 1999). Bu modelin boyutları kendi içindede ayrılmaktadır. Buna göre; müfredat bilgisi hedef ve kazanımlar bilgisi ile özel programlar ve materyal bilgisinden oluşmaktadır. Öğrenci bilgisi; feni öğrenmek için gerekli ön bilgiler alt boyutunu ve öğrencilerin zorlandıkları konular alt boyutunu içerir. Değerlendirme bilgisi; fen öğrenimi değerlendirme boyutları ile değerlendirme yöntemleri alt boyutunu içerir. Öğretim yöntemleri bilgisi ise; genel öğretim yöntemleri ve konuya özgü öğretim yöntemlerini kapsar. Konuya özgü öğretim yöntemleri kendi içerisinde konu ile ilgili etkinlik bilgisi ve konu ile ilgili gösterim bilgisinden oluşmaktadır (Magnusson vd., 1999).

Konuya özgü yapılan bu PAB çalışmasında hücre bölünmesi konusu seçilmiştir. Çünkü hücre bölünmesi konusu fen konuları içinde öğrenilmesi ve öğretilmesi en zor olan konuların başında gelmektedir (Brown, 1990; Clark, 2000; Lewis-Wood Robinson, 2000; Mickle, 1990; Öztaş vd., 2003). Bu konunun öğretilmesi ve öğrenilmesini zorlaştıran etmenler ise konunun soyut, detaylı ve karmaşık yapısı olarak özetlenebilir (Williams vd., 2012). Bu çalışmada deneyimli fen bilgisi öğretmenlerinin hücre bölünmesi konularını nasıl öğrettikleri açığa çıkarılarak diğer fen bilgisi öğretmenlerinin ve öğretmen adaylarının hücre bölünmesi konuları ile ilgili PAB' larının geliştirilmesi amaçlanmaktadır. Öğretmenlerin hücre bölünmesi ile ilgili PAB' larının geliştirilmesi konunun öğrenciler tarafından daha kolay anlaşılmasını da beraberinde getirecektir. Fen sınıflarında hücre bölünmesi konularının daha iyi anlatılması ve daha iyi öğrenilmesi fen okuryazarlığının bir alt boyutu olan genetik okuryazarlığı artıracaktır çünkü hücre bölünmesi konuları genetik konuları ile yakından ilişkilidir (Williams vd., 2012). Hücre bölünmesi konularında yapılan çalışmalar ayrıca fen okur yazarlığının bir diğer alt boyutu olan bilim süreç becerilerine olan ilgiyi arttıracaktır çünkü hücre bölünmesi konusu gözlem, deney yapma, hipotez kurma gibi bilim süreç becerilerini içeren etkinlikleri yapma olanağı sağlar (Cordero & Szewcak, 1994). Ayrıca biyoloji konularının tamamı birbiri ile ilişkilidir ve bir bütün olarak ele alınmalıdır ve bazı biyoloji konuları diğerlerine temel teşkil etmektedir. Hücre bölünmesi konusu diğer biyoloji konularının anlaşılması için bilinmesi gerekli bir konudur (Brown, 1990; Clark, 2000; Kazancı et al., 2003; Kindfield, 1994). Hücre bölünmesi konularının daha iyi öğretilmesi ve öğrenilmesi diğer biyoloji konularınında önünü açacak ve öğrenciler bu konuları daha iyi öğrenebilecektirler.

Daha önce yapılmış PAB çalışmaları genellikle öğretmen adayları ile yapılmıştır ve PAB'ın bir veya birkaç boyutu ele alınmıştır (Abell, 2008; Aydın & Boz, 2012). Ayrıca önceki çalışmalar genellikle kimya konularında ve orta öğretim kurumlarında yapılmıştır. Bununla beraber önceki çalışmalar kamu kurumlarında çalışan öğretmenlerle yürütülmüştür (Abell, 2008; Aydın & Boz, 2012). Bu çalışmalardan farklı olarak mevcut çalışma deneyimli fen bilgisi öğretmenleri ile PAB'ın bütün boyutları ele alınarak yapılmış ve konu olarak üzerinde daha az çalışma yapılmış biyoloji alanında bir konu seçilmiştir. Ayrıca mevcut çalışma ilköğretim düzeyinde ve özel öğretim kurumlarında yapılmış olması nedeniylede ilgili alanyazına katkılar sunmaktadır. Son olarak ise daha önce yapılan çalışmalar öğretmenlerin içerik alan bilgisine ve ilgili konu hakkında PAB'ına yoğunlaşırken, öğretmenlerin sürece yönelik alan bilgisi olan bilimin doğası bilgisini ihmal etmişlerdir (Khalick & BouJaoude, 1997). Bu çalışmada öğretmenlerin hem hücre bölünmesi ile ilgili PAB' ları ve içerik alan bilgileri alınmış hem de sürece yönelik alan bilgisini temsil eden bilimin doğası bilgileri öğrenilmeye çalışılmıştır.

