THE INVESTIGATION OF PEDAGOGICAL CONTENT KNOWLEDGE OF TEACHERS: THE CASE OF TEACHING GENETICS

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ABSTRACT

THE INVESTIGATION OF PEDAGOGICAL CONTENT KNOWLEDGE OF TEACHERS: THE CASE OF TEACHING GENETICS

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In this study science teachers' content knowledge and pedagogical content knowledge (PCK) on genetics was investigated with respect to science teachers' knowledge of curriculum, knowledge of students, and knowledge of teaching strategies. Five experienced science teachers (one male and four female) teaching genetics to 8th grades from five middle schools participated in the study. Case study, one of the qualitative research designs, was adopted as a research design. In order to gather information on content knowledge and PCK components, genetics test, pre-PCK interview, classroom observations, and post-PCK interview were employed.

Findings of the study revealed that participants did not fully comprehend basic concepts in genetics. In a similar vein, they did not express sound curriculum knowledge and they employed applications exceeding the curriculum border such as solving problem about hereditary diseases crossing. Moreover, participants represented generally sound knowledge of students with respect to both knowledge of requirements and difficulties of students while learning genetics. However, they had limited knowledge on teaching strategies for both subject specific (e.g. learning cycle) and topic specific (e.g. representation, activities). In addition, participants did not employed representations to teach genetics concepts meaningfully and any activities to help their students learn the relationships between genetics concepts. All of the participant teachers employed a similar teaching approach to overcome students' misconceptions and difficulties such as giving explanations.

Keywords: Pedagogical Content Knowledge, Science Teacher, Science Education, Genetics

ÖZ

ÖĞRETMENLERİN PEDAGOJİK ALAN BİLGİLERİNİN ARAŞTIRILMASI: GENETİK ÖĞRETİMİ DURUMU

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Bu çalışmada fen öğretmenlerinin genetik konusunda sahip oldukları alan bilgileri ve pedagojik alan bilgileri (PAB) araştırmada PAB, fen öğretmenlerinin öğretim programı bilgisi, öğrenci bilgisi ve öğretim stratejileri bilgisi yönlerinden incelenmiştir. Bu çalışmaya, beş ortaokuldan 8. sınıflara genetik dersini anlatan deneyimli beş fen ve teknoloji öğretmeni (biri erkek, dördü kadın) katılmıştır. Nitel araştırma metotlarından biri olan durum çalışması araştırma deseni olarak kullanılmıştır. Alan bilgisi ve PAB bileşenlerine ait bilgiler genetik testi, ön PAB görüşmesi, gözlem ve son PAB görüşmesi yolu ile toplanmıştır.

Çalışmanın bulguları katılımcıların genetik konusunda yeterli kavram bilgisine sahip olmadığını ortaya çıkarmıştır. Benzer olarak, katılımcıların sağlam bir öğretim programı bilgilerinin de olmadığı ve kalıtımsal hastalık çaprazlaması gibi öğretim programı sınırlarını aşan bazı uygulamaları yaptıkları gözlenmiştir. Bunlara ek olarak, çalışmaya katılan öğretmenlerin genel olarak genetik konusunun öğrenilmesi için gerekli olan öğrenci ihtiyaçları ve karşılaşılan öğrenci zorlukları hakkında sağlam bir bilgiye sahip oldukları tespit edilmiştir. Bununla birlikte, öğretmenlerin hem alana özel (öğrenme döngüsü gibi) hem de konuya özel öğretim stratejileri hakkında (gösterim ve etkinlikler gibi) sınırlı bir bilgiye sahip oldukları gözlenmiştir. Ayrıca, katılımcıların genetik kavramlarının anlamlı öğretimi için herhangi bir gösterim geliştiremedikleri ve genetik kavramları arasındaki ilişkiyi öğrencilerin anlamasına yardımcı olacak bir etkinlik geliştiremedikleri gözlenmiştir. Tüm katılımcıların öğrencilerin sahip olduğu kavram yanılgılarını ve öğrenme zorluklarını gidermede açıklamalarda bulunmak gibi benzer öğretim yaklaşımı kullandıkları tespit edilmiştir.

Anahtar Kelimeler: Pedagojik Alan Bilgisi, Fen Bilgisi Öğretmeni, Fen Bilgisi Eğitimi, Genetik

To My Wife Nurdane Aydemir

&

To my daughter Nilüfer Elvan Aydemir

&

To my son Vedat Emre Aydemir

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PCK	Pedagogical content knowledge

1. CHAPTER

INTRODUCTION

People's thoughts about teachers altered as the time passed. About 100 years ago, knowing content meant that the teachers could teach the subjects efficiently (Shulman, 1986). The content knowledge far outweighs the method of teaching, which is considered as the second important thing, for the qualification of a teacher. In the second section of the twentieth century, the thoughts about the ability to teach changed and pedagogical knowledge consists of classroom management, teaching methods, questioning techniques and evaluation. Furthermore, some studies about teachers' teaching behavior and evaluation of students' success were carried out. Shulman (1986) uses George Bernard Shaw's phrases to describe this situation. "He who can, does. He who cannot, but knows some teaching procedures, teaches." (p. 4).

Shulman (1986) wanted to know the answer of question "What is the missing paradigm?" and found out that the missing paradigm was pedagogical content knowledge, which is described as the combination of content knowledge and pedagogical knowledge. Pedagogical content knowledge means that teachers utilized analogies, illustrations and examples to make the subjects more understandable for the students (Shulman, 1986).

Science teachers are envisaged to have a detailed knowledge of science subject matter and scientific concepts. Moreover, they are expected to comprehend the students really well and their knowledge of instructional strategies, assessment strategies, and curricular resources should be extensive (Gess-Newsome, 1999).

Teachers can gain all of this knowledge during their education which can back up the knowledge mentioned earlier. Teacher education should enhance teacher effectiveness and thereby student learning should be more. Consequently, studies about teacher knowledge have to be conducted on account of their playing an important role in supplying detailed and extensive data for the development of the teachers and programs (Avraamidou & Zembal-Saul, 2005; Friedrichsen, 2008; van Dijk & Kattmann, 2007; van Driel, Verloop, & de Vos, 1998).

The aforesaid, pedagogical content knowledge is really a foremost term and it is the most crucial part for teaching (Shulman, 1987). Comprehending the composition of pedagogical content knowledge is extremely essential so that teacher educators can easily find out the areas to improve prospective teachers' pedagogical content knowledge (Gess-Newsome & Lederman, 1999; Käpylä, Heikkinen, & Asunta, 2008; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008). Provided that the inexperienced teachers have the skill, it is possible for them to learn pedagogical content knowledge, which can increase their capability to teach the subject matters more effectively (Rollnick et al., 2008). Additionally, it helps inexperienced teachers to find new methods in order to talk over issues as long as content knowledge goes hand in hand with practice. According to the research, pedagogical content knowledge assists them to generate new methods so that they can develop themselves (Loughran, Berry, & Mulhall, 2006; Loughran, Mulhall, & Berry, 2008; Rollnick et al., 2008).

In spite of the fact that the construct of PCK is complicated, it has affected the studies done approximately for two decades about the link between subject matter and pedagogical knowledge. Besides, it showed how the content knowledge was crucial for teaching and how it helped the teachers to improve themselves (Borko & Putnam, 1996; Bransford, Brown, & Cocking, 1999; Carter, 1990; Cochran & Jones, 1998; Cochran-Smith & Lytle, 1999; Donovan & Bransford, 2005; Grossman, Schoenfeld, & Lee, 2005; Morine-Dershimer & Kent, 1999; Munby, Russell, & Martin, 2001). Grossman et al. (2005) articulated that the centrality of PCK was necessary for the teacher education curriculum and teachers need to have pedagogical knowledge about the subject matters in order that they can reach a great variety of learners to explain the subjects. What is more, Magnusson, Krajcik, and Borko (1999) uttered that science teachers could change and prepare the learning situations by taking the needs of individual learners into consideration with the help of PCK. It was said that science teachers need to understand the content very well and have a detailed knowledge of the curriculum, student understanding, divergent teaching strategies, in addition to the aims of different assessment techniques so as to be effective teachers. Besides, they should know how to put all of them into practice. It is the effective teachers who use all the components of PCK to provide a classroom environment in which learners can reach all the subject matters easily. Additionally, Bransford et al. (1999) emphasized how it was important for teachers to possess considerable skill in teaching in which they should concentrate on understanding rather than memorization and they should prepare activities where students will take part in, which helps them to consider their own learning and perception.

Upon analyzing science education at K-12 and undergraduate levels, finding the relationship between how teachers' knowledge affects practice is vital on the grounds that the connection between what teachers think and how they teach is strong. The link between them has an enormous effect on both for student learning and teacher education (Ball & Bass, 2000; Borko & Putnam, 1996; Carter, 1990; De Jong, Veal, & van Driel, 2002; Grossman, 1990; Kagan, 1992; Reynolds, 1992; Springer, Stanne, and Donovan, 1999). When the performance of students at all levels is analyzed, it is clearly seen that teachers need to use PCK cautiously in order to assist learning.

1.1 Pedagogical Content Knowledge as a Topic Specific Knowledge

Most of the studies that have been carried out about PCK up to now have highlighted its nature and development instead of focusing on how it is implemented in the classroom environment concerning specific subjects (De Jong et al., 2002; van

Driel et al., 1998; Veal & MaKinster, 1999). Researchers are presently conducting more studies to explain the results of desirable PCK to utilize it for specific science topics and to reveal how PCK affects teachers' carrying out activities in a real classroom environment to make the learning more effectively (Cochran & Jones, 1998; Morine-Dershimer & Kent, 1999, Van Driel et al., 1998). In addition, Magnusson et al., (1999) and Abell (2008) have studied PCK in detail to find out the areas which are needed for teaching specific science topics and to analyze how it exerts its effects on teachers' practice in specific teaching contexts.

When PCK is used for a specific topic, it shows teachers' understanding both for the difficulties that students face whilst studying the topic and the most effective instructional strategies, analogies, demonstrations, details that are essential for the students to reach the topic (Veal & MaKinster, 1999). Although every science topic has its own concepts, terms, they all have various instructional strategies and methods to succeed in their goals. The difference in instructional strategies and methods emphasizes the need to discover special PCK for each topic. That is to say that teachers need to have divsergent pedagogical content knowledge for each topic.

A science teacher having considerable knowledge about PCK should obtain a detailed knowledge of the subject matter, competencies and content representations unique to each science topic in theory. When this knowledge is combined with knowing learners and context really well, it lets the teachers foster conceptual understanding among students. Teachers' being knowledgeable about their topic influences their teaching effectively and teachers not knowing the subject matters, content structure, teaching methods and employed materials in detail decreases their teaching efficiency, which reveals that those teachers are lack of enough pedagogical content knowledge (Käpylä et al., 2008; Rollnick et al., 2008). Besides, teachers who have erroneous and insufficient knowledge about their area are likely to convey wrong conceptions to the students, which gives rise to students' having difficulty in understanding concepts (Käpylä et al., 2008).

The topic of genetics was chosen to study PCK in the present study since it is one of the topics that students' tendency to memorize the subjects is well-known, which makes them improve some misconceptions about the subject (Cavallo, 1996). According to the studies, genetics is one of the most foremost and challenging topics of science (Bahar, Johnstone & Hansell, 1999; Banet & Ayuso, 2000; Kindfield, 1991; Venville & Donovan, 2007). It has been articulated in the studies that chromosomes, genes, alleles, homozygous, heterozygous, dominance, recessiveness, mitosis, meiosis and fertilization are the main concepts that the students do not comprehend the meaning completely (Clark & Mathis, 2000; Lewis, Leach & Wood-Robinson, 2000a; Lewis, Leach & Wood-Robinson, 2000b; Slack & Stewart, 1990). The most crucial reason why the students do not fully understand genetics concepts is their having an abstract nature (Law & Lee, 2004) and a connection with different levels of organizations such as macroscopic level, microscopic level and submicroscopic level. Because of their having a relationship with each other, it is essential that the students know the link for coherent understanding (Marbach-Ad & Stavy, 2000). Students should know the connection between each genetics concept meaningfully so as to better perceive scientific concepts such as reproduction, biological diversity of organisms, mutation, adaptation, evolution and the applications of genetics daily especially cloning, medicine, agriculture, forensic science and genomics (Tsui & Treagust, 2007; Rotbain, Marbach-Ad & Stavy, 2006). Furthermore, it has been highlighted in the studies that when the teachers prepare activities in which the students are involved actively with the help of teachers, it is possible for the students to boost meaningful understanding of genetics concepts.

In science curriculum, students see the word “genetics” for the first time at 8th grade, which is the time when they are 14 / 15 years old. According to Tobin and Capie (1982), a great number of students, who are at these ages, find it extremely difficult learning how to utilize integrated process skills and thereby teachers should carry out activities, which aim to develop those competencies. Or else, students may not understand abstract concepts such as genetics. Teachers, having sufficient pedagogical content knowledge, can succeed in breaking this cycle because teachers, who do not know their subject matters really well, cannot understand in which area the students are encountering some difficulties. Additionally, when the teachers are not skillful at analyzing the curriculum and lack the knowledge about how to apply appropriate instructional methods and assessment techniques in the classroom effectively, they aren’t liable to understand which skills the students should improve and what sort of misconceptions they have. All of the things mentioned above should be used in order better to teach the subjects and correct the students’ misconceptions about the topic of genetics. The pedagogical content knowledge is defined as the combination of various kinds of knowledge, which makes it easy for the students to learn specific topics (Shulman, 1986) and if teachers wish to teach the topic of genetics successfully, they need to have excellent pedagogical content knowledge. This emphasizes that science teachers call for pedagogical content knowledge on genetics in order that they can meet expectations.

The nature of pedagogical content knowledge, definition, and components are not clear and or has fuzzy meaning (Abell, 2007; Gess-Newsome, 1999; Hashweh, 1987). Moreover, the nature of pedagogical content knowledge isn’t explained easily, which brings about some problems (Abd-El-Khalick, 2006, Veal, Tippins, & Bell, 1998). The reason why the topic of genetics was chosen in the present study is that there is a great deal of knowledge and many studies, especially on students understanding, carried out about the genetics. In addition, this topic is studied at different levels from kindergarten to university (Bahar et al., 1999; Banet & Ayuso, 2000; Kindfield, 1991; Venville & Donovan, 2007). For the topic of genetics, researchers are believed to describe the components of pedagogical content knowledge more precisely.

The picture shown above is a marvelous example of the need to comprehend teachers’ pedagogical content knowledge on the topic of genetics. The reason why this topic has chosen is that middle school students find it really challenging and it has abstract concepts. Moreover, it is believed to be a prominent topic because that it has connections with other biological topics.

1.2 Significance of the Study

The term of PCK firstly used in 1986 and since then academicians have examined how PCK flourishes, what components it has and how the components affect each other. Previous studies claimed that the nature of PCK is specific (Cochran, King, & DeRuiter, 1991; Loughran, Mulhall, & Berry, 2004; van Driel et al., 1998; Veal & MaKinster, 1999). Nonetheless, there were not enough evidence to show how PCK is specific and how teachers convey their knowledge of different subjects to students by using PCK (Abell, 2008; van Driel et al., 1998). Consequently, it has been described in the literature that more topic specific PCK studies need to be done in the classroom to find out how teachers utilize their PCK whilst transferring their knowledge about the subject matters to pedagogically powerful representations so as to boost student learning (Abell, 2008; Avraamidou & Zembal-Saul, 2005; Bucat, 2004; De Jong, van Driel, & Verloop, 2005 Loughran et al., 2004; Morine-Dershimer & Kent, 1999; Shannon, 2006; van Driel et al., 1998). Loughran et al., (2004) underlined that the number of concrete illustrations of teachers' PCK is scarcely inadequate. Hence, ongoing research aims to give useful information on teachers' PCK and how skillful they are to utilize their PCK whilst teaching special topics due to PCK's being specific (van Driel et al., 1998).

As the information is obtained from the real classroom environment, this study is really crucial. For the aforesaid reasons, the purpose of this study was to provide valuable information on PCK literature about the nature of the construct and effective knowledge that teachers utilize in the real classroom environment while teaching. Real practitioners' experience reveals that topics are really important for teachers' teaching and assessment practices. Contrary to other studies, this study was carried out by taking experienced teachers' teaching practice in an authentic classroom into account.

This study intends to supply other science teachers teaching the same topic with valuable knowledge besides giving theoretical knowledge. Experienced teachers are liable to have many instructional methods and strategies, which might help other teachers' teaching. Therefore, thanks to sharing experience system, PCK can improve both teachers' practical and theoretical knowledge (Loughran et al., 2004).

With respect to the practical use, Bucat (2004) related the custom of teaching profession with "re-invention of the wheel." In contrast to other occupations, there is no information about the experience of qualified teachers to record. The investigators called the problem "professional amnesia." Bucat (2004) suggested two ideas to solve the problem. The first idea was that teachers, biologists and experts dealing with teaching science should work in collaboration with each other to produce an archive which should consist of knowledge about learning, learners' ideas, teaching strategies about special topics like genetics and ideas about how to implement them in the authentic classrooms. Secondly, experienced teachers should write some vignettes about their experience as it happens in other professions like architecture. The written vignettes should give valuable information about how to prepare lesson plans and utilize instructional strategies efficiently. The agenda, which includes a great deal of useful information about the techniques used by experienced teachers, will be an extensive repertoire not only for pre-service teacher education but also for professional development programs used by in-service teachers (Bucat, 2004). Like Bucat (2004), van Driel et al., (1998) articulated that one of the aims of PCK study is to cease "reinvention of the wheel." If experienced teachers do not dispense wisdom on a variety of methods used by them, teacher educators cannot share their experiences with inexperienced teachers. In this way, teaching looks like a game which doesn't have any audiences (Rollnick et al., 2008). As a result, the present study also intended to investigate experienced teachers' PCK. Likewise, Van Driel, Veal, and Janssen (2001) stressed the significance of examining experienced teachers' PCK because experienced teachers didn't provide pre-service and novice teachers with their experiences even though they had a large repertoire of practices. Consequently, by giving detailed information about their practices and sharing them, a precious source could be formed for pre-service teacher education program and in-service teacher trainings.