Araştırma Soruları

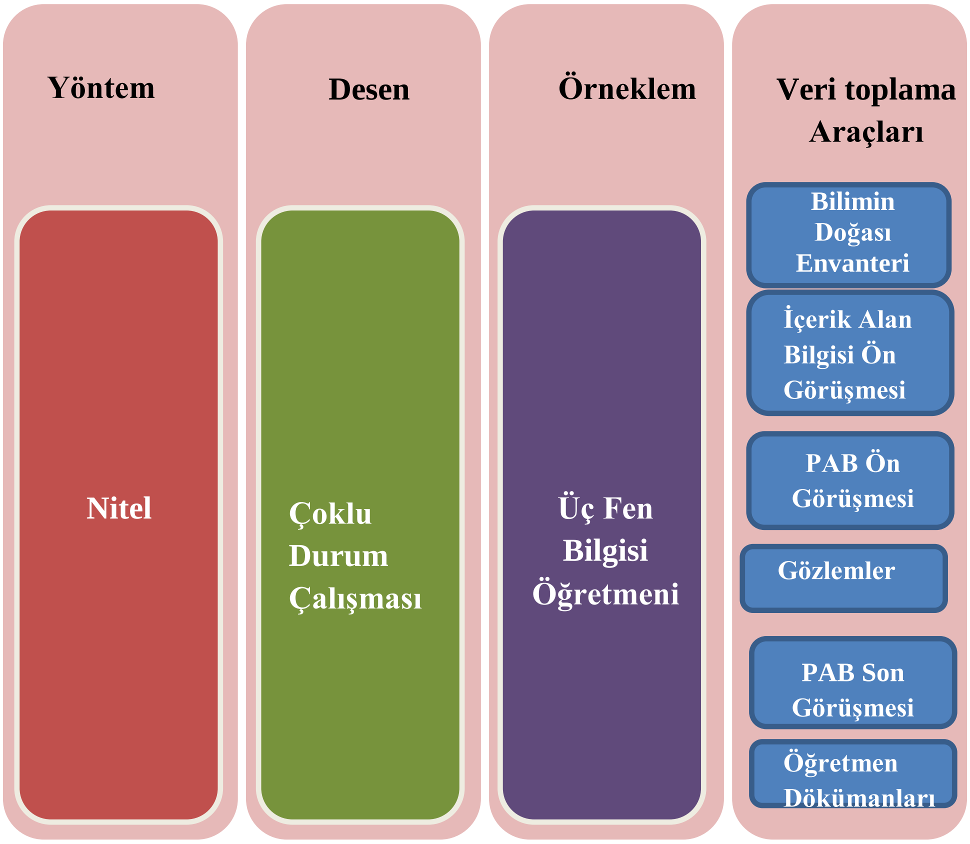
Mevcut çalışmanın iki araştırma sorusu ve bu soruların alt soruları bulunmaktadır. Araştırma soruları aşağıda verilmiştir:

1. Fen öğretmenlerinin hücre bölünmesi ile ilgili konu alan bilgisi nedir?
   1.1. Fen öğretmenlerinin sürece yönelik alan bilgisi (bilimin doğası bilgisi) nedir?
   1.2. Fen öğretmenlerinin içeriğe yönelik alan bilgisi nedir?
2. Fen öğretmenlerinin hücre bölünmesi konusunda pedagojik alan bilgisi nedir?
   2.1. Fen öğretmenlerinin hücre bölünmesi ile ilgili fene karşı yönelimleri nedir?
   2.2. Fen öğretmenlerinin hücre bölünmesi ile ilgili müfredat bilgisi nedir?
   2.3. Fen öğretmenlerinin hücre bölünmesi ile ilgili öğrenci bilgisi nedir?
   2.4. Fen öğretmenlerinin hücre bölünmesi ile ilgili değerlendirme bilgisi nedir?
   2.5. Fen öğretmenlerinin hücre bölünmesi ile ilgili öğretim strateji ve yöntemleri nedir?

YÖNTEM

Çalışma Deseni

Pedagojik alan bilgisi örtük ve saklı bir bilgi alanıdır (Abell, 2008). Saklı olan bu bilgiyi anlayabilmek ve yorumlayabilmek için birçok farklı veriye ihtiyaç vardır. Bu yüzden bu çalışmada kapsamlı ve detaylı bilgi sağlayan nitel yöntemler (Cresswell, 2007; Merriam, 2009) tercih edilmiştir. Çalışma deseni olarak nitel çalışma yöntemlerinden biri olan çoklu durum çalışması seçilmiştir çünkü çoklu durum çalışmasındaki her bir durum araştırma sorularına ayrı ayrı cevap vermektedir (Merriam, 2009). Çalışmanın yöntemi şekil-1'de sunulmuştur.



Şekil-1. Çalışmanın Yöntemi

Katılımcılar

Bu çoklu durum çalışmasına üç deneyimli fen bilgisi öğretmeni katılmıştır ve öğretmenlere rumuz olarak Selim, Burcu ve Ahmet isimleri verilmiştir. Çalışmaya katılan öğretmenlerin kişisel bilgileri Tablo-1' de sunulmuştur. Örneklem seçilim yöntemi olarak nitel çalışmalarda sıklıkla kullanılan amaçlı örneklem yöntemi seçilmiştir. Amaçlı örneklen yöntemi aracılığı ile kriterler belirlenerek örneklem ile ilgili detaylı ve kapsamlı bilgiye ulaşmak amaçlanmıştır.

Tablo-1 Öğretmenlerin Kişisel Bilgileri

Öğretmen	Cinsiyet	Tecrübe (yıl)	Fakülte /Alan	Öğretmenlik Deneyimleri	Haftalık Ders Saati
Selim	Erkek	8 yıl	Eğitim/İFÖ*	Dershane deneyimi Kolej deneyimi	10
Burcu	Kadın	11 yıl	Eğitim/İFÖ	Dershane deneyimi Kolej deneyimi Dershane Kitabı Yazarlığı Dershane Soru Hazırlama Ulusal Bilim Projeleri Katılımı Laboratuvar Öğretmenliği	30
Ahmet	Erkek	9 yıl	Eğitim/İFÖ	Dershane deneyimi Kolej deneyimi	12

*İlköğretim Fen Bilgisi Öğretmenliği

Veri Toplama Araçları

Bu çalışmada veriler 2013-2014 yılı güz döneminde 8.sınıflarda görev yapan ve özel okullarda çalışan fen bilgisi öğretmenlerinden elde edilmiştir. Çalışma süresince öğretmenlerin konu alan bilgilerini ve pedagojik alan bilgilerini öğrenmek amacıyla bilimin doğası envanteri (Lederman vd., 2002), içerik alan bilgisi ön görüşmesi, sınıf içi gözlemler, PAB ön görüşmesi, PAB son görüşmesi ve öğretmen dökümanları kullanılmıştır. Veri toplama araçları ve ilgili hedef bilgi türleri Tablo 2'de sunulmuştur.

Tablo 2. Veri Toplama Araçları ve İlgili Bilgi Alanı

Veri Toplama Aracı	İlgili Bilgi Alanı
Bilimin Doğası Envanteri	Sürece Yönelik Alan Bilgisi
İçerik Alan Bilgisi Ön Görüşmesi	İçerik Alan Bilgisi
Sınıf İçi Gözlemler	Pedagojik Alan Bilgisi/ Tüm Boyutlar
PAB Ön Görüşmesi	Pedagojik Alan Bilgisi/ Tüm Boyutlar
PAB Son Görüşmesi	Pedagojik Alan Bilgisi/ Tüm Boyutlar
Öğretmen Dökümanları (Yazılı Sınavlar)	Pedagojik Alan Bilgisi/ Değerlendirme Boyutu

Veri Analizi

Bu çalışmada öğretmenlerden elde edilen veriler hedeflenen bilgi türlerine göre ayrı ayrı kodlanıp kategorilere ayrılmıştır. Sürece yönelik alan bilgisi ile ilgili olarak; öğretmenlerin ön görüşmede bilimin doğası ile ilgili sorulara verdikleri cevaplar Lederman vd. (2002) ve Bilican (2014)'ün geliştirdiği derecelendirme ölçeğine göre kodlanmış ve ilgili kategorilere (yetersiz, yeterli, bilgili) ayrılmıştır. Öğretmenlerin hücre bölünmesi ile ilgili içerik alan bilgilerini ölçmeye yönelik sorular araştırmacı tarafından hazırlanmış ve ilgili alanyazına göre derecelendirme ölçeği oluşturulmuştur. Bu ölçeğe göre katılımcıların verdikleri cevaplar kavramsal anlayışlarına ve ontolojik kategorilerine göre ayrılmıştır. Kavramsal anlayışları göz önüne alındığında alanyazınla eşleşen cevaplar bilgili kategorisinde yer almış, eksik cevaplar kısmen bilgili kategorisine girmiş ve yanlış ve kavram yanılgısı barındıran cevaplar naif kategorisinde yer almıştır. Öğretmenlerin cevap vermediği kavramlar ise herhangi bir kategoriye dahil edilmemiştir. Ontolojik kategoriler göz önüne alındığında ise ilgili kodlar alan yazından çıkarılarak madde ve süreç kategorilerine dahil edilmiştir. Öğretmenlerin sorulara verdikleri cevaplar ilgili kodlara göre bu kategorilere yerleştirilmiştir.

Pedagojik alan bilgisi ile ilgili olarak ise kategoriler kullanılan modele (Magnusson vd., 1999) bağlı olarak oluşturulmuştur. Bu modele göre her bir boyut ve onların ilgili alt boyutları kategorileri temsil ederken, kodlar ilgili alan yazından ve öğretmenlerin görüşme sorularına verdikleri cevaplardan türetilmiştir.

SONUÇLAR ve TARTIŞMA

Bu çalışmada öğretmenlerin konu alan bilgisi ve pedagojik alan bilgisi araştırılmıştır.

1. Fen Bilgisi Öğretmenlerinin Alan Bilgisi

Çalışmanın sonuçlarına göre öğretmenlerin sürece yönelik alan bilgilerini temsil eden bilimin doğası bilgileri düşük bulunmuştur. Fen bilgisi öğretmenleri bilimsel yasaların değişmez olduğunu, bilimin sosyo kültürel değerlerden etkilenmediğini ve bilim adamlarının tamamen tarafsız olduğunu iddia düşünmektedirler. Fen bilgisi öğretmenlerinin bilimin doğası ile ilgili yetersiz görüşte bulunmalarının bir takım sebepleri bu çalışmada öne çıkmaktadır. Örneğin fen bilgisi öğretmenlerinin üniversite yıllarında bilimin doğası dersi almaması onların bu konuya yabancı olmalarına neden olmuş olabilir. Öğretmenler kendilerini müfredatın uygulayıcısı olarak gördükleri için müfredatta hücre bölünmesi konusunda özel olarak bilimin doğası ile ilgili kazanım bulunmaması öğretmenlerin hücre bölünmesi konularında bilimin doğasını ihmal etmesine neden olmuş olabilir. Ayrıca, Temel Öğretimden Orta Öğretime Geçiş Sınavı (TEOG) kazanımları değerlendirdiği için ve kazanımlarda bilimin doğasına yer verilmediğinden dolayı öğretmenler genel anlamda bilimin doğasını ihmal etmiş olabilirler. Bununla beraber öğretmenlerin fene karşı yönelimleri neden bilimin doğasını göz ardı ettiklerini ortaya koymaktadır. Öğretmenlerin fene karşı yönelimleri genel olarak müfredat kazanımlarını öğretmek üzerine kurulu olduğu için öğretmenler bilimin doğasını kazanımların öngördüğü ölçüde uygulamaktadır. Oysa ki bilimin doğası fen okuryazarlığının bir bileşenidir ve fen okuryazarı nesiller yetiştirmek Milli Eğitim öğretim programının temel amacıdır (MEB, 2006). Bu noktada, Milli Eğitim öğretim programı hücre bölünmesi konularında bilimin doğası kazanımlarını daha fazla vurgulamalıdır. Bilimin doğası ile ilgili kazanım olmasının yanı sıra öğrencilere bilimin doğasının öğretilmesi ile ilgili etkinlikler sunulmalı ve materyaller geliştirilmelidir aksi takdirde sadece bu kazanımların olması bilimin doğası öğretimini sağlayamayabilir (Hanuscin vd., 2010). Bunun dışında bilimin doğası ile ilgili olarak öğretmenlerin bilimin doğasına karşı yönelimlerininde değişmesi gerekmektedir. Bu noktada bilimin doğası bilgisi, fene karşı yönelimler ve müfredat bilgisi arasında bir etkileşim olduğu düşünülebilir. Örneğin; fene karşı yönelimlerinde bilimin doğasının önemini kavrayan bir öğretmen bilimin doğası hakkında daha fazla bilgi edinebilir. Bununla beraber müfredat bilgisi sağlam olan bir öğretmen fen bilgisi öğretim programının amacının fen okur yazarı birey yetiştirmek olduğunu ve bilimin doğasının fen okur yazarlığı için bir ön koşul olduğunu bilir.