To finish, it is hoped that investigating experienced teachers' PCK will make a major contribution to PCK literature. Research studies have been conducted to emphasize PCK improvement of pre-service teachers (Loughran et al., 2004; Nilsson, 2008; Shannon, 2006; van Driel, de Jong, & Verloop, 2002; Zembal-Saul, Krajcik, & Bluemenfeld, 2002). Nonetheless, both pre-service and novice teachers don't provide extensive and valuable knowledge about PCK (Magnusson et al., 1999; Shulman, 1987). Therefore examining experienced teachers' practice would be a marvelous example of how teachers utilize PCK in the real classroom environment.

To summarize, the most foremost aim of the present study was to have extensive information about how experienced science teachers use their PCK whilst teaching the topic of genetics. Most crucial components of this study are studying into teachers' PCK in the topic of genetics and revealing how PCK is significant; presenting real examples of experienced teachers' using their PCK in specific topics. Concrete examples are expected to assist both for pre-service and beginning teachers with applying their knowledge in theory and practice (van Driel et al., 2001). Furthermore, they will be an important resource for professional development programs.

In the present study, the topic of genetics was chosen to study science teachers' PCK because this topic hasn't been examined with respect to topic specific PCK before and studies about genetics have showed the misconceptions and difficulties students face (Bahar et al., 1999; Banet & Ayuso, 2000; Venville & Donovan, 2007). In order better to show how PCK is important for each topic, the topics should be different from each other and so it is essential that unstudied topics be chosen.

The study in which experienced science teachers' PCK was investigated is a qualitative case study. It gives extensive information about people, events and groups that are emphasized (Merriam, 1998). Researchers can obtain detailed information from case studies. Consequently, case study design was selected so as to get more information from the teachers. Moreover, PCK model adopted in this study is modified version of Magnusson et al.'s model (1999). Three of components of

Magnusson et al.'s model (1999) were studied and these were knowledge of curriculum, knowledge of students and knowledge of teaching strategies.

1.3 Statement of the Problem

The main aim of the study was to investigate science teachers' content knowledge and PCK on genetics. The PCK was investigated with respect to science teachers' knowledge of curriculum, knowledge of students, and knowledge of teaching strategies. Accordingly, this study sought to answer the following research questions:

1. What are the science teachers' understandings of genetics?
2. What is the nature of science teachers' pedagogical content knowledge regarding the topic of genetics?
   i. What is the science teachers' knowledge of curriculum regarding the topic of genetics?
   ii. What is the science teachers' knowledge of students regarding the topic of genetics?
      a. To what extent are science teachers knowledgeable about the requirements of students while learning genetics?
      b. To what extent are science teachers knowledgeable about the difficulties students experience while learning genetics?
   iii. What kinds of strategies do science teachers employ to teach genetics?
      a. What kind of representations do science teachers employ during teaching genetics?
      b. What kind of activities do science teachers conduct during teaching genetics?
      c. What kind of strategies do science teachers employ to overcome the difficulties students experience while learning genetics?

1.4 Definitions of Important Terms

The research questions consist of several terms that required their definitions.

Pedagogical content knowledge (PCK): it was defined by Shulman (1987) as

> represents the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction (p. 8).

Magnusson et al. (1999) defined PCK

> is a teacher's understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction. (p. 96).

Knowledge of curriculum: it defined the knowledge of goals and objectives for students in the subject they are teaching, besides the expression of those guidelines through the topics addressed during the educational year.

Knowledge of students: Teachers' knowledge of students about genetics was analyzed under two dimensions in this study; namely knowledge of students' requirements and students' difficulties (Magnusson et al., 1999). The knowledge of students' requirements means that development of knowledge in a specific area needs prior knowledge and skills (Magnusson et al., 1999). A teacher should have this knowledge to help students to learn new topic appropriately. The knowledge of students' difficulties refers to teachers' knowledge of the science concepts that students find difficult to learn and this knowledge includes source of the students' difficulties (Magnusson et al., 1999).

Knowledge of Topic Specific Strategies: Knowledge of topic specific strategies is the strategies employed to help students comprehend specific science concepts

Magnusson et al.’s (1999). According to Magnusson et al.’s (1999) PCK model, this knowledge also has two categories: representations and activities. In this study these two categories represents knowledge of topic specific strategies.

The term “representation” refers to teachers’ knowledge of ways to represent specific concepts or principles in order to facilitate students’ learning (Magnusson et al., 1999). This knowledge includes teachers’ ability to invent representation to aid students in developing an understanding of specific concepts or relationships. Teachers should also have knowledge about the relative strengths and weaknesses of a particular representation. Illustrations, examples, models, or analogies are the examples of representations. A topic specific example was about electricity circuit; water flowing through pipes and a bicycle chain (Magnusson et al., 1999).

The term “activities” refers to knowledge about activities that can be employed to help students comprehend specific concepts or relationships (Magnusson et al., 1999). This knowledge also includes knowledge of the conceptual power of a particular activity; it presents signals or clarifies important information about a specific concept or relationship. Problems, demonstrations, simulations, investigations, or experiments can be the examples of activities. For example, teachers should be able to decide what activities to use with middle school students to help them understand the distinction between temperature and heat energy (Magnusson et al., 1999).

2. CHAPTER

LITERATURE REVIEW

In this section of the study, the theory and the models of pedagogical content knowledge, the pedagogical content knowledge studies in science education, in biology education, studies on genetics, and lastly pedagogical content knowledge conceptualization in this study were explained.

2.1 Defining Pedagogical Content Knowledge

Teacher educations, ranging from faculty education to special certification programs, are based on the common attitude that it is the acquisition of content knowledge and pedagogical knowledge by teachers (Shulman, 1986). However, there was no evidence to suggest that a science teacher's content knowledge or pedagogical knowledge was automatically transferred into teacher practice (Gess-Newsome & Lederman, 1999). It was accepted that teaching requires content knowledge (such as chemistry, biology, physics etc.) and general pedagogical knowledge (such as teaching strategies, assessment, classroom management, etc.). Shulman (1986) proposed that there might be a third type of knowledge and this knowledge should be particularly different from two, and combined two. In his approach, the importance of the content knowledge or the pedagogical knowledge was not minimized. Instead, combination of these two types of knowledge was offered with adding an understanding of what makes learning of specific topics easy or difficult for learners. In other words, it is a special “amalgam” of pedagogical knowledge and content knowledge (Shulman, 1986, p.8). Shulman (1986) offered a new concept to this amalgam, pedagogical content knowledge (PCK).

At first, Shulman (1986) defined PCK as special form of content knowledge that:

> ...embodies the aspects of content most germane to its teach ability. Within the category of pedagogical content knowledge I include, for the most regularly taught topics in one's subject area, the most useful forms of representations of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations—in a word, the ways of representing and formulating the subject that make it comprehensible to others...[It] also includes an understanding of what makes the learning of specific topics easy or difficulty: the conceptions and preconceptions that students of different ages and backgrounds bring with them to the learning of those most frequently taught topics and lessons (pp. 9-10).

Shulman (1987) perceived PCK as an exclusive category of the knowledge basis of teacher profession because it is recognized as a distinct body of knowledge for teaching that distinguished between the content specialist and pedagogue. Moreover, he recommended that PCK was the most important knowledge basis of teaching since teaching required the teacher to transform their content knowledge into forms that were "pedagogically powerful and yet adaptive to the variation in ability and background presented by the students" (Shulman, 1987, p. 15).

The Shulman also emphasized that the relationship of content knowledge and pedagogical knowledge in PCK should be reciprocally supportive and integrated as they work synergistically to assist teachers in making content accessible and comprehensible to all students. Shulman’s understanding of PCK includes that PCK composed of not only combination of content knowledge and pedagogical knowledge but also knowledge of the learner, knowledge of the curriculum and knowledge of the context (Wilson, Shulman, & Richard, 1987). This understanding proposed a dynamic teaching process where teachers use different knowledge to meet emerging conditions in a particular teaching context to support learning.

Based on the perception of the dynamic usage of different knowledge in PCK, the centrality part of the Shulman understanding of PCK was the teachers’ competence to transform their content knowledge in combination with the knowledge of specific students learning difficulties, prior understandings, and conceptions into pedagogically powerful representations to facilitate students' learning. The term "transformation" used by Wilson et al. (1987) and they defined transformation as the activities conducted by teachers to start from their understanding of a topic and the representation they uses to facilitate that comprehension to the different alternative representations needed to initiate and support students' understandings of the same topic. On other hand, PCK does not mean a bag of tricks containing various kinds of representations to utilize in the classroom and PCK actually mean pedagogical reasoning, a process of thinking and action that supports the transformation of subject matter (Shulman, 1987; Wilson et al., 1987).

The concept of pedagogical reasoning according to Shulman (1987) and Wilson et al. (1987) involves comprehension, transformation, instruction, evaluation, new comprehension, and reflection concerning the act of teaching. Transformation exists when the teachers interprets and critically reflects on the subject matter and finds diverse method to represent the subject matter through metaphors, analogies, illustrations, activities, assignments, and examples; adapts the subject matter to the students' characteristics such as sex, abilities, prior knowledge including preconceptions and misconceptions; and finally tailors the material to the specific students in the classroom (Shulman, 1987; Wilson et al., 1987). Subject matter knowledge in PCK provides teacher so as to transformation of process between the students and teacher could be effective and flexible. Transformation in PCK is not solely required a sound understanding of subject matter and pedagogical knowledge but also required other information such as knowledge of learners and the context. Since definition of PCK by Shulman (1986), PCK definition was made by other researcher with adding knowledge components and researchers developed different models to explain the nature of PCK.

2.1.1 PCK as a Developing Concept

In this section the development of the concept of pedagogical content knowledge and its models and components were presented.

The researchers define the PCK with different knowledge components and drew models to explain the nature of the PCK in their studies (). Shulman (1987) identified seven categories of teachers' knowledge; (1) content knowledge; (2) general pedagogical knowledge; (3) curriculum knowledge; (4) pedagogical content knowledge; (5) knowledge of the learners and their characteristics; (6) knowledge of educational contexts; and (7) knowledge of educational ends, purposes, and values and their philosophical and historical grounds.

The following studies on PCK inspired from the Shulman's views. Tamir's (1988) understanding of PCK included subject matter knowledge and pedagogical knowledge. The pedagogical knowledge in Tamir's view (1988) included two sub-dimensions; general pedagogical knowledge and subject matter specific pedagogical knowledge. The latter one was indeed PCK and subject matter specific pedagogical knowledge consisted of knowledge of instructional strategy, curriculum, knowledge of students' understanding, and knowledge of assessment. The new knowledge component of Tamir's PCK understanding (1988) was knowledge of assessment.

PCK in Grossman's (1990) understanding was at the center of the teacher knowledge model (Figure 2.1). In her model, PCK is surrounded by three knowledge components; subject matter knowledge, general pedagogical knowledge and knowledge of context. The development of PCK is influenced by these three knowledge components and the PCK influences development of these three knowledge components. Preparation of teaching should include sufficient training in each of these knowledge components so that teacher has the capability to transform their subject matter into form that students can access. This understanding had an impact of the following PCK studies to explain teacher classroom actions.

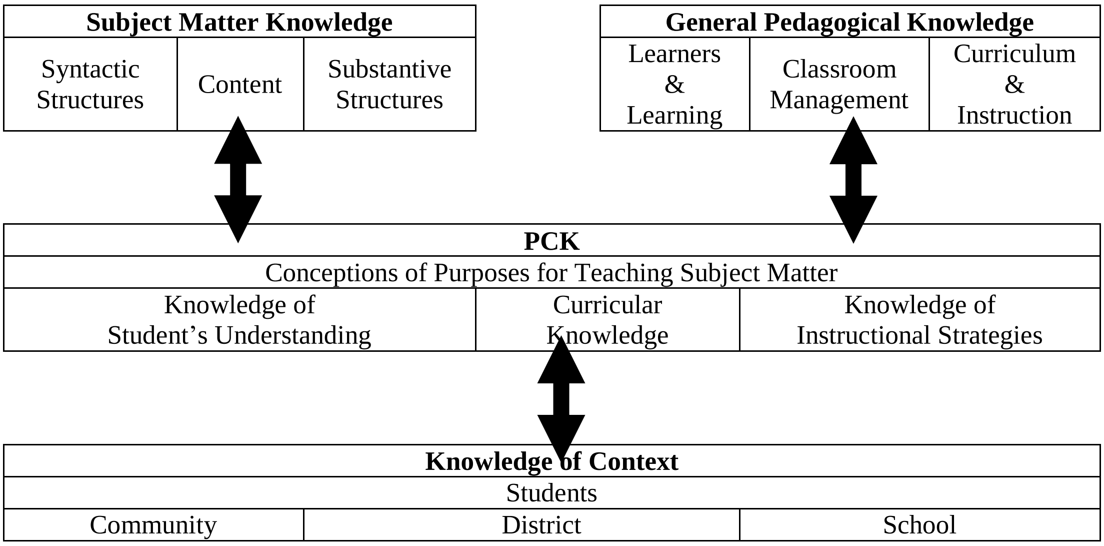


Figure 2.1 Grossman (1990) model for pedagogical content knowledge (p. 5)

Cochran et al. (1991) defined PCK

> concerns the manner in which teachers relate their pedagogical knowledge (what they know about teaching) to their subject matter knowledge (what they know about what they teach), in the school context, for the teaching of specific students (p. 4).

In the following paper, Cochran, Deruiter and King (1993) criticized the understanding of teacher knowledge as a static entity, a pre-packed knowledge available in teacher repertoire such as a representation or analogies for development of a concept. They underlined teaching process has a dynamic nature and requires different knowledge components such as pedagogical knowledge, subject matter knowledge, and knowledge of context in a real time to explain difficult subject matter for specific students in a distinctive learning context. They believe PCK were continually constructed in dynamic teaching process constantly in the context by teachers. In this manner, Cochran et al. (1993) stated that PCK also should be stated in a constructivist perspective and they prefer to use pedagogical content knowing (PCKg) to reflect its dynamic nature. Cochran et al. (1993) defined PCKg as a teacher’s integrated understanding of the following knowledge components; pedagogy, subject matter content, student characteristics, and the environmental context of learning and the transformation of the knowledge components occurred in real time while they forming PCKg in teaching context.

Cochran et al. (1993) schematized their model (Figure 2.2). They used the arrows and expanding circle in the model to display dynamic nature of knowledge such that the each knowledge starts with limited knowledge and develops with the help of the experience in the teaching context. The bold arrows and expanding central circle in the models means the growth in PCKg. The intersection or the overlapping circles means the integration of the knowledge components in PCKg. Cochran et al. (1993) asserted that the knowledge components in PCKg were so integrated that they cannot be considered as a distinct knowledge from each other. Although the circles were in similar sizes in the PCKg model, the development of knowledge components are not same. Moreover, it is underlined that PCK develops over time as a result of experience and the contribution of knowledge components to PCKg is relative during teaching.

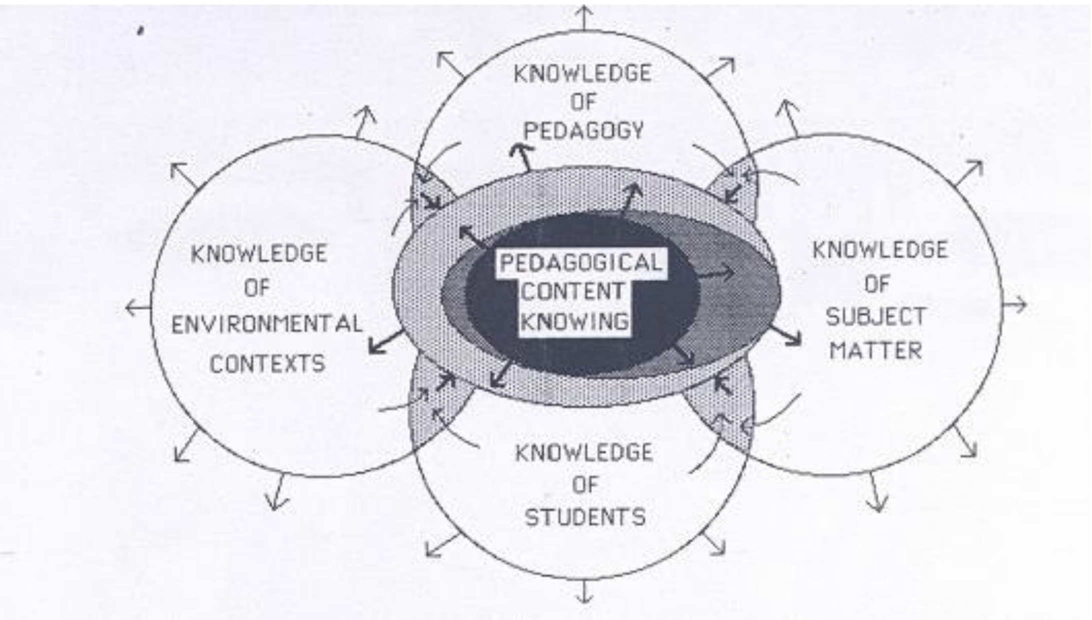


Figure 2.2 Cochran et al.'s PCKg Model (1993, p. 238)

Veal and MaKinnester (1999) offered hierarchical taxonomy of pedagogical content knowledge and they were identified ten components of pedagogical content knowledge. These components are arranged in hierarchical three levels (Figure 2.3).