Bu çalışmada ayrıca fen bilgisi öğretmenlerinin hücre bölünmesi ile ilgili içerik alan bilgileride araştırılmıştır buna göre fen bilgisi öğretmenleri içerik alan bilgisini temsil eden temel kavramlar, mitoz ve mayoz konularında birbirinden farklılaşmışlardır bunun yanında fen bilgisi öğretmenleri hücre döngüsü hakkında yetersiz bilgi sahibidirler. Öğretmenler genel olarak allel gen konusunda yetersiz bilgi sahibidirler ve konu ile ilgili alan yazında yer alan allel gen iki adet gendir veya allel gen genden daha büyüktür gibi bir kavram yanılgısına sahiptirler (Levis vd., 2000). Allel kavramının yanı sıra öğretmenler genetik ve hücre bölünmesi konularını birbirine bağlayan "Bağımsız Dağılım Yasası" (Sadava vd., 2011)' nı da bilmemektedirler. Bu noktada öğretmenlerin mayoz bölünme ve genetik arasında yeterince bağ kuramadıkları söylenebilir. Öğretmenlerin genetik konuları ile hücre bölünmesi konularını birbirine bağlayamamalarına sebep olarak ise ders kitabında hücre bölünmesi konularının ve genetik konularının ayrı başlıklarda anlatılması olabilir. Bu durum alan yazında bulunan çalışmalarda da desteklenmektedir (Appleton & Kindt, 1999; Brown, 1990).

Ayrıca bu çalışmada öğretmenlerin ontolojik olarak madde kategorisinde yer aldıkları ve süreç kategorisine geçemedikleri görülmüştür. Örneğin; öğretmenler sentromer, kinetekor, sentriol, kromozom, DNA ve gen konularında genellikle süreç kategorisine geçememişlerdir. Chi ve arkadaşları (1994)'nın belirttiğine göre öğretmenler kavramsal olarak bir konuyu anlasalar bile süreç kategorisine geçemezlerse o konuyu öğretmek için hazır olamazlar. Bu yüzden fen bilgisi öğretmenleri kapsamlı analizler sonucunda hücre bölünmesi temel kavramlarını anlatmak için yeterli görülmemektedirler.

Öğretmenlerin mitoz ve mayoz hakkındaki bilgileri göz önüne alındığında ise öğretmenlerin mayoz konusunda daha fazla zorlandıkları görülmüştür. Bu durumun mayoz konularının daha detaylı olması (Dikmenli, 2010) ve müfredattaki sınırlamalarla ilişkili olduğu düşünülmektedir. Müfredatta tetrat, sinaps, kiazma, interkinez gibi konular yetr almadığı için öğretmenlerin mayoz ile ilgili bilgilerinin müfredat ile sınırlı olduğu düşünülmektedir ve benzer şekilde müfredatta hücre döngüsü konusu yer almadığı için fen bilgisi öğretmenleri hücre döngüsü konularını bilmemektedirler. Sonuç olarak öğretmenlerin müfredat bilgisinin öğretmenlerin içerik alan bilgisini sınırlandırdığı söylenebilir.

Öğretmenlerin hücre bölünmesi konularında zorluk yaşamalarının bir diğer sebebi ise konunun kendine özgü bir terminolojisinin olmasıdır (Lankford, 2010; Lewis vd., 2000; Öztaş vd., 2003). Bu terminolojide yer alan kavramlar ve bu kavramların isimlerinin birbirine yakın olması öğretmenlerin bu konuları eksik yada yanlış anlamasına neden oluyor olabilir (Örneğin; Kromatin iplik, Kromatit, Kromozom, kardeş kromatit, homolog kromozom gibi).

2. Fen Bilgisi Öğretmenlerinin Hücre Bölünmesi ile ilgili Pedagojik Alan Bilgisi

Fen Bilgisi Öğretmenlerinin hücre bölünmesi ile ilgili fene karşı yönelimleri görüşmelerde öğrenciyi hayata hazırlamak ve öğrencinin öğrendiği bilgiyi günlük hayatında kullanmasını sağlamak iken, gözlemler sırasında fene karşı yönelimleri müfredattaki kazanımları öğretmek ve öğrencileri TEOG' a hazırlamak olmuştur. Miranda (2010) yaptığı çalışmasında öğretmenin öğrenciye dönük inançlarının ve öğrenci bilgisinin büyük ölçüde öğretim yöntemini belirlediğini ortaya koymuştur. Buna göre fen öğretmenleri öğrencinin düşünsel becerilerini, fene karşı tutumunu ve motivasyonunu önemsemelidir bununla beraber öğrenci bilgisi ile ilgili ön bilgiler ve öğrencinin anlamakta zorlandığı noktalar konusunda ilgi sahibi olmalıdır. Öğrenci merkezli bir yönelime sahip olan öğretmenin öğrenci bilgisinin daha fazla olacağı düşünülmektedir (Dreshler & Van Driel, 2008). Fakat bu çalışmada öğretmenler öğrenci merkezli bir tutum sergilememelerine rağmen öğrenc bilgilerinin yetersiz olmadığı görülmüştür. Fen bilgisi öğretmenleri ön bilgi olarak öğrencilerin hücre konusunu, kromozom yapısını ve hareketlerini bilmeleri gerektiğini düşünmektedirler. Ayrıca, öğrencilerin zorlandıkları hücre bölünmesi konuları olarak kardeş kromatit, homolog kromozom gibi kavramları ve kardeş kromatitlerin ayrılması, homolog kromozomların ayrılması gibi süreçleri örnek olarak göstermişlerdir. Bununla beraber fen bilgisi öğretmenleri öğrencilerin hücre bölünmesi konularında kavram yanılgıları hakkında da bilgi sahibidirler. Öğretmenler bu kavram yanılgılarının sebepleri olarak ise ön bilgi eksikliği, ders kitabı, günlük hayatta kullanılan dil gibi kaynakları göstermektedirler.

Öğrenci merkezli bir yönelime sahip olmayan öğretmenlerin hücre bölünmesi ile ilgili öğrenci bilgilerinin yeterli olması öğretmenlerin tecrübesi ve geçmiş yaşantıları ile ilintili olabilir (Cochran vd., 1993; Park & Oliver, 2008; Veal vd., 1999). Çünkü öğretmenler öğrencilerin kavram yanılgılarını ortaya çıkarmaya çalışmasa bile öğretmenlerin mesleklerindeki geçmiş deneyimleri onları bu konular hakkında daha fazla bilgi sahibi yapmaktadır. Ayrıca bu çalışmada yer alan fen bilgisi öğretmenleri geçmiş yaşantılarında dersane öğretmenliği yaptıkları için ve dersaneler de çoktan seçmeli sorulara odaklandıkları için öğremenler doğru cevabın ne olduğunu anlatırken çeldiriciler hakkında da bilgi sahibi olmaktadırlar. Bu çeldiriciler genellikle sıklıkla görülen kavram yanılgıları olarak ortaya çıkmaktadır.

Öğretmenlerin öğrenci bilgilerini etkileyen bir diğer etmeninde konu alan bilgisi olduğu ön görülmektedir (Akerson, 2005; Veal & MaKinster, 1998). Örneğin bu çalışmada yer alan öğretmenler genetik ve hücre bölünmesi ilişkisi hakkında yeterli bilgi sahibi değildirler dolayısıyla öğrencilerin bu konuları birbirine bağlamakta zorlanacaklarını belirtmemişlerdir. Benzer şekilde sentrozom, sentromer, sentriol gibi kavramlarda ontolojik olarak madde kategorisinde kalan ve süreç kategorisine ulaşamayan öğretmenler öğrencilerin genetik transfer mekanizması hakkında bilgi sahibi olamamışlardır.

Bununla beraber değerlendirme bilgisininde öğrenci bilgisi üzerinde etkisinin olduğu düşünülmektedir (Hanuscin vd., 2010; Folk, 2012). Öğretmenler yaptıkları ölçme ve değerlendirmeler sonucunda öğrencilerin bilgilerini öğrenme fırsatı bulurlar bir anlamda değerlendirme öğrenme ve öğretme süreçlerini birbirine bağlar (Hanuscin vd., 2010). Bu çalışmada fen bilgisi öğretmenleri sadece öğrencilerin içerik alan bilgisini değerlendirmeyi tercih etmişlerdir. Dolayısı ile sadece öğrencilerin içerik alan bilgileri sayesinde bilgi sahibi olabilecekler ve öğrencilerin bilimsel süreç becerileri, bilimin doğası bilgisi ve disiplinlerarası konular ile ilgili gösüşleri hakkında bilgi sahibi olamayacaklardır. Bu noktada öğretmenlerin fene karşı yönelimlerinin ve müfredat bilgilerinin öğretmenin değerlendirme bilgisini etkileyeceği söylenebilir. Çünkü bu çalışmada öğretmenlerin fene karşı yönelimleri sadece içerik alan bilgisini aktarmaya yöneliktir ve bilimin doğasını, bilimsel süreç becerilerini ve disiplinlerarası temaları ihmal etmektedir. Bununla beraber, müfredattaki hedefler öğretmenlerin neyi değerlendirmesi gerektiğini göstermektedir. Bu anlamda öğretmenlerin değerlendirme bilgilerini arttırmaları için fene karşı yönelimlerini değiştirmek ve müfredat bilgilerini arttırmak gerekmektedir. Çalışmada yer alan öğretmenler genellikle geleneksel değerlendirme yaklaşımlarını tercih etmişlerdir ve sadece bir öğretmen alternatif değerlendirme yaklaşımı olarak kavram haritası ve poster kullanmıştır. İki öğretmen ders boyunca soru sorarak öğrencilerin öğrenmelerini anlamaya çalışmıştır ve bu şekilde öğrenci bilgilerini arttırmaya çalışmışlardır. Öğretmenler geleneksel değerlendirme yaklaşımlarını kullanım nedeni olarak alternatif yaklaşım yöntemlerini bilmemelerini göstermişlerdir. Ayrıca, TEOG gibi çevresel etmenlerinde öğretmenlerin değerlendirme bilgisini şekillendirdiği söylenebilir (Uşak vd., 2011, Yarden & Cohen, 2009). TEOG sınavında öğrenciler geleneksel yöntemlerle değerlendirildiği için öğretmenlerde çoktan seçmeli soru gibi geleneksel yöntemleri tercih ediyor olabilirler (Yarden & Cohen, 2009).

PAB'ın bir diğer bileşeni de öğretim stratejileri bilgisidir. Bu çalışmada fen bilgisi öğretmenlerinin düz anlatım ve soru sorma yöntemlerini kullandıkları görülmüştür. Bu durum öğretmenlerin fene karşı yönelimleri ile paralellik göstermektedir. Öğretmenler öğretmen merkezli yöntemleri seçmeleri ile ilgili olarak öğrenci merkezli yaklaşımları bilmemelerini ve sınırlı zamanlarının olduğunu belirtmişlerdir.