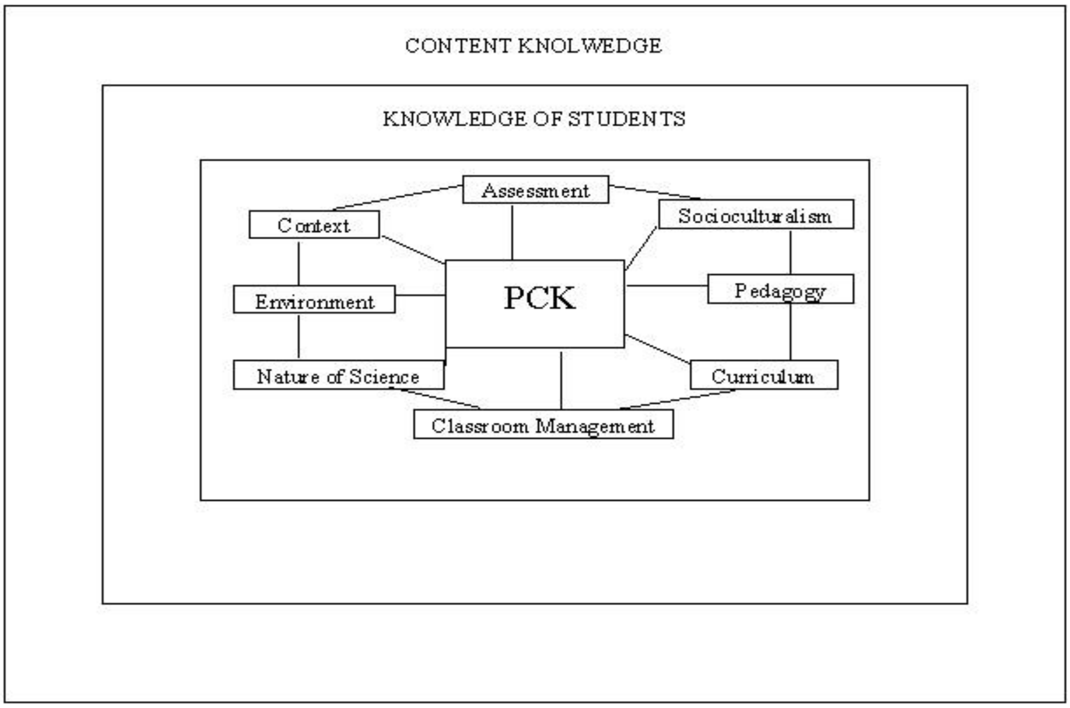
The bottom level of the hierarchical model is content knowledge. According to Veal and MaKinnester, strong content background is essential in hierarchical model to the development of pedagogical content knowledge (1999). Content knowledge can be consisted of general, domain specific, or topic specific. Intermediate level of model takes place with knowledge of students. It was claimed that only after a teacher understands or realizes the importance of the student component of teaching, can be possible to learn or develop the other components of pedagogical content knowledge (Veal & MaKinnester, 1999). The top-level includes eight components (pedagogy, assessment, classroom management, curriculum, context, environment, nature of science, socioculturalism). These eight components are not arranged in a hierarchical manner because they can be developed and understood by the teacher at any time during their teaching career.

The taxonomy of pedagogical content knowledge components does not mean a linear progression of knowledge development. Authors suggest that the taxonomy represents a multifaceted and synergistic developmental relationship between the various components. The hierarchical model includes more components with regard to other models. Another difference is that the hierarchical model does not directly imply the pedagogical knowledge. Students' knowledge is given more privilege from contextual knowledge. Pedagogical knowledge and contextual knowledge are integrated under pedagogical content knowledge in this model.

Developer of hierarchical model (Veal & MaKinnester, 1999) claimed that the other models have deficiency for accepting the idea that pedagogical content knowledge is a product of the three knowledge; subject matter, pedagogical knowledge, and contextual knowledge and pedagogical content knowledge can be transformed directly one setting to other setting. Veal and MaKinnester (1999) argued the concept of transformation and they offered the concept of "*translation.*" Because pedagogical content knowledge is context based and do not directly transformed one situation to other. It can be only translated/adapted to other contexts. Veal and MaKinnester (1999) simulated this situation with language and they states that it is just as Spanish words translated into English, science concepts translated into understandable units of meaning for students. While translation a phrase or idea from one language to another one, the translator should take into account; the audience’s level of understanding, the correct words to use and grammatical order, etc. When the principles of translation are applied to science teaching, the teachers must have the associated knowledge of translator (knowledge of students, content, pedagogy, context and environment) to properly convey her/his message (the science topic) and provide appropriate opportunities for students to discover science concepts and content within an activity or laboratory.

Veal and MaKinnester (1999) argued that the development of pedagogical content knowledge requires one to integrate different types of knowledge, but components in the models could have been developed separately. In addition, the variety of developing ways of pedagogical content knowledge from their components implies that there is not only one prescriptive way to constructing pedagogical content knowledge to a teacher. Other characteristic is compatible with nature of pedagogical content knowledge in the model is the interconnectedness of the pedagogical content knowledge components. This supports the idea of a teacher as a lifelong learner. Teachers have varying degrees of pedagogical content knowledge, and they continually develop each of the components throughout their teaching career.

a. Bird's Eye View



b. Side View

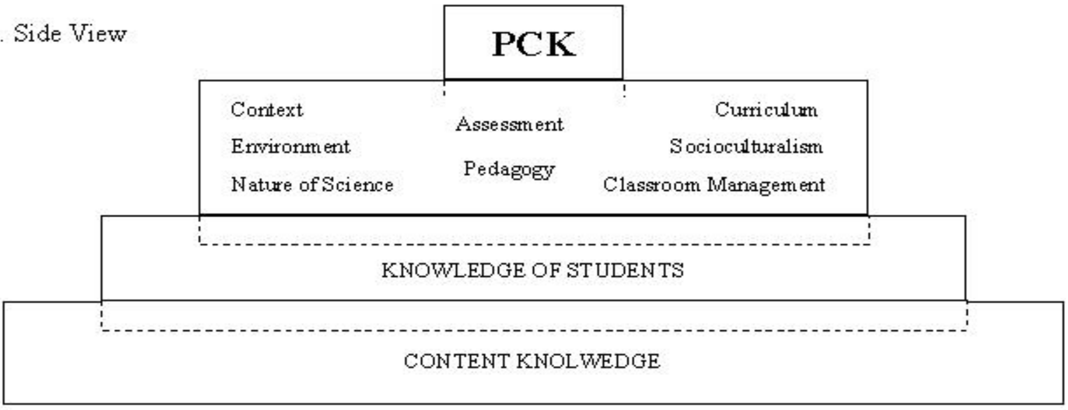


Figure 2.3 Hierarchical Model of PCK (Veal & MaKinster, 1999, p. 11)

Magnusson et al. (1999) defined PCK

> is a teacher's understanding of how to help students understand specific subject matter. It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction. (p. 96).

Their understanding of PCK was influenced the idea that PCK is the results of a transformation of other knowledge components (1999). Magnusson et al. (1999) teacher knowledge model included four knowledge components; subject matter knowledge, pedagogical knowledge, knowledge of context, and pedagogical content knowledge (see Figure 2.4). Although their teacher knowledge model components were similar to Grossman ones (1990), Magnusson et al. (1999) asserted that teachers' beliefs have a deep effect on all aspects of teaching as well teachers' knowledge, and they added belief to knowledge components. The lines and the arrows at the ends of line in the figure display the nature of the relationship between components. They believed that there is a reciprocal relationship between the knowledge components and they display the reciprocal relationship with two-direction arrows.

Magnusson et al. (1999) conceptualization of PCK model for science teaching was composed of five components (Figure 2.5); orientations to science teaching, knowledge and beliefs about science curriculum, knowledge and beliefs about students' understanding of specifics science topics, knowledge and beliefs about assessment in science, and knowledge and beliefs about instructional strategies for teaching science. They preferred to use the term "orientations to science teaching" instead of Grossman's "conception of purposes for teaching particular subject." Moreover, they added "knowledge and beliefs about students' assessment in science" to the PCK model by inspiring from Tamir (1988).

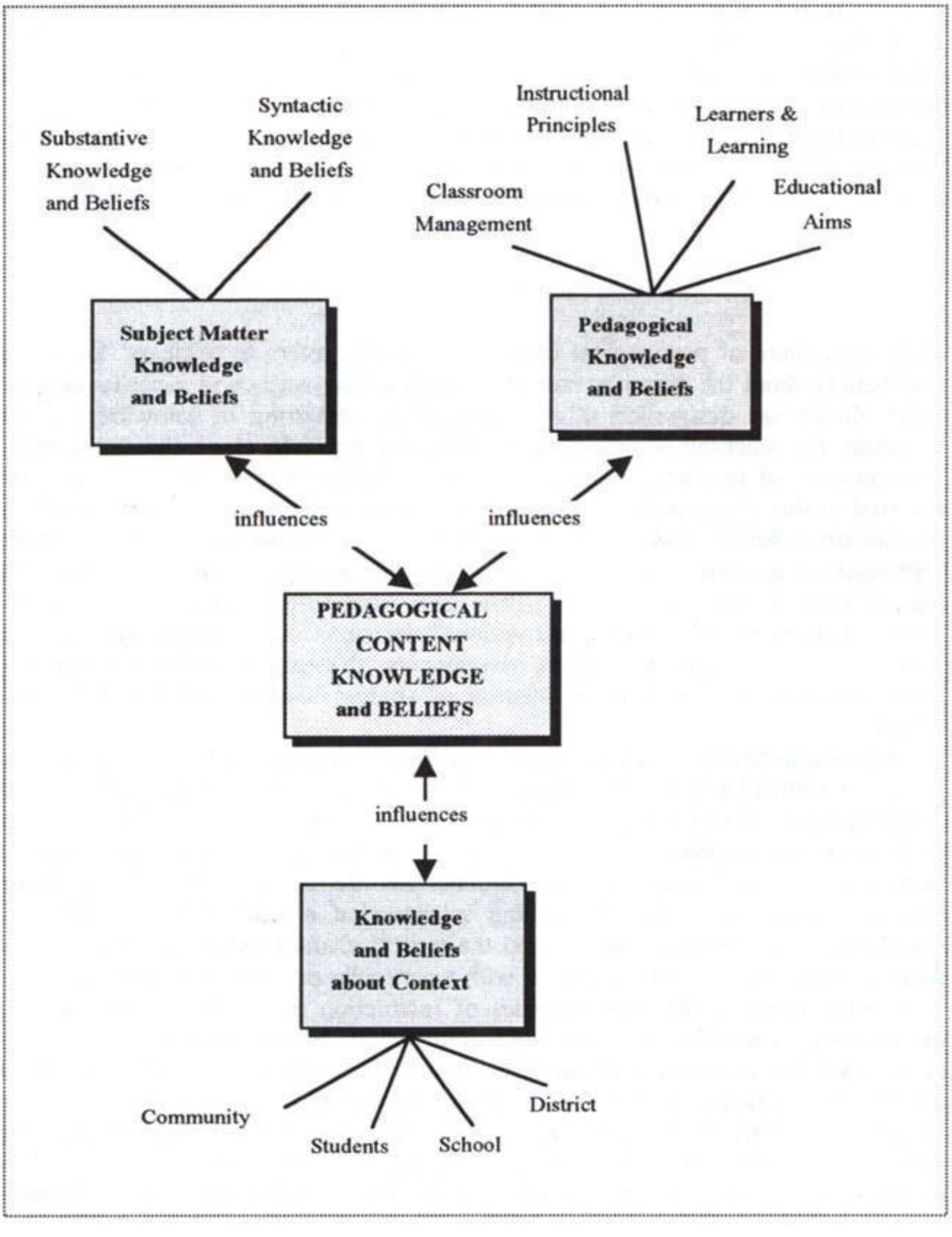


Figure 2.4 Magnusson et al. Model of the Relationships Among the Domains of Teacher Knowledge(1999, p.98).

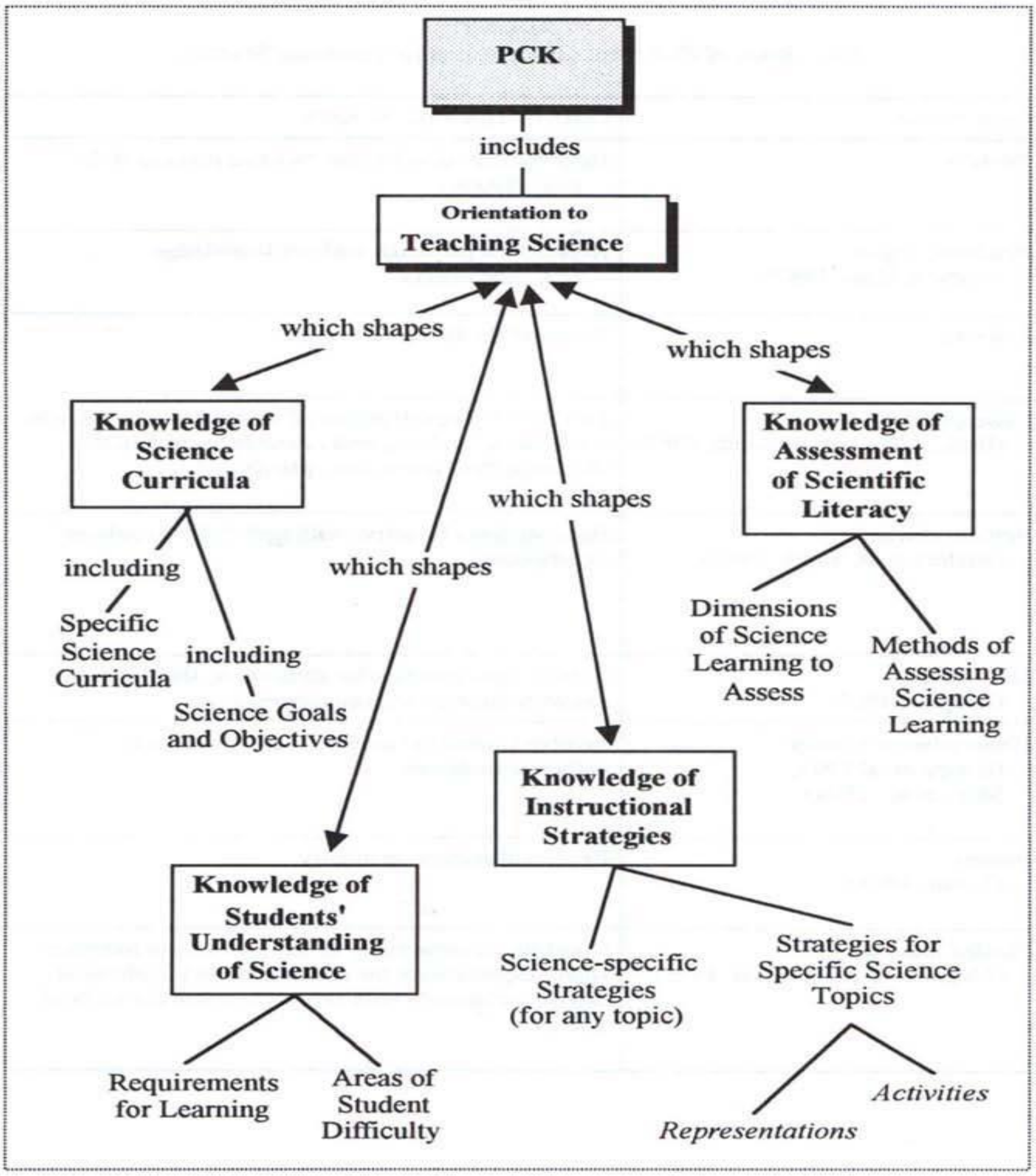


Figure 2.5 PCK Model of Magnusson et al. (1999, p.99)

The component of orientation to science teaching refers to teachers' knowledge and beliefs about main of science teaching at a grade level. This component embodies the teachers' general conceptualization of science teaching. This knowledge serves teachers as a conceptual map that guide pedagogical decisions about topics such as daily objectives, homework content, the use of teaching material, evaluation of students learning etc. According to Magnusson et al.

(1999), the orientation to science teaching of a teachers are process, academic rigor, didactic, conceptual change, activity-driven, discovery, project-based science, inquiry, and guided inquiry. Magnusson and her colleagues (1999) admitted that even though some of the orientations share similar characteristics, teacher's rationale behind the instruction make the orientations distinguishable.

The second component of PCK is the knowledge and beliefs about science curriculum. Magnusson et al. (1999) held this component in two categories; mandated goals and objectives, and specific curricular programs and materials. For Wilson et al. (1987), curricular knowledge is a separate domain of the knowledge base for teaching. On the other hand, Magnusson et al. (1999) consider curriculum knowledge as section of PCK because they believe curriculum knowledge is among the knowledge that distinguishes the content specialist from the pedagogue. One of the sub-dimensions of the curriculum knowledge is *Knowledge of Goals and Objectives* and it defined the knowledge of goals and objectives for students in the subject they are teaching, besides the expression of those guidelines through the topics addressed during the educational year. The other sub-dimension is *Knowledge of Specific Curricular Program* and includes knowledge of the programs and materials that are relevant to teaching a specific topic.

Knowledge of students understanding of science is the third component of Magnusson et al.'s (1999) PCK model and means that teachers should have knowledge about the learners to help them develop specific scientific knowledge. This knowledge has two sub-dimensions and one is *Knowledge of Requirements for Learning*. This knowledge includes teachers' knowledge and beliefs about prerequisite knowledge for learning specific knowledge and knowledge of the abilities and skills that students might need to learn specific concepts. Teachers should also know how students varying in developmental, ability levels, different learning styles. Teachers expected to know learners' individual differences and provide different opportunities to learner with different needs. *Knowledge of Areas of Student Difficulty* is another sub-dimension and refers to teachers' knowledge of the science concepts or topic that students find learning difficult and knowledge of the reason why students find learning them difficult. The given examples of students' difficulties were the abstractness of some of the science concepts, problem solving related difficulties such as students' lack of effective planning to solve problems, and misconceptions of students.

Knowledge of Assessment in science is the fourth components of Magnusson et al.'s (1999) PCK model and includes two sub-dimensions: knowledge of dimensions of science learning to assess and knowledge of methods of assessment. The former refers to knowledge of the aspects of students' learning that are important to asses for a particular topic such as knowledge, application, and science process skills, etc. The latter refers to knowledge of the method that is suitable to utilize in assessment to the specific aspects of students learning which are important for a particular topic such as paper-pencil test, portfolio, laboratory practical exam etc. Teachers also are expected to be knowledgeable about the strengths and weaknesses of an assessment method for a special topic.

Knowledge of Instructional Strategies is fifth and the last component of Magnusson and her colleagues' (1999) PCK model and composed of two sub-dimensions; knowledge of subject specific strategies and knowledge of topic specific strategies. These two dimensions were differ in their scopes and subject specific strategies means applications specific to teaching science and topic specific strategies is particular application specific to a topic or a concept in science.

Knowledge of subject specific strategies includes general approaches utilize during performing the science instruction such as learning cycle, guided inquiry, conceptual change, etc. The Magnusson et al. (1999) asserted that this knowledge is related to orientation to teaching science in which there are general approaches to science instruction that are consistent with the goals of particular orientations. This knowledge requires that teachers should be able to describe and demonstrate a strategy and its phases in an effective way.

Knowledge of Topic Specific Strategies is employed to help students comprehend specific science concepts. According to Magnusson et al.'s (1999) PCK model, this knowledge also has two categories: representations and activities.

Representations refer the knowledge of techniques to represent specific concepts or principles to aid students in developing understanding such as analogies, models, illustration and examples, etc. This knowledge contains also teachers' ability to invent new representations to help students in learning a specific concept and relationships. Moreover, teachers should aware of the relative strengths and weaknesses of particular representations. Activities, as the latter category of these components, are utilized by teachers to help students comprehend specific concepts or principals; such as problems, demonstration, simulations, investigations, experiments. Teachers should be knowledgeable about the strengths and weaknesses of a particular activity the extent to presents or clarify an important concept or relationship.

Magnusson et al. (1999) supported that the components of PCK should function as a unity to teach science effectively and any deficiency in coherence the components results in problems developing PCK and using PCK in classrooms. They gave an example that one of the research on knowledge of students difficulties concluded that teachers have good knowledge of students' difficulties in learning specific topics but they do not have good knowledge about strategies to help students to solve their learning difficulties. This revealed,

> The independence of the components of pedagogical content knowledge in that changes in teachers' knowledge of one component may not be accompanied by changes in other components that are also required for effective teaching (p. 108).

This kind of interaction emphasized the complexity of the construct of components and difficulty in the description of individual components' contributions to the overall effect.

The recent model is the hexagonal model of PCK (see Figure 2.6), developed by Park and Oliver (2008). PCK is the center of this hexagon. The five components of PCK were similar to Magnusson et al.'s model and they only added self-efficacy as a component of PCK. In the hexagonal model, Park and Oliver (2008) explained PCK at two levels; namely, understanding and enactment. Understanding refers to the awareness of teachers for difficulties of teaching a particular concept, effectiveness of instructional strategies, and misconceptions of students for a particular topic. Enactments refer to the performance of teachers' understanding of difficulties, misconceptions, and the strategies that are appropriate to use teaching particular topics in a classroom context.

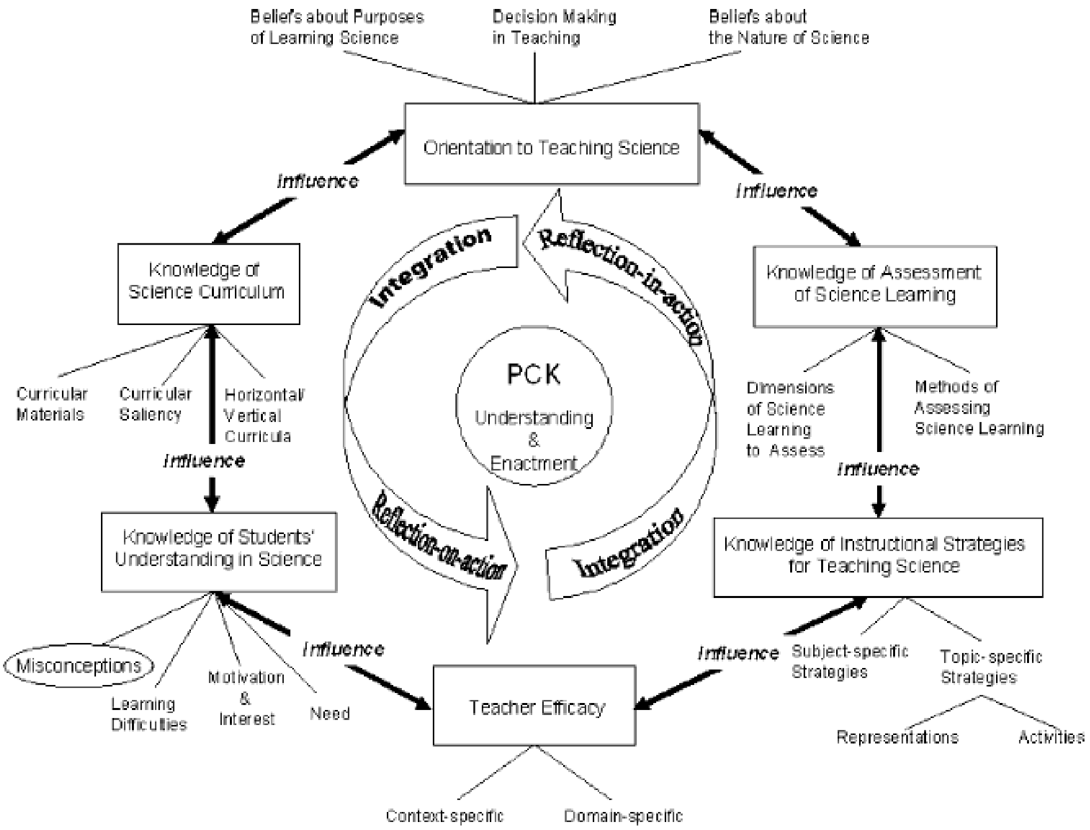


Figure 2.6 Hexagonal Model of PCK (Park and Oliver, 2008, p. 279)

Park and Oliver (2008) declared that teachers' PCK is developed with reflection; for example, learners' influences cause a difficult question, which is beyond the scope of teachers' subject matter knowledge, and the instructional strategies employed in the class, and this situation help teachers to find new and useful strategies for future classes. They categorized teachers' reflection according to its time and they employed the terms reflection in and reflection on action. They put reflection in and reflection on action at the center of hexagonal PCK model since they believed that reflection is vital for development of PCK and assist teachers to incorporate PCK components. In their research, they mentioned two teachers experienced similar situation that shattering of zinc. One of the teachers employed her PCK including subject matter knowledge, knowledge of curriculum, knowledge students at that situation and teacher asked to students the reason of it. Students answer for the teachers question included elements, compounds, oxidation of zinc etc. This is an example of reflection in action that is generated in the case of unexpected situation during teaching. On the other hand, other teacher had the similar experience in the lab, she did not change her teaching when zinc was shattered. Instead of changing teaching, she prefers to provide metal in different shape for the next year. This is an example of reflection on action that is generated with help of thinking on the practice after teaching.

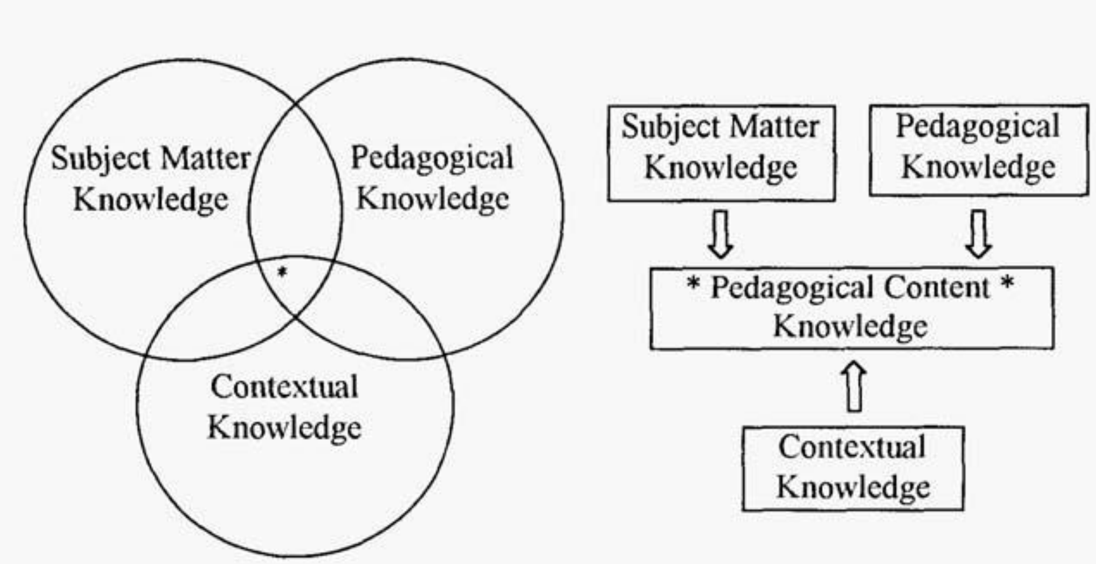
Their hexagonal model accepted that the teachers' self-efficacy that is affective part of PCK. They stated that the higher self-efficacy teachers have about their PCK, the more they use PCK in the class due to the fact that self-efficacy activates teachers in realization of what they understand in class.

According to Park and Oliver (2008), a characteristic nature of PCK is the development in one of the components in this model might activate development of other components and at the end the development of PCK. They highlighted this does not mean that development of PCK is straightforward and one components development cause directionally development of PCK. They believed that PCK development is complicated and behaves harmoniously in development of PCK.

2.1.2 Summary of the Models

There are numerous definitions, perceptions, and model of PCK in the literature. For the different understanding of PCK, Gess-Newsome (1999) developed a continuum model to examine PCK models and her continuum model includes with two extreme models of PCK; namely integrative and transformative (Figure 2.7).

Gess-Newsome's (1999) two extreme models of PCK summarized the all the models understanding. At the one extreme, PCK does not exist in the integrative model. This model is proposed that the knowledge of subject matter, pedagogy and contextual knowledge are developed separately and that they are integrated during the act of teaching (Figure 2.7). The integrative model based on the idea that three types of knowledge form PCK during the act of teaching and they are necessary for successful teaching. The task of the teacher is to select independent knowledge bases of subject matter, pedagogy, and context. After that, teachers integrate them to create effective learning opportunities. The experienced teacher smoothly moves from one type of knowledge to other while teaching.



* = knowledge for classroom teaching.
Figure 2.7 Two Models of Teacher Knowledge (Gess-Newsome, 1999, p. 12)

Gess-Newsome (1999) proposed those teachers who use integrative model might not see the importance of knowledge integration and they probably continue to emphasize the important of subject matter knowledge over pedagogy. This results in transmission modes of teaching with little regard for content structure, classroom audience, or contextual factors. This model means that pedagogical content knowledge does not exist as a separate knowledge but is an amalgam of the three types of knowledge (Shulman, 1987). Gess-Newsome (1999) underlined that traditional teacher preparation programs separate these three knowledge domains and little attention is given to contextual knowledge. It is claimed that this cause a potential deficiency for novice teachers in classroom.

Transformative model (Figure 2.7) recognizes PCK is the synthesis of subject matter, pedagogy, and contextual knowledge, which is needed to be an effective teacher (Gess-Newsome, 1999). While teaching, the subject matter knowledge, pedagogical knowledge, and context exist and they are latent resources. They are accepted as employed for transformed into pedagogical content knowledge and they become viable. This model accepts that pedagogical content knowledge is a product of three types of knowledge. In this model, all teaching knowledge is contextually bound, the potential of making transfer or drawing generalization across the teaching episodes difficult and limited.

Although many researchers studied on the nature of PCK, its definition and components are not clear or has fuzzy meaning (Abell, 2007; Gess-Newsome, 1999; Hashweh, 1987). Each researcher defined and explained PCK through different model and components. For this reason, each model of PCK has different knowledge components and sub-components, and offers different explanations to relationship among these components. However, subject matter knowledge, pedagogical knowledge, and knowledge of context are the shared knowledge components for most of the PCK models. Moreover, knowledge of representations and knowledge of students are two parts whose existence in PCK most of the researchers agree on (van Driel et al., 1998). As in the Gess-Newsome continuum model (1999), some of the researchers (Magnusson et al., 1999) perceived PCK as a new type of knowledge as in the transformative model; on the other hand, some of the other researchers perceived PCK as mixture of knowledge as in the integrative model (Cochran et al., 1991, 1993). PCK was accepted as personal and private knowledge of a teacher for a specific subject matter (Hashweh, 2005). This means PCK can change from one teacher to another, and even for the same teacher from one topic to another (Hasweh, 2005). PCK develops with experience, and this means an increase in experience generally lead to an increase in PCK (Gess-Newsome & Lederman, 1999; Veal et al., 1998).

Even though PCK is not clearly defined and PCK models have missing parts, PCK models do not clearly explain the interaction between the components, PCK is a construct to help researcher to study teacher knowledge (Abell, 2007; Grossmann, 1990). Along with cognitive components, PCK might include affective components, such as self-efficacy (Park & Oliver, 2008) and beliefs (Hasweh, 2005; Magnusson et al., 1999).

In this section, the studies investigating the nature of PCK were elaborated and the studies focused on teachers' PCK employed in classroom were reviewed in the next headings.

2.2 PCK Studies in Science Education

Studies on PCK in science education were reviewed on the influence of content knowledge, teachers' expertise area, and teaching experiences.

Lee and Luft (2008) explored five experienced science teachers' general PCK. Particularly, they attempted to clarify how experienced teachers view necessary knowledge for science teaching for more than two years. Interviews, classroom observations, lesson plans, and monthly reflective summaries were employed for collecting data. Interviews were conducted three times over the course of the study. In the first round interview, participants' background characteristics were questioned; in the second round interview teachers were asked to clarify their teaching followed by their classroom instruction, and in the third round interview, teachers were requested to draw a diagram representing the components of PCK. Card sort activity was employed to elicit teachers' ideas about types of knowledge that are necessary for teaching. During the activity, teachers were asked to relate given types of knowledge with teaching. According to the teachers, subject matter knowledge, knowledge of goals, students, teaching, curriculum organization, assessment, and resources were the necessary knowledge in teaching. All the teachers agreed on the view that subject matter knowledge was the most critical one in teaching science. However, there were differences among the teachers with respect to their views about relating other types of knowledge with science teaching. Teachers claimed that their PCK developed through experience in teaching and participation in workshops. Although they viewed knowledge necessary for teaching science, there were differences in their representations for general PCK with respect to grouping knowledge and their interactions. Moreover, knowledge of resources was the most stated type of knowledge the participants. This finding suggested further research to explore knowledge of resources as a component of PCK.

All the model of PCK gave importance to the content knowledge and Ingber (2009) examined six science teachers' PCK in planning in and outside of their expertise area. More specifically, teachers' planning, use of resources, and use of instructional strategies were clarified. Data were collected using survey and think aloud protocols during planning. Findings demonstrated that teachers employed terminology better in their area than they did outside of their expertise while they were planning. They were able to relate more concepts in their area than they did outside of their area. In a similar vein, they were more knowledgeable about the resources required for enhancing subject matter knowledge and teaching during planning a unit in the area of expertise than they did it for a unit outside of the area. However, planning for units in and outside of teachers' expertise area did not make a significant contribution to their choice of instructional strategy The author further claimed that instructional strategy use was teacher-specific rather than being topic-specific.

Another study examining the influence of subject matter knowledge in teaching was conducted by Rollnick et al. (2008). The participants included three experienced teachers; two of whom were working in high school and the other was working in an access program aiming to prepare students for admission to undergraduate education. The focus of the study was on the mole concept in the high school context, while it was on the chemical equilibrium topic in the access program.

Content Representation (CoRe), Pedagogical and Professional-experience Repertoire (PaP-eRs), interviews before and after teaching, observation, and field notes were employed for collecting the data. Rather than the teachers, researchers filled out the Content Representations using the information taken from other data sources. In the high school context, both teachers firstly covered the conceptual part of mole concept and then followed the calculation part of the topic. However, teachers stressed on calculations rather than conceptual understanding of the mole concept because of the inclusion of algorithmic questions in external exam system. In addition, the conceptual and calculation part of the mole concept was not linked by those teachers. Researchers explained having such a finding with teachers' lacking depth of understanding of the topic. Additionally, interview results demonstrated limited teacher subject matter knowledge in the mole concept. For example, one of the participants admitted the inadequacy of her subject matter knowledge in the topic and further claimed that her ability of teaching the mole topic increased as she learned more about that topic. The teacher participated in the access program possessed sound subject matter knowledge in chemical equilibrium topic, thorough understanding of curricular saliency related to sequence and connection of the topic in the curriculum, and deep knowledge of learner characteristics due to having an experience in teaching. The teacher managed to transform subject matter knowledge to knowledge for teaching via blending knowledge of learner and context. That is, the findings of the study indicated the critical role of subject matter knowledge for having teachers with rich and deep PCK because the teacher with rich PCK focused on the conceptual part of the topic and employed a variety of student-centered strategies while teachers with limited PCK just taught algorithms. Although the subject matter knowledge of participants affected teaching practice, researchers pointed out to the importance of the teaching context. That means, just focusing on the development of subject matter is not adequate; efforts need to be exerted to have a better school and classroom context. The authors may consider topic-specific and context-specific nature of PCK in addition to subject matter knowledge in interpreting the differences between case studies.

Depth of subject matter knowledge does not always guarantee effective development and practice of PCK. For example, in a study conducted by Lederman and Latz (1993), it was demonstrated that well equipped secondary science teachers in their specialty area also struggled with transforming that knowledge into meaningful representations, which is a critical characteristics of PCK facilitating the linkage of learners and their experiences with the material. In another study Lederman, Gess-Newsome and Latz (1994) investigated the development and changes in twelve pre-service teachers' subject matter and pedagogy knowledge structures throughout their teacher education program. At the beginning of the program, participants demonstrated inconsistent subject matter knowledge structure; however, these structures became increasingly complex, interrelated, and integrated networks over the course of the program. The pedagogical structures were mainly teacher-oriented but little student-oriented at first. As time passed, these structures became more complicated and reflected more student-oriented components of instruction. Both of these knowledge structures were likely to be affected by teaching experience. However, all of the teachers perceived pedagogy and subject matter knowledge as separate entities to be integrated while teaching. These teachers had not blended subject matter and pedagogical knowledge in their teaching practice throughout the study due to time and experience requirements of PCK (Lederman et al., 1994).

The other important component in PCK was pedagogical knowledge and Sanders, Borko, and Lockard (1993) conducted a case study in order to investigate the content knowledge, pedagogical knowledge and PCK differences in the pre-active, interactive and post-active levels of teaching of three experienced science teachers teaching in and out of their area of certification. The data obtained from interviews and classroom observations revealed the effects of subject matter knowledge and PCK on a teacher's practice. The teachers seemed as experts in while teaching in their area but as novice teachers while teaching outside of their area. Teachers had a difficulty in identifying the important points in outside of their specialty areas. In addition, teachers inconsistently constructed feasible explanations to student questions and were in a difficulty of getting the students back on topic when they moved into a different direction with the questions. These difficulties originated from their lack of familiarity with the subject matter and the inter correlations among the various concepts within the topic. To deal with their lack of content knowledge and to avoid from being unfamiliar with the material, they talked more and planned less risky instructional activities. On the other hand, they talked less and planned more risky and student-centered instructional activities in their specialty area. The teachers' PCK influenced not only their planning but also their practice. In their expertise area, they had a sound understanding of their students' prior knowledge, possible misconceptions, or learning difficulties in specific topics. Similarly, they considered students' experiences and tried to make linkages between student questions and content areas during classroom instruction by making the learning task understandable. However, teachers working outside their content area did not consider students' prior knowledge and experience with the material and they struggled with finding appropriate representations to facilitate student understanding. This study provided substantial information about the influence of teachers' subject matter and PCK on their teaching practice but little information about teachers' use of PCK in making instructional decisions in or out of their expertise area. There was not any discussion on how teachers transformed their subject matter knowledge or how they related those transformations to student understanding. Moreover, classroom observations demonstrated that teachers' practice of PCK on their teaching was not as desired level.