Öğretim stratejileri bilgisi öğrenci bilgisi ile doğrudan ilintilidir ve bu durum daha önceki çalışmalarda da belirtilmiştir (Akerson, 2005; Aydın vd., 2010; Boz & Boz, 2008; Brown vd., 2013; Demirdoğan, 2012; Hanuscin vd., 2010). Öğretim öğrenci ihtiyaçlarını gidermeye yönelik olmalıdır ve bunun için öğretmen öğrencilerini iyi tanımalı onların ihtiyaçlarına cevap verebilmelidir bu noktada öğretmenlerin yapılandırmacı yaklaşımları kullanmaları gerekmektedir fakat fen öğretmenleri geleneksel öğretmen merkezli yaklaşımları tercih etmişlerdir. Öğretmenlerin öğrenci bilgisinin öğretim stratejileri bilgisini etkilediğini gösteren bulgulardan birisi öğrencilerin sınıf düzeyidir. Öğretmenler bu yaş grubunun öğrenci merkezli (drama vs.) yaklaşımlarda sıkıldığını ve bu yüzden düz anlatım yöntemini seçtiklerini ifade etmişlerdir. Bunun dışında öğretmenlerin konu alan bilgilerinin ve çevresel faktörlerin (laboratuvar araç gereç eksikliği, aile beklentisi, okul politikası gibi) öğretmenin öğretim stratejieri bilgisini etkileyeceği düşünülmektedir.

Öğretim stratejilerini etkileyen bir diğer boyutun da müfredat bilgisi olduğu düşünülmektedir (Folk, 2012; Hanuscin vd., 2010). Çünkü müfredat tarafından öneriler etkinlikler öğretmenin kullanması halinde doğrudan öğretim stratejilerini oluşturmaktadır. Bu yüzden müfredatta yer alan poster etkinliği ve vejetatif üreme deneyini yapan öğretmenlerin hem müfredat bilgisi hemde öğretim stratejileri bilgisinin etkilendiği söylenebilir. Ayrıca müfredatta öğretmenlerin hücre bölünmesi konularını 5E öğrenme yöntemi ile öğretmeleri önerilmektedir. Bu anlamda 5E öğrenme yönteminin bilinmesi ve uygulanması öğretmenlere müfredat bilgisi ve öğretim stratejileri bilgisi açısından fayda sağlar. Bu çalışmada öğretmenler önerilen etkinlikleri genel olarak yapmamışlardır buna sebep olarakta yaklaşan TEOG sınavını göstermişlerdir.

Bu çalışmanın öğretmenler müfredat bilgisi ile ilgili olarak hücre bölünmesi konusunun müfredattaki yerini bilmişlerdir. Ayrıca hücre bölünmesi ile ilgili kazanımlara hakimdirler. Öğretmenler hücre bölünmesi konusunun kalıtım konusu, hücre konusu, üreme, büyüme ve elişme konuları ile ilgili olduğunu belirtmiştirler.

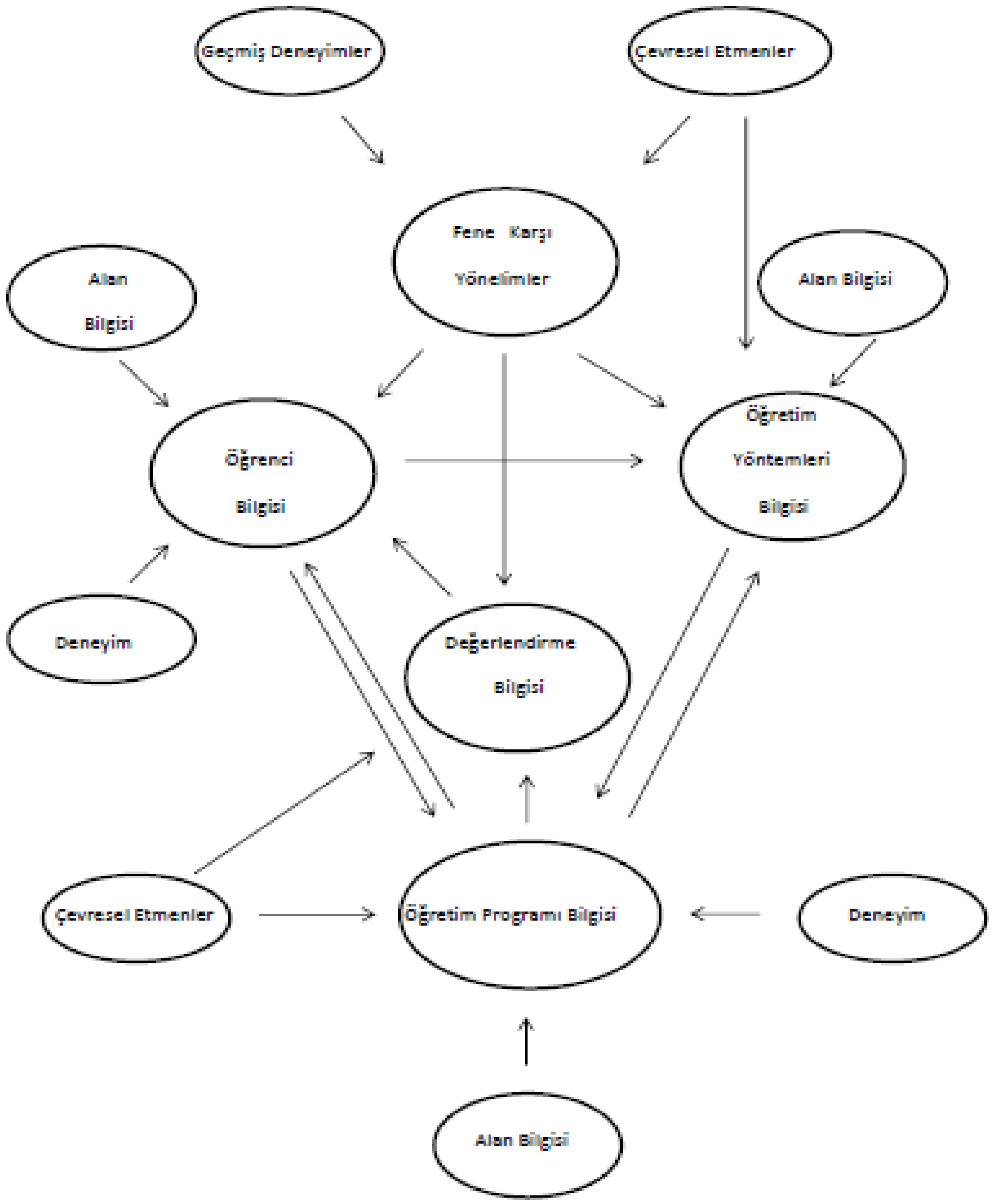
Öğretmenlerin hücre bölünmesi ile ilgili müfredat bilgileri onların deneyimleri ile ilgili olabilir. Öğretmenlerin müfredat bilgisi öğrenci bilgisi ile yakından ilgilidir buna göre öğretmenler öğrencilerin zorlandıkları noktalar hakkında müfredatı ihtiyaçlar doğrultusunda şekillendirmektedir (Bayer & Dawis, 2012; Miranda, 2010). Bu çalışmada öğretmenler ön bilgi olarak önemli gördükleri kromozom, DNA gibi konuları bu yüzden mitoz konusundan önce anlatmak istemekte fakat müfredata bağlı oldukları için bu değişimi yapamamaktadırlar. Ayrıca öğretmenlerin yaklaşan TEOG sınavından dolayı ders kitabındaki ve çalışma kitabındaki etkinlikleri yapamamaları onların müfredat bilgilerini de olumsuz yönde etkilemektedir. Bu çalışmada öğretmenler ders kitabını öğretimleri için temel kaynak olarak görmektedirler. Ders kitabının temel kaynak olarak kullanılması belki öğretim stratejilerini etkiler fakat öğretmenin öğrenci bilgilerini geliştirmeye yardımcı olmamaktadır çünkü ders kitapları genel öğrenci seviyesine göre hazırlanmaktadır (Bayer & Davis, 2012). Dolayısıyla öğretmenler kendi sınıflarında öğrenci bilgilerini arttırmak istiyorlarsa ders kitabını birincil kaynak olarak görmemeli ona alternatif kaynaklar bulmalıdırlar.