Ball and Bass (2000) pointed out the iterative process for developing PCK and attempted to understand how teachers became knowledgeable as they practice the same topics in their teaching and how students interpret and use representations of particular topics. Sanders et al., (1993) acknowledged the essence of PCK development by emphasizing, "Cyclical process, in which teachers transform, instruct, evaluate, reflect, gain new comprehension, comprehend and transform again" (p. 725). Developing PCK is a lengthy and complex process due to its cyclical aspect and the fact that most teachers teach a topic once a year (Veal, 1998).

The all PCK studies gave importance to the teaching experience for the development of PCK. The relation of PCK with the experience was analyzed by Lee et al. (2007). The participants included 24 beginning teachers through induction year. They just stressed on knowledge of learner instructional strategy of the teachers attending to the different induction programs, such as e-mentoring and science-specific programs. Pre and post interviews, observations of participants' teaching, and documents related to teaching were employed for collecting data. Interview and observation data were analyzed using a rubric including three levels of teachers' use of knowledge of learner and instructional strategy. The levels were specified as limited, basic, and proficient. Kruskal-Wallis test results indicated a non-significant difference between the teachers engaged in different induction programs with respect to PCK levels (H (4, 24)= 2.89, p=.44). Descriptive statistics showed that all of the teachers' PCK was either limited (76%) or basic level (%24) at the early school years,; but an improvement was observed towards the end of the school year, 65 % of the teachers' PCK was at limited level, 34 % of them was at basic and only 1% of them was at the proficient level. These findings highlighted the weakness of pre-service teacher education programs in PCK development by pointing out to the insufficiency of beginning teachers' PCK. Although teachers were equipped with rich subject matter knowledge, they were not able to use their subject matter knowledge during their teaching practice appropriate to learners' level and interests.

Veal et al. (1998) were also interested in the evolution of PCK and investigated PCK development of two prospective secondary physics teachers in their science curriculum class through their student teaching field experiences. Participants' PCK development was observed using two content-specific, situational vignettes: Linear Motion; and Heating the Discussion with Thermodynamics. Three major findings for PCK development in these prospective physics teachers were described in this study. First, the teachers viewed classroom experience as an integral part of PCK development. Second, the teachers became to adopt student-oriented teaching approach and began to actively reflect on their science teaching and learning beliefs, which in turn affected their teaching practice. Finally, the development of PCK was not a simple and linear process. It was also shown that content knowledge integrated with knowledge of learners was essential in the development of PCK. The authors further claimed that participants' teacher education experiences, especially student teaching practice, improved their views about science teaching and learning by influencing their practical knowledge of classroom practice. In addition, there was an increasing recognition of student learning styles and their prior content understandings in conjunction with their own personal development of topic-specific PCK. Many of the changes in these teachers initiated with actual hands on teaching, which highlighted the essence of classroom experience in dealing with "apprenticeship of observation" for developing PCK.

The findings about the development of PCK revealed by Veal et al., (1998) are considered as ordinary by some researchers. However, Veal et al. (1998) supported their findings with a research, which supplied a unique feature about the complexity of the evolution of PCK process in teacher education. While presenting some informative topic-specific research on PCK, their study was limited due to its exclusive reliance on self-reports specifying what the teacher would do in each vignette and not what they actually did in the complexity of the classroom. How these teachers' topic-specific PCK can be developed and leveraged to help learning of authentic students the relevant topics remains as a question unless their study is extended into the classroom. While this review of PCK research in science education is by no means comprehensive, it does serve as a means for expressing what has been done in the science field related to this complex construct. Teachers' prior beliefs about teaching and learning developed over time influence the evolvement and practice of PCK. Teachers' prior beliefs about teaching and learning are susceptible to change through teacher education or in-service programs (Ball & Bass, 2000; Lee & Luft, 2008; Sanders et al., 1993). Teaching experience is, another key factor considered to be a major source for the evolvement of PCK (Ball & Bass, 2000; Lederman et al., 1994; Rollnick et al., 2008; Veal et al., 1998). Subject matter knowledge has been viewed as important for strong PCK, high quality planning, asking high-level questions, allowing learner participation in class, and considering learners' difficulties. On the other hand, when teachers' subject matter knowledge is limited; planning, use of terminology, making changes in the flow, conducting learner-centered activities, and increasing student voice in the class are very desirable for teachers (Ingber, 2009; Sanders et al., 1993). In a similar vein, teachers are inclined to ask low-level questions (Lederman & Latz, 1993; Sanders et al. 1993) and not to make connections between algorithmic and conceptual parts of the topics (Rollnick et al., 2008). However, sound subject matter knowledge does not require the strong PCK. Ingber (2009) displayed teachers having limited and strong subject matter knowledge in different topics. However, there was not any significant difference between the teachers having limited and strong PCK with respect to using instructional strategies. This finding is not congruent with the topic-specific nature of PCK.

The studies mentioned above investigated the nature and development of PCK in science generally. The next section limits current PCK literature on the biology as a subject matter.

2.2.1 PCK Studies in Biology Education Research

The PCK research in the biology community appears to parallel what we have seen in the larger science education community. Much of the work has been on examining the nature and development of PCK (Carlsen, 1993; Friedrichsen & Dana, 2005; Gess Newsome, 1992; Hasweh, 1987). Later studies focus on examining PCK for specific topics; photosynthesis (Hasweh, 1987; Abd-El Khalick, 2006; Käpylä, et al., 2008), cell (Friedrichsen & Dana, 2005; Cohen & Yarden, 2008), evolution (Veal & Kubasko, 2003). Some of researches investigated the effect of experience on PCK (Abd-El Khalick, 2006; Cohen & Yarden, 2008; Lankford, 2010). This section is designed to provide the reader with a comprehensive understanding of the PCK research in biology.

Hashweh (1987) studied the effect of subject matter knowledge on pre-active and interactive features of teachers' practices. His study described three biology and three physics teachers' subject matter knowledge of particular biology and physics topics and subsequently investigated the influence of this subject matter knowledge on teachers' instructional planning and simulated teaching using the critical incidents method. Researcher assessed subject matter knowledge of teachers for the topic of levers from physics and topic of photosynthesis from biology. The teachers were asked to read a textbook chapter on the topic and explain their plan with thinking aloud method, and explain their responds in a case that probably occur while teaching the topic.

The results of the Hashweh (1987) study reveal that when working with a topic in their field of expertise, teachers displayed more detailed knowledge and a deeper understanding and better organization of the structure of the discipline. Participants of the study were also better able to critically examine the topic, reject the meaningless parts, and control it when it overlapped with their prior subject matter knowledge and approach. They had fewer inaccuracies with the teaching material than outside of their field of expertise. On the contrary, when working with a topic outside of their field of expertise, teacher inclined to follow the chapter closely in their planning process and the book chapter function as guidance in their instruction organization to include choice of activities, and examples. During the interactive portion, teachers when teaching in their area were more possible to recognize misconception of students, better use potential learning opportunities and correctly interpret students' comments. Teacher working outside of their field of experience tended to reinforce student misconceptions, incorrectly dealt with understanding of students, mostly showed deficiency of the knowledge to deal successfully with students learning difficulties, and they had difficulty in selection of effective representation to support learning of students.

In 1987 his study, Hashweh did not refer to PCK concept but his work included the implications of PCK. In his study, many of the PCK's components were touched in his findings for instance the importance of possessing strong subject matter knowledge, knowledge of students to be able to connect the material to the learner. His study included the interactive portion of the teachers' practice; it was not an actually real classroom practice. Thus, this limited the findings of the study to reflect the reality. Due to the fact that there might be enormous difference in what a teacher says I will do in the classroom versus what actually does in the real classroom (Lederman et al. 1994).

Gess Newsome, in her dissertation (1992), aimed to investigate the nature of biology teachers' subject matter structures and the relationship between these structures and classroom practices. She studied with five experienced biology teachers and collected data by means of interviews, classroom observations, and instructional materials. In her study, she observed 15 times during teachers teaching biology in a semester.

Gess Newsome (1992) found that the subject matter structure of participants teachers depend on content. In other words, teachers have different subject matter structure for cell, ecology, botany and so on. All teachers found they identify the interactions among the content parts in their subject matter structures. Moreover, subject matter structures of teachers mainly based on early content experiences such as college content course and they changes with experiences on content including the learning or teaching. Gess Newsome suggested when teachers had the opportunities to reflect their subject matter structures; they develop their subject matter structures. The opportunities can be various for a teacher, for example, reflection on the meaning of the content as it is employed in the practice. She underlined on point about these opportunities and teachers may have similar opportunities but they did not develop their subject matter structures. Due to the fact having heavy course load, unexpected teaching conditions, deficiency in pedagogical and content knowledge, teacher may not change their subject matter structures.

Gess-Newsome (1992) categorized the relationship of teachers' subject matter structures and classroom practice in three levels; direct translation, limited translations affected by the interactions of other variables, or no relationship. She (1992) defined the variables affecting the translation of subject matter structures into classroom practice. Teacher intentions, as the first variable, varied one teacher to another teacher during translation of the content into teaching practice. As the second variable, the content knowledge level of teacher affects how content was taught. She explained with an example and one-participant teachers made more connections, give more examples related to students daily life, spend more time for whole class activities at the content on which teacher has good knowledge. The pedagogical knowledge refers in this study to the ability of the teachers to translate their goals into classroom practice. The low ability in pedagogy caused the deficiency of translation of subject matter structures to teaching practice. Students found as the most significant variables affecting the teaching practice in the classroom. As given last two variables, teachers' autonomy and time were the other two tremendous influence translations of subject matter structures into teaching practice.

Carlsen (1993) thought that pedagogical language in the classroom not only served communicate the subject matter content but also served as vehicle that defined and reinforced the students-teacher relationship. His studies design was based on comparison of the planning and classroom discourse of four novice biology teachers' teaching on familiar topics and unfamiliar topics. Carlsen (1993) employed card-sorting task to determine in which topics participants feel have satisfactory knowledge and two low and two high ranked subjects were selected for observation During familiar topics, the teachers allowed their students to participate more, they have more control over the discussion, and they utilized more high cognitive demanding questions to students. On the other hand, when they teaching unfamiliar topics, participants of the study dominated the conversation and their teaching included more low cognitive demanding questions. This study provided the evidence that PCK supported decisions could be observable in the classroom discourse. The limitation of the study was that it did not examine how the discourse related to the actual subject matter of biology.

Veal and Kubasko (2003) studied with geology and biology teachers' on same topic; evolution. They investigated what are differences between geology and biology teachers' in teaching on same topics. In their study, researchers compared the preservice and inservice teachers teaching applications. Data collection was made by means of interviews, field notes, and classroom observations. The result of the study revealed that geology teachers teach evolution by connecting with rocks and earth; on the other hand biology teachers were prefer to connect with animate and life. They suggested that the content background of teachers cause differences in how teach a topic; evolution in this study. Moreover, preservice teachers employed more traditional method to teach evolution than inservice teachers and inservice teachers held various levels of complexity during teaching evolution. They explained that preservice teachers are inadequate knowledge of learner and of activities for teaching the topic.

Friedrichsen and Dana (2005) studied with four biology teachers’ to investigate their orientations and their sources. The employed data collection tools were observation, interviews, and card-sorting task. They stated that teaching orientations of teachers is complex and teachers’ science teaching orientations includes affective, schooling and subject matter goals. The affective goals refer to develop positive attitude toward the science, to support self-confidence, and have curiosity, which were vital for the participant of the study. The schooling goals mean prepare students for university and life. Teacher subject matter goals of participant teachers were not the central goals for their teaching. Friedrichsen and Dana (2005) found that orientations were specific to topic that they taught. Moreover, orientations are not static and can be changed with the time data collected. The researchers argued the labeling teaching orientations with one orientation stated in the literature due to the fact that the notion of one strict orientation contradicts the sophisticated and instable nature of orientations.

Another study was conducted by Abd-El Khalick (2006) aimed to describe preservice and experienced secondary biology teachers' global and specific subject matter structures and reveal the relationship between these structures and teaching experience. In his study, teachers' global and specific subject matter structures respectively show their conceptions and organization of their disciplines (biology) and of specific topics within those disciplines (photosynthesis). The sample consist of two preservice, final semester of five years, and two experienced secondary biology teachers, one is twelve years and other is eight years. Teachers were administered two open-ended questionnaires and they were individually interviewed which is aimed to assess their conceptions of biology and photosynthesis (Abd-El-Khalick, 2006). The result of Abd-El-Khalick study depicted that preservice teachers' global subject matter structures mainly comprised discrete listings of college biology courses or isolated chunks of information delivered in such courses (2006). While some of the teachers participated in this study, hold a linear, topical view of biology with sequences that resembled high school biology textbooks, other preservice teachers presented more integrated views of the discipline that showed evidence of connections and pervasive themes.

For the Abd-El-Khalick (2006) study, global subject matter structures did not discriminate preservice and experienced biology teachers. On the other hand, these results were not the same with specific subject matter structures. Conceptions of photosynthesis clearly separated the teachers into the two groups as preservice and experienced. The views presented were consistent within both preservice and experienced group and differed from those of the other group in two major ways. One was the level of detail emphasized by preservice teachers. They emphasized various structural and chemical details of photosynthesis while the experienced teachers presented much simpler account that was limited to inputs and outputs. The experienced teachers viewed photosynthesis as part of a larger picture. They emphasized its critical role in supplying the food energy and oxygen necessary for the survival of almost all living organisms. This role of photosynthesis was overlooked by the preservice teachers. To sum up, teaching experience and student needs were the most important factors in the data to explain these differences.

Käpylä et al. (2008) investigated the effect of the quantity and quality of content knowledge on PCK. The investigated topic was photosynthesis and plant growth. They studied with 10 primary and 10 secondary biology preservice teachers. The two groups were distinct from each other only amount of content knowledge and both groups had similar pedagogical studies applied, based on their preservice education. The employed method in this study was the lesson preparation method followed by interview. The results of the study underlined that good content knowledge has positive effect on preservice teachers' pedagogical content knowledge and thus on effective teaching (Käpylä et al., 2008). Content experts were more aware about students' difficulties than content novices were. It is predictable to be very difficult for a content novice to distinguish students' naïve conceptions because of teachers own misconceptions. Preservice teachers having erroneous and insufficient knowledge would transfer their own naïve understanding to their students and in this way increase to students' difficulties. Besides, content experts were able to mention more vital concepts to be learned. They were also able to select the significant topics to be learned. Experts select activities that are more direct to help students to learn.

In the same year, 2008, ten years following modification in the curriculum in Israel Cohen and Yarden conducted a study to examine junior-high-school science teachers' PCK regarding the cell topic. The participant in this study composed of a workshop (n=12) and three groups (n=59) and six science teachers were interviewed in this study. The authors of the study developed specific six tools were developed to reveal the teachers pedagogical content knowledge. These are namely, teachers' responses to students' answers of biological concepts, semi-structured interviews, visual illustrations, teachers' tests, unfamiliar test questions, questionnaire (Cohen & Yarden, 2008). The results of the study revealed that teachers appeared to experience struggles among personal beliefs about the significance of the cell topic and their classroom applications (Cohen & Yarden, 2008). As an example, even though the significance the teachers positioned on teaching the cell topic, their distresses about their students' difficulties decrease. Researchers underlined that teachers could not have appropriate knowledge of the subject matter and pedagogy to be instruct. Besides, teachers' PCK do not supply the essential alteration in the teaching of the topic of cell. Teachers' PCK on cell topic do not change as required change in curriculum. The teachers transformed their teaching the topic of cell only lightly: teachers cannot do any serious change. The author of the study mentioned some features that can contribute to the formation of teachers' PCK (Cohen & Yarden, 2008). One is sourced from a teacher oneself (interior features) and other is sourced from the teaching organization (outside features). Lankford (2010) investigated six experienced biology teachers' PCK in diffusion and osmosis topics in her dissertation. One teacher employed lecturing and validation experiments in her teaching and researcher label it as "knowledge transmission orientation." Five of them held constructivist orientation and researcher explain this orientation as students take an active role in learning and engage with teaching activities to knowledge construction. All of the teachers selected to teach diffusion prior to teach osmosis and they prefer to use representations from simple to complex. In this manner, all of them began with cellular level representations and flowingly employed complex representations such as organs of plants. They found that students experienced difficulty in use of the terminology employed for explanation of diffusion and osmosis. Moreover, students have difficulty in comprehension and visualization of the event at the molecular level, especially direction of water movement in osmosis. The teachers' explanation for these difficulties was deficiency of students in chemistry knowledge. Based on knowledge of learners' difficulties, four of the participants change their instruction and they benefited from animations prepared for explanation for diffusion and osmosis at molecular level. Teacher asked students their prediction prior to apply demonstrations and investigations. This helped teachers to have an idea about students' prior knowledge and to design teaching and evaluate what they have learned up to a specific point. Although teachers' goals regulated by curriculum standards and teachers have sufficient curriculum knowledge, teachers sometimes provided more knowledge than necessary knowledge, which is offered by textbook or curriculum such as random molecular motion.

In a recent study, Brown, Friedrichsen, and Abell (2012) focused on four prospective science teachers' knowledge development at the subject specific level for three knowledge components; orientations, knowledge of learners, and knowledge of instructional sequence during a port-baccalaureate teacher education program. Data of the study were collected through a lesson-planning task and two interview observation cycles while the participants' practicum. The teaching orientations of prospective teachers, their instructional sequence, and the knowledge of student understanding of science were coherent. Their science teaching orientations were shaped by their experience as a learner from 16-year education and these perceptions were resistant to change. Their teaching strategies were based primarily on transmitting information to students. Authors underlined that most of the prospective teachers are not implement effectively the methods they learned in science method courses. For example, they learned 5E learning cycles in method courses, however, they could not apply it in real practice. Besides, with the help of gained knowledge, experience, and interactions, prospective teacher developed their knowledge of learners and their knowledge of instructional sequences became more integrated. Moreover, in a yearlong experience of prospective science teachers, their knowledge of students learning difficulties was increase and they adapt their teaching according to knowledge of the requirements of learner.