Bu çalışmanın sonuçlarına göre öğretmenlerin fene karşı yönelimleri diğer boyutları da etkilemekte ve şekillendirmektedir. Fakat fene karşı yönelimlerin doğrudan müfredat bilgisini etkilediğine dair herhangi bir bulguya rastlanılmamıştır. Öğretmenlerin fene karşı yönelimlerinin öğretmenlerin geçmiş yaşantılarından, çevresel etmenlerden (TEOG, zaman sınırlaması) etkilendiği düşünülmektedir.

Bu çalışmanın sonuçlarına göre öğrenci bilgisi fene karşı yönelimlerden, değerlendirme bilgisinden, konu alan bilgisinden ve öğretmenin tecrübesinden beslenmektedir. Değerlendirme bilgisi ise fene karşı yönelimlerden, müfredat bilgisinden ve çevresel etmenlerden (TEOG) etkilenmektedir.

PAB'ın bir diğer bileşeni olan müfredat bilgisinin öğretmenin deneyiminden, öğrenci bilgisinden, öğretim stratejileri bilgisinden ve çevresel etmenlerden (TEOG) etkilendiği düşünülmektedir.

Son olarak ise diğer bileşenlerden en fazla etkilenen öğretimin yansıtıldığı öğretim stratejileri bilgisi olmuştur.Buna göre öğretim stratejileri bilgisi doğrudan fene karşı yönelimlerden, müfredat bilgisinden ve öğrenci bilgisinden etkilenmektedir. Aynı zamanda öğretmenlerin öğretim stratejileri bilgisi TEOG, veli beklentisi, zaman, okul politikası gibi çevresel faktörlerden de etkilenmektedir. Buna göre bu çalışmada yer alan fen bilgisi öğretmenlerinin hücre bölünmesi konularında PAB'ı için aşağıdaki şekil önerilebilir:



Şekil 2. Fen Bilgisi Öğretmenlerinin Hücre Bölünmesi ile İlgili Pedagojik Alan Bilgisi

Öneriler

Bu çalışmanın sonuçlarına bağlı olarak fen bilgisi öğretmenlerine hücre bölünmesi konularında bir profesyonel gelişim programı önerilmektedir. Bu bağlamda çalışmaya deneyimli fen bilgisi öğretmenleri alınması verilecek olan programın daha verimli olmasını sağlayacaktır. Fen bilgisi öğretmenlerine hücre bölünmesi öğretimi için verilecek olan bu programda öncelikle bilimin doğasının konu ile ilgili bir şekilde öğretmenlere anlatılması doğru olacaktır. Örneğin, hücre bölünmesi konusunun tarihteki bilimsel gelişimi üzerinden katılımcıların bilimin doğası bilgisi arttırılabilir. Bu konuda McComas (2012)' ın belirttiği üzere hücre bölünmesi konusunda bilim insanlarının pangenez görüşünden nasıl hücre bölünmesi konusuna geldiği anlatılarak bilimin doğasına ilişkin öğretmenlerin deney yapma, gözlem yapma, bilimsel bilginin değişebilir olması, bilim insanının öznel olması, bilimin toplumsal normlardan etkilenebilir olduğu ve bilim insanlarının her zaman yaratıcılıklarını kullanabildiği sonuçlarına varması sağlanabilir. Fakat bilimin doğası seminerlere entegre edilirken öğretmenlerin performansları aynı zamanda sınıf içi gözlemlerle de takip edilmelidir yani öğrenciler de bu seminerin bir parçası olmalıdır. Çünkü daha önce yapılan çalışmalar öğretmenlerin seminerlerde etkili performans göstermelerine rağmen bunu sınıflarına yansıtmadıklarını ortaya koymuştur (Guerra-Ramos, Ryder & Leach, 2009). Ayrıca bu seminerlerde bilimin doğasına; felsefecilerin gözünden bakıp öğretmenleri bu şekilde bilgili, kısmen bilgili ve bilgisiz olarak sınıflandırmaktansa, duruma pedagojik bir şekilde yaklaşıp öğretmenlerin görüşlerini almak daha başarılı sonuçlar verecektir. Bu noktada Hanuscin ve arkadaşlarının (2010) ortaya koyduğu şu yaklaşım benimsenebilir: öğretmenlere bilimin doğası ile ilgili çocukların analayabileceği bir dil oluşturmak, bilimin doğası kavramları ile ilgili daha basit tanımlamalar yapmak ve bilimin doğasını benzetimler yardımıyla öğrencilere anlatmak olabilir. Bu durumda seminerlerde öğretmenlere bilimin doğası anlatılırken çocukların aşina oldukları hikayeler üzerinden bilimin doğası konusu hücre bölünmesi konularına entegre edilebilir.