Although several studies were carried out about the nature and development of PCK about biology (Abd-El Khalick, 2006; Brown et al., 2012; Carlsen, 1993; Cohen & Yarden, 2008; Friedrichsen & Dana, 2005; Gess Newsome, 1992; Hashweh, 1987; Käpylä et al., 2008; Lankford, 2010; Veal & Kubasko, 2003), Van Driel et al. (1998) claimed that there is no enough researches about topics specific studies on PCK. Magnusson et al. (1999) and De Jong et al. (2002) have recently called for more research to characterize the PCK needed for teaching specific science topics and to examine its influence on all aspects of a teachers' practice in specific teaching contexts. In this manner, this study aimed to investigate science teachers PCK as a case of teaching genetics.

Moreover, Veal (1998) highlighted a need of PCK literature on studies which aimed to reflect the teaching methods and strategies required to illuminate topics within specific domains of science. Since each domain of science has its own concepts, terms and topics, and they are usually taught differently using alternative instructional strategies, methods, and representations to achieve instructional purposes unique to that subject. This distinction highlights the need for teachers to have a PCK for their individual subject. This study aimed to investigate science teachers PCK for the topic of genetics.

2.3 Studies on Students' Understanding on Genetics

A large body of national (Bahar, 2002; Karagöz & Çakır, 2011; Saka, Cerrah, Akdeniz & Ayas; 2006; Tekkaya, Çapa, & Yılmaz, 2000; Tekkaya, Özkan, Sungur, 2001; Tekkaya, 2002) and international (Banet & Ayuso, 2000; Kibuka-Sebitosi, 2007; Knippels, Waarlo & Boersma, 2005; Lawson & Thompson, 1988; Lewis & Wood-Robinson, 2000; Lewis, Leach, & Wood-Robinson, 2000a, b, c; Marbach-Ad & Stavy, 2000; Pashley, 1994;) studies has been conducted at various levels of schooling on the topic of genetics. This section describes the studies related to genetics topic.

In a study conducted by Lawson and Thompson (1988), the relationships between seventh grade students' misconceptions of genetics and natural selection and four cognitive variables (i.e., reasoning ability, mental capacity, verbal intelligence and cognitive style) were examined. One hundred and thirty one seventh grade American students attending to a life-science course at a public high school participated in their study. A test about principles of genetics and natural selection was administered to the students at the end of the instruction. Students' responses were analyzed in order to understand whether any relationship exists between reasoning ability, mental capacity, verbal intelligence and cognitive style and number of misconceptions. The findings of the study revealed a significant association between reasoning ability and students' number of misconceptions. The number of misconceptions held by the concrete operational students was greater than those held by formal operational students. Formal students appeared to understand the influence of the combination of parental genes carried in the sex cells rather than the environmentally induced changes in parents on a newborn child's characteristics. However, concrete operational students failed to understand it. It was suggested that formal reasoning patterns are essential for eliminating some biological misconceptions.

Pashley (1994) examined students' understanding of genetics, their misconceptions and how they might be eliminated. The participants were 96 American secondary school students from four different educational establishments. The students were studying on virtually identical tasks about the components of genetics. The chromosome model was utilized as a tool to eliminate students' misconceptions. The chromosome model allowed students to be aware of their current concepts and to dissatisfy with their concepts do not fit to scientifically accepted ones. Students were asked to explore the relationships between 21 different pairs of genetic terms included in a test booklet. The results indicated that the misconceptions were mostly related with the terms 'gene' and 'allele'. Three general types of misconceptions uncovered in this study were; a) Genes contain alleles; b) Alleles contain genes; c) Genes and alleles are the same. These misconceptions led to confusion between the other terms such as, homozygous, heterozygous, dominance or recessiveness. Chromosome model was considered as an effective tool for eliminating misconceptions and facilitating conceptual change. Moreover, students' performance in genetics improved as they overcame any difficulty with the relationship between gene and allele and the teachers considered their students' misconceptions.

Studying with 482 students (14-16 years of age), Lewis and Wood-Robinson (2000) investigated students' knowledge and understanding about the nature of genetic information, and how this information is conveyed and interpreted. Data were collected using written questions and small group discussions. The results demonstrated a confusion about the link between genes and genetic information, location of genes, link between genes and chromosomes, the meaning of genetic information, link between chromosome and genetic information, how genetic information is conveyed from cell to cell within an organism, difference between somatic and sex cells, difference between mitosis and meiosis, mechanism of crossing, link between cell division and continuity of genetic information. In addition, students were not aware about how a gene determines a characteristic. It was concluded that students had common confusion, uncertainty, and absence of fundamental knowledge about genetics.

Lewis et al. (2000a, 2000b, 2000c) conducted a number of studies to explore students' (*N*=482, mean age of 15) understanding of various genetics concepts. In the first study, Lewis et al. (2000a) examined students' understanding of size sequence of basic structures of genetics; relations among living things, chromosomes, and genetic information; and basic concepts of genetics. Data were collected using a written questionnaire. The findings revealed that students could not understand and confused size sequence of the six structures, namely, organism, cell, nucleus, chromosome, gene, and DNA. The findings also showed that students were not clear about the relationship between these structures; location of genes, chromosomes and DNA; structure of genes; importance of genes, chromosomes and DNA, and role of alleles. It was also found that students hardly make connections between related concepts Therefore, it was suggested that these relations should be taught explicitly.

In their second study, Lewis et al. (2000b) explored students' understanding of the continuity of genetic information between the cells of an organism, which is a key factor for understanding inheritance. The findings revealed that students could not conceptualize the genetic associations between cells of an organism and could not realize the difference between a gene and the information coded within that gene. The possible reason of having such a finding was asserted as the lack of a conceptual framework explaining the relations among the facts and supporting coherent understanding.

In their third study, Lewis et al. (2000c) examined students' understanding of cell division and fertilization. Analyses of the written data revealed that students confused the related topics and demonstrated weak and incoherent understanding. It was concluded that the more the students explore the relationship between basic structures like genes and chromosomes, the more they can understand the processes of mitosis, meiosis, and fertilization.

The misconceptions of students about the genetics topic were also examined by Banet and Ayuso (2000). Participants of the study were 267 secondary school students. Students' previous knowledge about the location of inheritance information was inquired using interviews and questionnaires. The participants thought that the cell structure, living organisms, sexual reproduction, and the concepts of genes, alleles, and chromosomes should be overviewed at the beginning of the instruction of genetics topic. The study was expanded by diagnosing 109 advanced secondary students' knowledge of genetics after traditional instruction. The findings of these two studies were applied to 177 secondary school students in a different research when planning, implementing, and subsequently modifying a teaching program based on constructivism. They showed that many students at the secondary school level held significant misconceptions about inheritance information location. The study also has highlighted some weaknesses in traditional genetics teaching method. They described the features of a teaching program including objectives and activities that will be pursued during different stages of instruction on inheritance information. The roles of teacher and students in that teaching program were also specified. The findings obtained from this study revealed that many students engaged in this particular teaching program on inheritance information changed their misconceptions about the location of inheritance information and held scientific knowledge. As seen in the results of the aforementioned studies, students hardly linked basic concepts with processes about genetics topic.

Marbach-Ad and Stavy (2000) attributed these difficulties to different levels of organization of genetics concepts, namely, macroscopic, microscopic, and submicroscopic levels of organization. They conducted a study to explore Israeli students' understanding at different levels of organization of genetics concepts and their ability to link between ideas and concepts across different levels. The participants of the study included three populations of students: 9th graders, 12th graders (N = 305) and pre-service biology teachers (N = 26). Data were collected using three different types of questions. One question was about molecular level; two of those measured students' ability to make connection between levels. It was shown that students struggled with linking between the major concepts because they are concurrently subjected to various concepts and processes at different levels of organization, which they cannot deal with them at the same time.

Knippels et al. (2005) focused on the abstract and complex nature of genetics to explore the applications of the findings of other researchers into secondary genetics education in Netherlands. The distinction between inheritance, reproduction, and meiosis in the curriculum explains the abstract nature of genetic, while the different levels of biological organization, e.g., molecule, cell, and organism, and supports its complex nature. They conducted a case study using observations and audio recordings of 13 lessons of traditional general upper-secondary genetic course. During the observations, students were requested to solve multiple genetics problems and to calculate the probabilities of specific traits in the next generation. Twenty-two students (aged 16-17) kept diaries about their learning outcomes, perceived difficulties, and questions. Then, interviews were carried out with six students (four girls and two boys). The results obtained from this study revealed to the necessity of adequately sequencing the subject matter according to the levels of biological organization and considering the connections between inheritance, sexual reproduction, and meiosis. The findings suggested that focus should not be on solving genetic cross problems, but on making connections between sexual reproduction, meiosis, and genetic traits. They further analyzed two chapters of three Dutch upper-secondary biology textbooks related to mitosis and Mendelian genetics and found no explicit conceptual associations between those chapters.

Saka et al. (2006) carried out a cross-age study to examine 175 Turkish students' understanding of gene, DNA, and chromosome concepts. Participants included 8th, 9th, 1lth graders, and pre-service biology and science teachers. Data were collected using written questions and interviews. All the students were requested to define gene, DNA, and chromosome concepts and draw them into a cell. The findings demonstrated that students at all grade levels held some misconceptions about gene and chromosome. In addition, students drew each of those three concepts separately pointing out the problems that they faced when connecting the concepts meaningfully.

It was suggested that the students at junior high school should learn the basic concepts meaningfully in order to acquire new concepts successfully in their further education.

Studying with 100 grade 11 biology learners attending schools located in rural areas, Kibuka-Sebitosi (2007), investigated students' conceptions and misconceptions related to genetics topic including genetic information in cells and Mendelian inheritance. Questionnaires, case scenarios, concept maps, interviews, and group discussion were employed for data collection. The findings obtained from the concept map analyses revealed that students hardly understood some genetic concepts including the difference between genes and chromosomes, things that are inherited and not inherited, and Mendelian inheritance. In addition, analyses of case scenarios indicated that students linked inheritance with faith, blood, hormones, and traditional beliefs. Students perceived the sources of their ideas as their own ideas, teachers, and their communities. It was suggested that students' prior understandings, especially the ones related with traditional beliefs, should be elicited by the educators at the beginning of the instruction of genetics and inheritance concepts.

2.4 Summary of the Literature Review

In light of the studies reviewed in the literature, there are different models explaining PCK (Cochran et al., 1993; Grossman, 1990; Magnusson et al., 1999; Veal & MaKinster, 1999). Although there are some differences in terms of components; knowledge of learner and knowledge of representations of subject matter are commonly included by the PCK models.

Previous studies indicated that PCK is a topic-specific construct that is developed through experience in teaching (Abell, 2007; Grossman, 1990; van Driel, et al., 1998) and content knowledge is necessary for solid PCK (Abell, 2007; van Driel et al,. 1998). Teaching experience is an essential source of teachers' PCK as well (Grossman, 1990; Shulman, 1987; van Driel et al,. 1998). However, experience may not always give rise to enhancement in PCK (Friedrichsen, Lankford, Brown, Pareja, Volkmann, & Abell, 2007). When it is the case, workshops and professional development activities should be provided to the teachers (Magnusson et al., 1994; Van Driel et al., 1998). Additionally, it was mentioned that PCK should be viewed as whole rather than separate components. The reciprocal interaction of the components is an indication of healthy PCK (Fernandez-Balboa & Stiehl, 1995; Magnusson et al., 1999; Marks, 1990; Veal & MaKinster, 1999). Researchers claimed that, due to the simultaneous use of different components, the line between components is not clear-cut (Grossmann, 1990; Marks, 1990; Fernandez-Balboa & Stiehl, 1995). In addition to knowledge types those teachers have, teachers' self-efficacy, metacognition, attitude towards teaching and orientation to science teaching may provide appealing information about PCK and they assumed to be the key to open the locked door of teachers' practical knowledge, PCK (Park & Oliver, 2008).

Besides, the reviewed genetics studies demonstrated that genetics is an important subject in science education. Several studies indicated that genetics is one of the most important yet difficult topics to teach and learn in school science (Rotbain et al., 2006; Kindfield, 1991; Tsui & Treagust, 2003; Tsui & Treagust, 2004). Some studies revealed that genetics concepts are poorly understood in all ages and these weak understanding lead students to learn by rote (Banet & Ayuso, 2000). Students were in a difficulty of understanding genetics concepts and held a variety of conceptions inconsistent with the scientifically accepted ones due to the abstract nature of the genetics concepts. Actually, genetics concepts such as inheritance, reproduction, and meiosis are hard to understand, learn and remember because of its abstract character (Bahar et al., 1999; Cavallo, 1996; Knippers et al., 2005; Lewis & Wood-Robinson, 2000; Lewis et al., 2000a, b, c). Several studies indicated that students struggled with learning concepts in genetics (Bahar et al., 1999; Banet & Ayuso, 2000; Kablan, 2004; Kindfield, 1991; Kubika-Sebitosi, 2007; Tsui & Treagust, 2004; Venville & Donovan, 2007). Moreover, research has shown that students could not fully capture major concepts in genetics such as chromosomes, genes, or alleles (Pashley, 1994; Lewis et al., 2000a; Lewis, & Katmann, 2004); could not effectively explain some concepts such as homozygous or heterozygous, dominance and recessiveness (Pashley, 1994; Lewis et al., 2000a; Lewis, & Katmann, 2004); held alternative views for some processes such as mitosis, meiosis, and fertilization (Cavallo, 1996; Clark & Mathis, 2000; Kindfield, 1991; Lewis, & Katmann, 2004; Lewis et al., 2000c) and could not understand the meaning of probability for genotypic and phenotypic frequencies (Pashley, 1994; Lewis et al., 2000; Lewis, & Katmann, 2004). Law and Lee (2004) indicated that understanding of genetics necessitates understanding of both not observable and abstract conceptual entities and interactions among these entities. In Turkey context, students are considered likely to learn basic genetics concepts including DNA, gene and chromosome at 8th grade. If students learn these concepts meaningfully at the this grade, they are likely to learn related advance concepts in further years meaningfully (Bahar, 2002; Karagöz & Çakır, 2011; Saka et al., 2006; Tekkaya et al., 2000; Tekkaya, Özkan, Sungur, 2001).

3. CHAPTER

METHODOLOGY

The method of inquiry is described in detail in this chapter. This chapter addresses some issues regarding the design of the study, the participants of the study, the data collection techniques, and tools employed in the research, the data collection procedures, the analysis of the data gathered, and the quality of the study.

3.1 Statement of the Problem

The main aim of the study was to investigate science teachers' content knowledge and PCK on genetics. The PCK was investigated with respect to science teachers' knowledge of curriculum, knowledge of students, and knowledge of teaching strategies. Accordingly, this study sought to answer the following research questions:

1. What are the science teachers' understandings of genetics?
2. What is the nature of science teachers' pedagogical content knowledge regarding the topic of genetics?
    i. What is the science teachers' knowledge of curriculum regarding the topic of genetics?
    ii. What is the science teachers' knowledge of students regarding the topic of genetics?
        a. To what extent are science teachers knowledgeable about the requirements of students while learning genetics?
        b. To what extent are science teachers knowledgeable about the difficulties students experience while learning genetics?

iii. What kinds of strategies do science teachers employ to teach genetics?
    a. What kind of representations do science teachers employ during teaching genetics?
    b. What kind of activities do science teachers conduct during teaching genetics?
    c. What kind of strategies do science teachers employ to overcome the difficulties students experience while learning genetics?

3.2 Design of the Study

This study aimed a deep understanding of PCK regarding the topic of genetics. The nature of PCK depends heavily on context, students, and teaching experience of a teacher and PCK of a teacher changes with teaching experience, students and context of teaching. Thus, qualitative approach was thought to be more suitable to study PCK and most of the research studies on PCK have been conducted by adopting a qualitative approach (Abell, 2008; Gess-Newsome, 1994; Loughran etc. 2006). In this manner, the methodology of the present study is based on qualitative approach and the case study design was adopted as one of the qualitative designs. Qualitative approach, in general, focuses on understanding the meaning that people have constructed, how they make sense of the world around them and the experience that they have in the world (Meriam, 1998). It concentrates on the process. It is rich in description, words and pictures instead of numbers are commonly employed (Meriam, 1998). Therefore, qualitative approach was preferred in this study and qualitative methodology and qualitative data analysis were intensely employed to investigate the science teachers' content knowledge and PCK on genetics.

Case study was selected as the study design in this study. Case study is defined by Meriam (1998, p.21) as "intensive holistic description and analysis of a single instance, phenomenon, or social unit." PCK is influenced mainly by context, students as well as teachers' characteristics concerning to teaching like their experience, content knowledge, pedagogical knowledge. Moreover, each of these factors changes with each teacher and these factors also change each teacher's PCK. Thus, the nature of PCK requires a holistic description and each teacher has to be analyzed separately. Moreover, in a case study, the case should be a single entity and a unit that has boundaries and cases are generally chosen because they represent an instance of the issue or hypothesis being studied in the study (Merriam, 1998). Moreover, according to Yin (2003), the boundaries and context of a case study have to be described to be informative about the research design. In this study, the context of the present study being a science teacher in public middle schools in Ankara, and content knowledge and pedagogical content knowledge were assumed all together. Each science teacher in public middle schools in Ankara establishes the "case" of the present study. The further information about teaching context of each case such as classroom size, classroom-laboratory conditions, students' characteristics etc. were given in detail in descriptions of cases. The Figure 3.1. helps to visualize the procedure of the study.

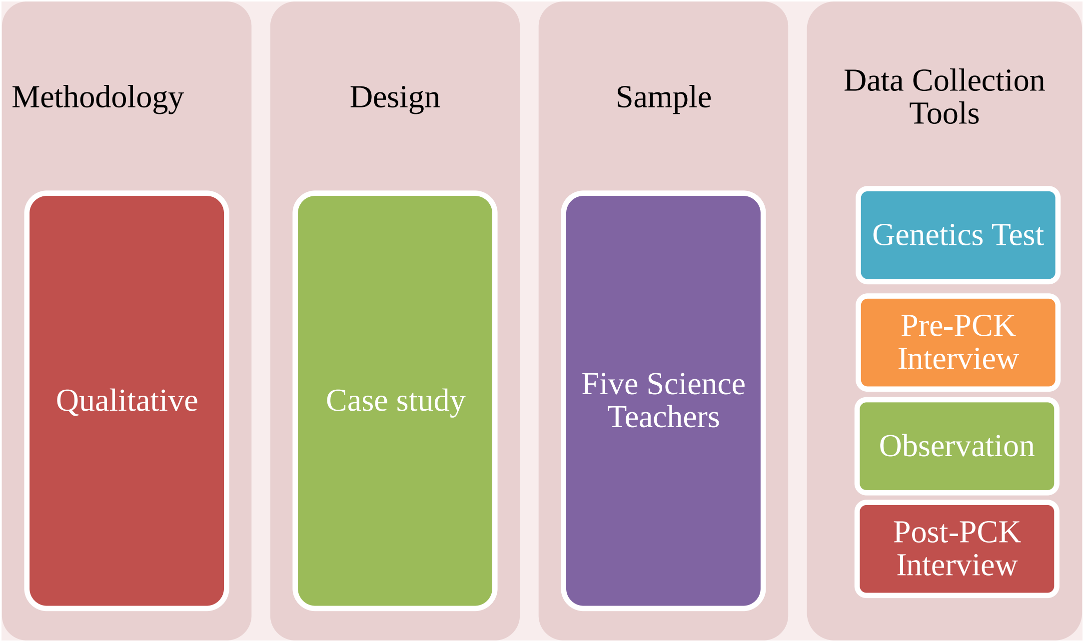


Figure 3.1. The Procedure of the Study

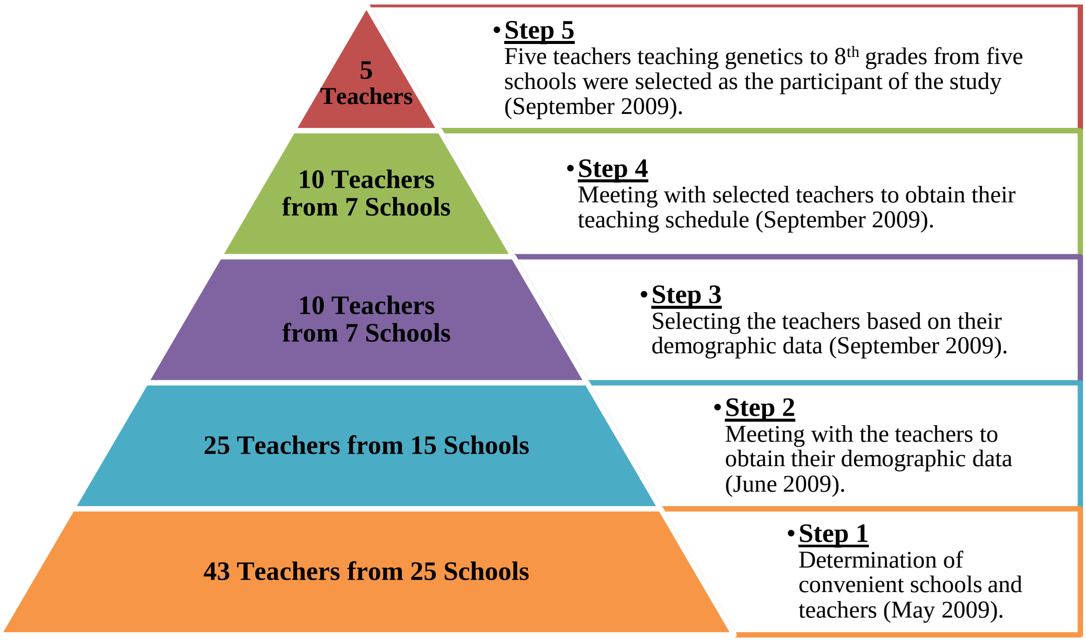
3.3 Participants of the Study

Qualitative studies do not aim to generalize the data as quantitative studies do. Therefore, their sampling techniques are different from quantitative methods. In the present study, the purposeful sampling method was employed to gather deeper and richer information about science teachers' PCK.

Purposeful sampling serves the idea that the researcher desires to discover, understand, and gain insight. For that reason, researcher should select a sample from whom most can be learned (Merriam, 1998). The powerful aspect of purposeful sampling is the selecting information-rich cases to be able to get in-depth information. To be able to select information-rich cases in purposeful sampling, the important task is to determine the selection criteria for the interest of the study (Merriam, 1998).

The criteria to select information-rich cases are based on the purpose of the study and the literature of PCK studies. In this aspect, the department that teacher graduated from, content knowledge, pedagogical knowledge, and teaching experience of teachers were utilized as criteria to select participants of the study. Since content knowledge is accepted as a great source of a teacher's PCK, as well department teacher graduated is the main source for a teacher of appropriate content knowledge and department teachers graduated selected as a criterion (Carlsen, 1999; Cochran et al., 1993, Magnusson et al., 1999; Van Driel et al., 2001). Moreover, taking pedagogy courses at university was another possible source for teachers' pedagogical knowledge. All PCK models (Carlsen, 1999; Cochran et al., 1993; Grossman, 1990; Magnusson et al., 1999; Shulman, 1987; Tamir, 1988) and studies included content knowledge and pedagogical knowledge in PCK. Furthermore, PCK studies (Grossman, 1990; Baxer & Lederman, 1999; Gess-Newsome, 1999; Magnusson et al., 1999; Van Driel et al., 2001) highlight teaching experience as the major factor in the development of PCK.

The participant teachers' selection procedure through purposive sampling was conducted in five steps (Figure 3.2).



- **Step 5**
  Five teachers teaching genetics to 8th grades from five schools were selected as the participant of the study (September 2009).
- **Step 4**
  Meeting with selected teachers to obtain their teaching schedule (September 2009).
- **Step 3**
  Selecting the teachers based on their demographic data (September 2009).
- **Step 2**
  Meeting with the teachers to obtain their demographic data (June 2009).
- **Step 1**
  Determination of convenient schools and teachers (May 2009).

Figure 3.2. The Sampling Procedure of the Study

Firstly, the selection of the location of middle schools as the study area was made and the convenient middle schools were chosen to be studied. The convenient schools was selected to enable researcher to increase the accessibility of the data and the time to be spent with each teacher. The planning of the selection of middle schools was completed in May 2009. In this step, 25 middle schools were targeted to reach teachers and there were 43 science teachers in these schools.

In the second step, the schools were visited by the researcher in the last week of June 2009. This week was selected purposively to reach the teachers in their available time because all teachers required to participate in in-service education in their schools in the last week of June. Then, the researcher met with teachers to obtain their demographic data in order to select to appropriate participants. In this meeting, researcher tried to obtain data regarding the sample criteria of the study. For this reason, the teachers were requested to tell a brief story about their teaching experiences in this meeting. After the meeting, there were 25 teachers from 15 schools who became volunteer to participate in the study.

In the third step, the analysis of teachers’ demographic data was employed according to selection criteria including their content knowledge, pedagogical knowledge, and teaching experience. The bachelor's degree (such as biology department in art and science faculty, biology education and science education in faculty of education), science courses related to genetics and biology courses enrolled in the university and participated inservice education related to genetics and biology was the main concerns for selection of teachers who could have sound content knowledge. For pedagogical knowledge, similar to content knowledge, the bachelor's degree from faculty of education or not, enrolled pedagogy courses in university and participated inservice education related to pedagogy and science education were taken into consideration to select teachers who could have sound pedagogical knowledge. Teachers' experience in teaching such as teaching years, cram school (dershane) experience, question writing for Ministry of National Education, science books editing, book writings, etc. were the main concern for selection of experienced teachers. The analysis was made according to participant selection criteria and teachers who could have more knowledgeable about content, pedagogy and more experienced on science teaching were selected due to the fact that the selected teachers could be the most information-rich cases based on the selection criteria. This step was resulted with seven schools and 10 teachers as the candidate participants of the study.

In the fourth step, the candidate teachers were visited again in the second week of September 2009 to obtain information about their weekly teaching schedule which would be later employed to arrange the teacher observations on the topic of genetics. In this step, schedules of seven schools and 10 teachers for 8th grade genetics topic were obtained.

In the fifth and the last step, weekly teaching schedules of teachers were taken into consideration because each of the teachers was observed four class hours in each week and weekly teaching schedule of schools included 30 class hours. When the weekly teaching schedules of teachers were taken into consideration, the number of the teachers had to be reduced to arrange the observation schedule. In order to increase as much variation in the sample as possible, the limitation of sample selection was based on the observation schedule of teachers. In the end, the teachers who could be most information-rich cases based on the selection criteria and who had appropriate schedule for observation were selected as the participant of the study. All the evaluation process of participant selection resulted in five science teachers (one male and four female teachers) from five middle schools. Some characteristics of these teachers (the used pseudonyms for the participant teachers was Beste, Melis, Mert, Nehir, and Seda) are given in Table 3.1. All teachers have different characteristics and these differences increased the opportunity to identify patterns and contrasts for the cases (Miles & Huberman, 1994). All teachers have similar teaching contexts due to the curriculum of 8th grade science course at public middle schools in Ankara. The detailed information about the participant teachers is given in the result chapter.

Table 3.1. The Characteristics of the Participants of the Study

Participant	Gender	Bachelor's degree	Graduation	Teaching experience (in years)	Involved educational
Beste	Female	Biology	Arts and Science Faculty	22	Writing of two science textbooks, Editing of science textbooks, Preparing science questions for cram school, Cram school (dershane) experience, Enrolled in genetics courses in undergraduate education
Melis	Female	Chemistry	Arts and Science Faculty	14	Participation of inservice education on science laboratory
Mert	Male	Biology	Arts and Science Faculty	17	Cram school (dershane) experience, Prepare science questions for cram school, Enrolled in genetics courses in undergraduate education
Nehir	Female	Science teacher	Institute of Education	30	Having science teaching experiences all over part of the country (West, East, North)
Seda	Female	Biology teacher	Faculty of Education	15	6 years of laboratory experience as a biologist, All teaching experience in science education, Preparing science questions for Ministry of National Education, Enrolled in genetics courses in undergraduate education,

3.4 Data Collection

In order to gather deep information on content knowledge and PCK components, genetics test, Pre-PCK interview, observation, and Post-PCK interview were utilized in the study. Creswell (1998) referred to this type of data collection as “multiple source of information.” Each data collection tool aims to investigate one or more PCK components. Table 3.2. indicates the data collection tools and investigated PCK components.

Table 3.2. Data Collection Tools

Data Collection Tools	Investigated PCK Components
Genetics test	Knowledge of content
Pre-PCK interview	Knowledge of curriculum Knowledge of students Knowledge of teaching strategies
Observation	Knowledge of curriculum Knowledge of students Knowledge of teaching strategies
Post-PCK interview	Knowledge of curriculum Knowledge of students Knowledge of teaching strategies

The data were collected from science teachers teaching genetics topic to 8th grade students in public schools in Ankara in the fall semester of 2009-2010 education year. The details about each part of the data collection procedure are explained in the following sections.

3.4.1 Genetics test

To investigate science teachers’ content knowledge on genetics topic, the content test was developed by the researcher (Appendix A). The genetics test consisted of two open-ended questions; one is genetics concepts question and the other one is genetics crossing question.

In the concept question section, seven genetics concepts including gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous were expected to be defined by science teachers.

In the crossing question section, a monohybrid-crossing question, was asked to evaluate teacher knowledge about crossing. It was an open-ended question:

> It is known that the yellow seed color character is dominant over green seed color for peas. What would happen, if you cross yellow and green seed plants?

The objectives of the genetics test and its two questions were based on the concepts and crossing covered in 8th grade middle school science curriculum (Ministry of National Education, 2006) as shown in Table 3.3. and the literature of related genetics studies (Bahar et al., 1999; Banet & Ayuso, 2000; Cavallo, 1996; Clark & Mathis, 2000; Dogru-Atay & Tekkaya 2008; Knippers et al., 2005; Lewis, & Katmann, 2004; Lewis et al., 2000a, b, c; Marbach-Ad & Stavy, 2000; Rotbain et al., 2006; Saka et al., 2006; Tatar & Cansungu-Koray, 2005; Tekkaya et al., 2001; Yilmaz, Tekkaya, & Sungur, 2011).

Table 3.3. Objectives and Explanations of Genetics Topic Stated in 2006 Science Curriculum for Genetics Topic (Ministry of National Education, 2006)

Objectives
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene. 2.5. Understand the relationship between phenotype and genotype. 2.6. Solves crossing problems related to inheritance of a single character.
Limitations
2.3. Only monohybrid crossing should be given as an example, dihybrid crossing should not be given. 2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited disease.
Warnings
2.6. It should be stated that sex is depend on sex chromosomes.

The genetics test was reviewed by two-science education specialists to determine if the items were consistent with the stated curriculum objectives and the literature. This was employed in constructing the content validity of the instruments. Prior to actual study, the pilot of the genetics test was conducted with the seven science teachers from the public schools in Ankara. The criteria for selecting pilot cases were similar to actual participants of the study. During the pilot study, space was provided for respondents to make criticism and recommendations for improving the test. The enlightenment of the results of the pilot study helped to revise basic issues such as change in the question statements to increase the understanding and to finalize form of the genetics test before the actual study.

During main study, teachers were informed verbally that their identities would remain confidential at all times, by means of pseudonyms being used in all reports related to the study. The genetics test was administered to science teachers at their available times in schools and all of the participant teachers completed the test around 30 minutes.

3.4.2 Observation

Teachers were observed in the classroom during teaching of genetics topic. The observation provides useful information and gives an opportunity to obtain rich data about teachers' pedagogical application and teaching strategies, which are the reflection of teachers owned PCK and its components. In the observation, it was also aimed to observe a teacher's concrete pedagogic action that is employed for a particular reason in response to teachers' PCK and components (Loughran et al., 2004).

Observation was conducted on genetics topic and it was lasted from the first week of the October to second week of the November in 2009, about six weeks. Observation started two weeks ago before the teaching of genetics topic in the classroom to make both teachers and students familiar with researcher. There was not any observation data collected before the teaching of genetics topic. Field notes and voice recorder were used for obtaining genetics observation data. Teachers were informed about the observation and their permissions were obtained before collecting the observation data.

The observation data were transcribed and then analyzed for investigation of PCK components. The field notes were intended to describe the classroom, students, teachers writings on blackboard, teachers' teaching strategies like grouping students, questioning, using models, pictures, newspaper, Internet pages, and video demonstration and context of the teaching as much as possible without any judgment (Bogdan & Biklen, 1998). The voice recordings were transcribed completely including every kind of teachers' and students' talks if they are related to teaching genetics. This transcription was completed with the field notes. This kind of data helps imagination of act of teaching in the classroom in a more complete picture. An example of transcription of observation was given in Appendix B. The observation data, combination of voice recording and field notes, entered to NVivo qualitative data analysis software. The analysis of observation data was utilized according to aim of the study to be able to investigate teachers' PCK components.

3.4.3 Interviews

Interview is accepted as the major source of qualitative data needed for understanding of the study (Meriam, 1998), serves as an important source of information for the case studies as well (Yin, 2003). In fact, interviews are a crucial data collection tool for PCK studies because ideas of teachers were not observable to the researcher and interviews enable teachers to reflect their ideas related to teaching. In this study, two separated interview protocols were prepared and conducted; pre-PCK interview and post-PCK interview. These interviews were explained in the following titles.

3.4.3.1 Pre-PCK Interview

In this study, the pre-PCK interview was conducted to obtain a more complete picture of science teachers' PCK on genetics. In the pre-PCK interview, PCK components; knowledge of curriculum, knowledge of students and knowledge of teaching strategies were investigated based on content covered in genetics test. During interviews, the following questions in Table 3.4. were directed to the teachers for each genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous) and genetics crossing separately (Appendix C).

Table 3.4. Pre-PCK Interview Questions

1. What are the objectives related with the concepts of genetics and crossing in the science curriculum?
2. What kinds of factors do affect students' learning of the concept of genetics / crossing?
    i. What are the requirements needed for the students' learning of the concept of genetics / crossing?
    ii. What are the difficulties faced by students while learning of the concept of genetics / crossing?
3. What kinds of teaching strategies do you use to teach the concept of genetics / crossing?
    i. What kinds of representation do you use in order to teach the concept of genetics / crossing?
    ii. What kinds of activities do you use in order to teach the concept of genetics / crossing?
    iii. What kinds of teaching strategies do you use in order to overcome students' difficulties of learning the concept of genetics / crossing?

The pre-PCK interview was a semi-structured interview and conducted with participating teachers after the completion of genetics test and before the genetics observation. The semi-structured interview enabled researcher to ask further question to deepen the understanding of teachers' teaching and to obtain data related to the purpose of the study. Two-science education professors were examined the interview questions based upon the research questions and the purpose of the study.

The pre-PCK interview was piloted before employed in the study. The pilot of the pre-PCK interview was conducted with three-science teacher at public schools in Ankara. The criteria for selecting pilot case were similar to actual selection of participant of the study. In the pilot study, teachers were asked whether the interview questions were clear enough and their suggestion to help modify the pre-PCK interview. All necessary revisions were made to construct the final version of the pre-PCK interview protocol. During the main study, the entire interview with science teachers was voice recorded with the permission of the each participant of the study and transcribed. The pre-PCK interviews were conducted with science teachers at their available times in schools and took around 120 minutes.

3.4.3.2 Post-PCK Interview

Even though data were collected from classroom observations and observations provided detailed information of teachers' teaching of genetics topic, teachers were interviewed after observation of genetic topics to be able to obtain ideas of teachers on teaching genetics topic and deepen the observation data in line with the purpose of the study.

The post-PCK interview questions were prepared based upon the collected observation data of each teacher. Each one of the teachers' teaching was different and exemplified different PCK components and accordingly each teacher's post-PCK interview questions were different from each other. For example, when Melis changed the order of genetics topic in her teaching, the question of post-PCK interview: "What is the reason for changing topic order?" was directed to Melis. Mert applied an activity about probability by grouping students and the researcher asked the following questions to him: "Why did you make activity about probability?" and "Why do prefer to apply activity in groups?" Moreover, during interview, some additional questions were asked in order to understand and clarify the reasons of their decision on teachings in the classroom. For instance, Melis stated that "I changed order of topics to help students learn better…" and the researcher directed at this time an additional question like: "Why do you think that changing topics order helps to students learn better?"

The post-PCK interviews were conducted afterward the obtaining and analysis of genetics teaching observations data to prevent teachers become alerted or change their teaching due to the post-PCK interview questions. The post-PCK interviews ranged from 90 minutes to 120 minutes. The entire interviews with science teachers were audio recorded with the permission of the participant of the study and transcribed.

3.5 Data Analysis

In the case study, the data analysis aimed to provide an intensive and holistic description of the case (Merriam, 1998; Yin, 2009). In qualitative study, the role of the researcher is to make sense of the data by means of interviews and observations (Merriam, 1998). Besides interpretation of the findings, researcher tries to understand what the data tell (Bogdan & Biklen, 2007). The data collection and analysis are not separate procedures in qualitative studies, and they occur concurrently (Bogdan & Biklen, 2007). The data collection of the present study also helped researcher to gain insights about teachers' PCK and gave an idea about how to analyze the obtained data. Data analysis includes complex procedures involving examining, categorizing, testing, and recombining evidence, and inductive and deductive reasoning to address the initial propositions of the study (Yin, 2009). The analysis of the data in this study was made according to the aim of data collection tools and the nature of the obtained data. In this point of view, the procedures for data analysis of content knowledge and PCK were explained in the following titles.

3.5.1 Content Knowledge of Teachers

Teachers' content knowledge was investigated with the help of genetics test. The genetics test included two open-ended questions and the following titles explained data analysis of concept question and crossing question.

3.5.1.1 Concept question

In the concept question, science teachers expected to define seven genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous, see Appendix A). The answers of teachers for the definition of concepts were analyzed by comparison with scientific definitions given in Table 3.5 (Mason, Losos, & Singer, 2011).

Table 3.5. The Scientific Definitions of the Genetics Concepts

Concepts	Definition
Gene	a segment of DNA (on a specific site on a chromosome) that is responsible for the physical and inheritable traits or phenotype of an organism.
Dominant gene	expressed in an organism's phenotype, masking the effect of the recessive allele or gene when present.
Recessive gene	is masked by the effects of the dominant gene. The recessive trait may be expressed when the recessive genes are in homozygous condition or when the dominant gene is not present.
Genotype	the entire set of genes in a cell, an organism, or an individual. A set of alleles that determines the expression of a particular characteristic or trait (phenotype).
Phenotype	the physical appearance or biochemical characteristic of an organism as a result of the interaction of its genotype and the environment.
Homozygous	an individual (or a condition in a cell or an organism) containing two copies of the same allele for a particular trait located at similar positions on paired chromosomes. A 'homozygous' individual for a particular trait is described to possess either a pair of dominant alleles (e.g. AA) or a pair of recessive alleles (e.g. aa). Same alleles for a trait are expressed in the phenotype of a homozygous individual.
Heterozygous	an individual (or a condition in a cell or an organism) containing two different alleles for a particular trait. An individual has one dominant allele and one recessive allele, i.e. Aa, for a particular trait. Dominant allele for a trait would express itself over the recessive one in the phenotype of a heterozygous individual.

Note. The scientific definitions of the genetics concepts were adapted from Raven et al. (2011).

The teachers' definitions were coded as sound and partial understandings. If teacher's answer was acceptable according to scientific definition, her/his definition was coded as a sound understanding. On the other hand, if teacher's answer is lack in depth and includes some deficiency according to scientific definition, her/his definition was coded as partial understanding. If a teacher understanding was either an unscientific understanding or including misconceptions, her/his definition was coded as a naïve understanding. In the study, none of the participant teachers' knowledge was found as naïve. For this reason, only two codes, sound and partial understanding, were utulized in the analysis of concept questions.

The analysis of teachers' answers revealed that some of the teachers' definitions of genetics concepts included partial answer. For example, the definition of gene in Table 3.5 includes one part as "is a segment of DNA (on a specific site on a chromosome)" and this part explains what a gene is. Moreover, the other part of the definition of gene, which is "that is responsible for the physical and inheritable trait or phenotype of an organism," explains the function of a gene. The definition of some teachers included only the part of what the gene concept is and the others included the function of a gene. The interpretation and analysis of teachers' definitions needs different approach rather than just stating that knowledge of teacher is partial because the deficiency of teachers' knowledge in this situation is related to the difficulty in connecting the function and structure of a concept. The literature states that students generally experience the similar difficulty in genetics concepts (Marbach-Ad & Stavy, 2000; Lewis & Kattman, 2004; Lewis et al., 2000c). This difficulty was stated by Chi, Slotta, and Leeuw (1994) with theory of ontological categorization of concepts. Their theory assumes that entities in the world belong to different ontological categories, such as matter (things) and processes. Most of the scientific concepts, such as the gene, belong to a subcategory of processes, linked to the function of a concept (Figure 3.3). Nevertheless, students' initial conceptions of these concepts are in matter category, linked to what a concept is. Students have to advance the category from matter to process during gaining knowledge on the concepts (Figure3.3). However, before to teaching the concepts to students, teachers should have conceptual knowledge in process category. Hence, the teachers' definitions of genetics concepts were analyzed according to theory of ontological categorization (Chi et al. 1994) in this study. Teachers' definitions were categorized as matter and process with explanation of its categorization. To illustrate, the ontological categorization of gene concepts was shown in Figure 3.3

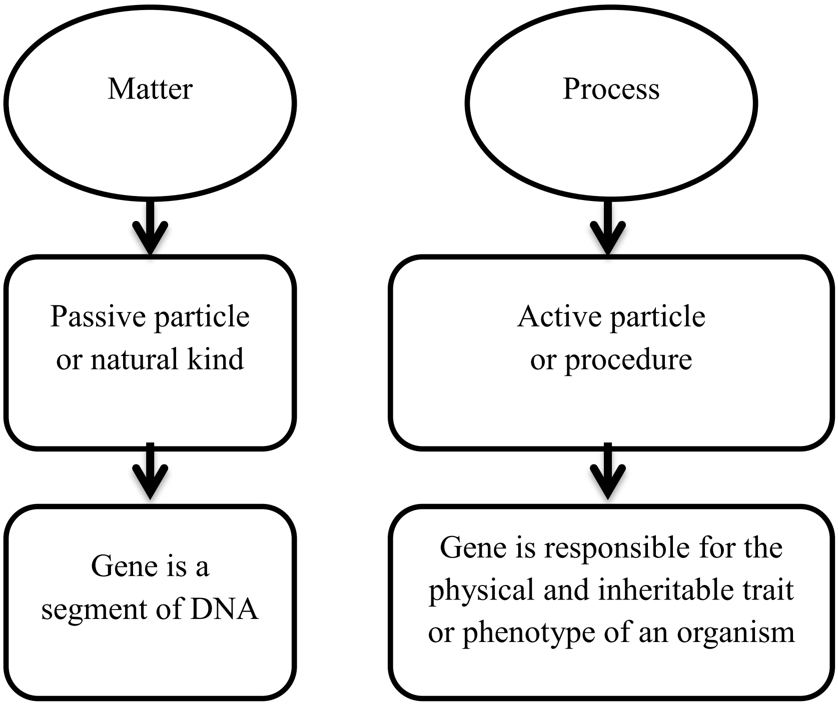


Figure 3.3. The Ontological Categorization of Gene Concept Adopted from Chi et al. (1994) and Venville and Treagust (1998).

The scientific definition and ontological categorization analysis were made by two-science education specialist. After determination of coding procedures, two-science education specialists were coded teachers definitions independently. Inter-rater reliability between the two coders was calculated by means of formula offered by Miles and Huberman (1994). Their formula is:

$$\text{Reliability}=\frac{\text{Number of agreements}}{\text{Total number of agreements + disagreements}}\text{x100}$$

and the inter-reliability of two coders was found to be %93. The disagreements in the coding were discussed and consensus was reached at the end of the coding procedures. Teachers' understandings of genetics concepts were evaluated by using two related categories named knowledge (Sound versus Partial) and ontological (Matter versus Process) levels.

3.5.1.2 Crossing question

In the crossing question, a monohybrid-crossing question was asked to obtain data about teachers’ understanding about crossing (Appendix A). The question and expected answer were given below;

> Question: It is known that the yellow seed color character is dominant over green seed color for peas. What would happen, if you cross yellow and green seed plants?

Expected answer of the asked monohybrid-crossing question was described in Figure 3.4.

Part A				
Phenotype:	Dominant character Yellow		**Phenotype:**	**Recessive character** **Green**
Genotype:	Homozygous Dominant	Heterozygous	**Genotype:**	**Homozygous Recessive**
	YY	Y**y**		**yy**

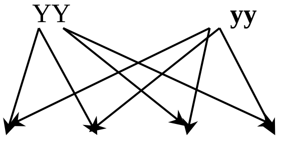
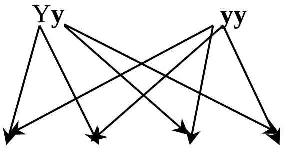
Part B					
Crossings	**Probability 1**			**Probability 2**	
Phenotype:	Yellow	**Green**	**Phenotype:**	Yellow	**Green**
Genotype:	Homozygous Dominant	Heterozygous	**Genotype:**	Heterozygous	**Homozygous Recessive**
	YY	**yy**		Y**y**	**yy**
					
Genotype:	Y**y** Y**y**	Y**y** Y**y**	**Genotype:**	Y**y** Y**y**	**yy yy**
Phenotype:	yellow yellow	yellow yellow	**Phenotype:**	yellow yellow	**green green**
Genotype ratio:	100% heterozygous yellow		**Genotype ratio:**	50% heterozygous yellow	**50% homozygous recessive green**
Phenotype ratio	100% yellow		**Phenotype ratio**	50% yellow	**50% green**

Figure 3.4 Expected Answer of the Monohybrid-Crossing Question

This crossing question was employed to evaluate teachers' understanding of key facts, and principles of genetics. Teachers' answers for crossing were analyzed by two-science education professionals according to answer checklist of crossing. The checklist (Table 3.6) was constructed by the researcher according to expected answer adopted from science textbook (Ministry of National Education, 2007, p. 28).

Table 3.6 The Answer Checklist of Crossing Question

Teachers should be able to	Does the answer of teachers include following item?	
	Yes	No
A- Writing two different (homozygous and heterozygous) genotype probabilities according to given dominant character phenotype		
B- crossing showing the following knowledge and skills		
1- Transition text to notation of Genotype (Dominant gene, Recessive gene, Homozygous, Heterozygous)		
2- Crossing gametes		
3- Crossing alleles genotype		
4- Writing proportion of the genotypes		
a. Writing same and different types proportion		
b. Writing total proportion is 1 (1/4, %25 etc)		
5- Writing genotype (notation or text) to phenotype		
6- Writing proportion of phenotype		
a. Writing same and different proportion		
b. Writing total proportion is 1 (1/3, 1/2 , %100 etc)		

The analysis was made in two steps according to the answer checklist of crossing question. The correct answer of the teacher for step A is expected to include two different (homozygous and heterozygous) genotype probabilities according to given dominant character phenotype. For this reason, if the answer of teachers included two different crossings and probabilities, it was accepted as the accurate answer. If teacher's answer included one probability of genotype, either homozygous or heterozygous, it was accepted as the inaccurate answer. The correct answer of teacher for step B is expected to include all six items in step B and if any step is missed in the answer, then the answer was accepted as inaccurate. If either step A or step B, and their sub-items were missed, then the answer was accepted as partial understanding. The sound understanding for crossing questions means that the answer of teachers should include accurate answer for step A, step B and all the sub-items. The following titles included the explanation for data analysis of PCK and components.

3.5.2 PCK and Components

The content knowledge obtained from the genetics test and information about characteristics of teachers have an explicit nature. The nature of the data affected the data analysis and genetics test data were analyzed more straightforwardly than the data analysis of pre-PCK interview, observation, and post-PCK interview because pre-PCK interview, observation, and post-PCK interview were aimed to obtain data about components of PCK. The boundaries between components are not clear and there is a reciprocal interaction among the components during teaching (Magnusson et al., 1999; Marks, 1990; Veal & MaKinster, 1999). Moreover, teachers employed simultaneously different components of PCK while teaching a topic and the line between components is not clear-cut (Fernandez-Balboa & Stiehl, 1995; Baxter & Lederman, 1999). For this reason, PCK has an implicit nature for analysis (Loughran, Milroy, Berry, Gunstone, & Mulhall, 2001; Van Driel, Beijaard, & Verloop, 2001). Thus, analysis of pre-PCK interview, observation, and post-PCK interview data were based on the aimed components of PCK.

Each PCK components data was gathered through one or more data collection tools. Table 3.7. displays the PCK components and data collection tools employed in the present study.

Prior to data analysis, all data collected from pre-PCK interview, observation and post-PCK interview were transcribed and entered to NVivo qualitative data analysis software. This software allows the researcher to import transcripts as text, create codes (termed “nodes” in the program), and highlight and code pieces of text ranging from a few words to a complete transcript. This software was helpful for coding data visually. The codes were constructed by means of PCK model of

Magnusson et al. (1999), literature of genetics studies and the researcher's experiences with the data. For example; the PCK model of Magnusson et al. (1999) includes knowledge of students' component and it has sub-components as knowledge of students' requirements and knowledge of students' difficulties. In addition, genetics studies were also adopted during the construction of coding procedures. For example, as a code for students requirement "scientific knowledge" prior to learning genetics such as DNA, genetic code, cell division, fertilization stated in Banet and Ayuso (2000), Cavallo (1996), Friedrichsen and Stone (2004) Lewis and Wood-Robinson (2000) studies and "maturity" as a code of students' requirements stated in studies of Lawson and Thompson (1988), and Lewis and Kattman (2004). Besides, this knowledge also depends on the students and students in the classroom might have different kind of requirements and difficulties from genetics literature. For this reason, researcher's experience with data is an important point in construction codes and analysis of data.

Table 3.7. PCK Components and Data Collection Tools

Investigated PCK Components	Data Collection Tools
Knowledge of curriculum	Pre-PCK interview Observation Post-PCK interview
Knowledge of students	Pre-PCK interview Observation Post-PCK interview
Knowledge of teaching strategies	Pre-PCK interview Observation Post-PCK interview

The constant comparative method of data analysis developed by Glaser and Strauss (1967) was a commonly employed in the most of the qualitative studies (Meriam, 1998) and this method was adopted in the present study as well. Based on this method, the analysis of data was begun with a participant data for one PCK component. To illustrate, the analysis of knowledge of students was started with data of Beste and her answer to pre-PCK questions related to knowledge of students and then her observation and post-PCK interview were analyzed in this manner. In this part, the researcher built up tentative codes to analysis. Tentative codes build up according to PCK model of Magnusson et al. (1999), genetics literature and the researcher's experience with the data. The same procedures were carried out with new participant teacher data and the researcher came up with similar or new codes compared with first participant data. This process includes comparing one set of data from one participant to another one and this comparison helps to determine similarities and differences among codes (Meriam, 1998). These codes were given tentative names and recurrence of the similar codes was emerged to existing codes. The researcher began to integrate codes according to consistency until codes saturated and this process brought to end producing the final codes for analysis of the study.

The coding analyses of each PCK components were made by two coders who have experience in PCK, science education and qualitative research. Inter-rater reliability between the two coders was calculated by means of formula offered by Miles and Huberman (1994) and it was calculated as %90. The inconsistencies were discussed again and consensus was reached at the end.

Each component of PCK was analyzed separately and data analysis procedure of each component was different from each other. The following titles explain each of data analysis of PCK components.

3.5.2.1 Knowledge of Curriculum

The topic of genetics occupied an important place in the science curricula developed by Ministry of National Education (1992, 2000, 2004, and 2006). In 2006 science and technology curriculum, genetics topic took place with topic of cell division and the topics order and suggested period for each topic in 2006 curriculum were given in Table 3.8.

Table 3.8. Topics and Suggested Time Period for Cell Division and Genetics

Topics	Suggested Time Periods
1. Mitosis	4 lesson hours
2. Genetics	6 lesson hours
3. Meiosis	5 lesson hours
4. DNA and Genetics Code	4 lesson hours
5. Adaptation and Evolution	3 lesson hours

Teachers' knowledge of curriculum were analyzed in line with the objective with regard to genetics topic stated in the 2006 science curriculum. Table 3.9 shows the objectives, limitations, and warnings, related with aim of this study, in 2006 science curriculum.

Table 3.9. Objectives and Explanations Stated in the 2006 Science Curriculum for Genetics Topics (Ministry of National Education, 2006)

Objectives
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene. 2.5. Understand the relationship between phenotype and genotype. 2.6. Solves crossings problems related to inheritance of a single character.
Limitation
2.3. Only monohybrid crossings should be given as an example, dihybrid crossings should not be given. 2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.
Warning
2.6. It should be stated that sex depends on sex chromosomes

Teachers' knowledge of curriculum about genetics was evaluated with the help of pre-PCK interview (see Appendix C) and classroom observation. In the pre-PCK interview, the question "What are the objectives in curriculum for genetics concept / crossing?" was asked for each genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous) and genetics crossing to the participant teachers.

The answers of teachers for curriculum question were investigated according to curriculum objectives and eighth-grade science teacher guide book's content by two-science education professionals. A checklist was prepared by the researcher according to 2006 curriculum objectives (Table 3.10). The teachers' responses about objectives were evaluated by using the checklist in the extent of which the objectives were met. The teachers' answers were coded as "yes," if it accurately met with the curriculum objectives. The teachers' answers were coded as "no," if it was an inaccurate answer. Moreover, if teachers' answers included a partial answer or added an objective that is not stated in the 2006 curriculum, it was coded as "partial" answer.

In addition to pre-PCK interview, observation data were transcribed and the checklist for curriculum objectives for genetics topic was prepared. This observation checklist was employed during analysis to understand whether teachers follow the objectives stated in 2006 science curriculum. Moreover, if any objectives did not meet or partially meet during teacher's teaching, the reason was asked to the teacher during post-PCK interview. The analysis of interviews and observation of the teaching were made by two-science education professional.

Table 3.10. Curriculum Objectives Checklist for Curriculum Knowledge of Teacher

2006 Curriculum Objectives for Genetics Topic	Does teacher's answer meet curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene. 2.5. Understand the relationship between phenotype and genotype. 2.6. Solves crossings problems related to inheritance of a single character.			
Limitation			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossings should not be given. 2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.			
Warning			
2.6. It should be stated that sex depends on sex chromosomes			

3.5.2.2 Knowledge of Students

In this section, teachers' knowledge of students about genetics was analyzed under two following headings; students' requirements to learn genetics and students' difficulties while learning genetics topic.

3.5.2.2.1 Students' Requirements to Learn Genetics

In this study, the requirements of students mean that development of knowledge in a specific area needs prior knowledge and skills. A teacher should have this knowledge to help students to learn new topic appropriately. The related data were obtained through pre-PCK interview and post-PCK interview with the teachers. The probed question related to knowledge of students in pre-PCK interview for each genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous) and genetics crossing was "What are the