Öğretmenlerin bilimin doğası konusunu derslerinde uygulayabilmeleri için öğretim programınında desteğine ihtiyaç duyulmaktadır. Buna göre öğretim programı bilimin doğası ile ilgili etkinliklere yer vermelidir ve konu ile ilgili özel kazanımlarda bulunmalıdır (Hanuscin vd., 2010).

Çalışmada ayrıca öğretmenlerin içerik alan bilgisi ile ilgili de bazı sorunlar görülmüştür. En önemli iki problemin öğretmenlerin hücre bölünmesi konularında madde kategorisinden süreç kategorisine çıkamaması ve hücre bölünmesi konusu ile genetik konusu arasında yeteri kadar ilişki kuramamalarıdır. Önerilen programda bu kapsamda hücre bölünmesi temel kavramları verilirken kavramların ne olduğu kadar bu kavramların işlevlerine de değinilmesi gerekmektedir ki öğretmenler süreç kategorisine geçebilsinler. Bununla beraber mitoz ve mayoz konuları seminerlerde verilirken allel gen konusuna ve bağımsız dağılım yasasına özellikle dikkat edilmelidir. Öğretmenlerin allel geni ve bağımsız dağılım yasasını dikkatle öğrendikleri takdirde hücre bölünmesi ve genetik konularında daha fazla bağlantı yapabilecekleri düşünülmektedir. Ayrıca öğretim programı hazırlayıcılarının biyoloji konularını hazırlarlarken konuları birbiri ile ilişkilendirmesi gerekmektedir. Örneğin konuları birbirinden ayrı bölümler halinde vermek öğretmenlerin ve öğrencilerin aynı konuyu farklı konularmış gibi düşünüp konuyu anlamamalarına neden olabilir (Cho vd., 1985).

Yapılması önerilen seminer için öğretmenlerin öncelikle fene karşı yönelimleri üzerinde durulmalıdır. Çünkü öğretmenler derslerde öğrenci merkezli bir yaklaşım geliştirmemişlerdir. Öğretmenlerin bu konu ile ilgili inançlarını değiştirmek çok zor olduğu için (Luft & Roehring, 2007) ve bu boyut diğer boyutları şekillendirdiği için bu boyuta öncelikli önem verilmelidir. Öğrenci merkezli yaklaşımlar ön plana çıkarılarak öğretmenlere öğrenci merkezli öğretim strateji ve yöntemleri öğretilmelidir. Bununla beraber alternatif değerlendirme yaklaşımlarının da öğretilmesi gerekmektedir çünkü öğretmenlerin bu konuda eksiklikleri olduğu açıktır. Öğrenci merkezli bir yaklaşım öğretmenlerin deneyimleri ile zenginleştirdikleri öğrenci bilgilerini de etkileyecektir. Ayrıca alternatif değerlendirme yaklaşımları öğretmenin öğrenci bilgisini daha kolay anlamasına yardımcı olacaktır. Öğretmenlere verilecek olan seminerde ayrıca fen okur yazarlığının vurgulanması beklenmektedir çünkü fen okur yazarlığı öğretim programının temel amacıdır. Fen okuryazarlığının alt boyutları olan bilimin doğasına, bilimsel süreç becerilerine, bilim toplum ve teknoloji konularına yapılan vurgu öğretmenlerin fene karşı yönelimlerini etkileyebilir ve buda öğretmenlerin değerlendirme bilgilerini geliştirebilir. Bir başka ifadeyle sadece içerik alan bilgisini değerlendiren öğretmenler fen okur yazarlığını benimseyip ona göre yönelimlerini değiştirirlerse değerlendirme bilgilerini de bu değişimden etkilenecek ve içerik alan bilgisinin dışında da değerlendirmelerde bulunacaklardır. Değerlendirme bilgisinin değiştirilmesi ve geliştirilmesi öğrenci bilgisini arttıracaktır. Öğrenci bilgisi artan öğretmenlerde uygun öğretim stratejilerini benimseyeceklerdir.

Son olarak ise bu çalışmada ortaya konan öğrenci bilgileri, kavram yanılgıları, öğretim stratejileri, öğretmen etkinlikleri, öğretmenlerin kullandıkları benzetimler, modeller, öğretmenlerin konular arası yaptıkları ilişkilendirmeler hücre bölünmesi öğretimine yabancı olan öğretmen adayları için faydalı olabilir dolayısıyla çalışmanın bulguları öğretmen eğitimi veren kurumlarda kullanılabilir. Böylece öğretmen adayları ilerisi için hücre bölünmesi konularında bir ön hazırlık yapmış olabilirler.

APPENDIX M

TEZ FOTOKOPİSİ İZİN FORMU

ENSTİTÜ

- [ ] Fen Bilimleri Enstitüsü
- [x] Sosyal Bilimler Enstitüsü
- [ ] Uygulamalı Matematik Enstitüsü
- [ ] Enformatik Enstitüsü
- [ ] Deniz Bilimleri Enstitüsü

YAZARIN

Soyadı : Mehmet
Adı : Şen
Bölümü : İlköğretim

TEZİN ADI: A Study on Science Teachers' Pedagogical Content Knowledge and Content Knowledge Regarding Cell Division

TEZİN TÜRÜ : Yüksek Lisans [x] Doktora [ ]

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

TEZİN KÜTÜPHANEYE TESLİM TARİHİ: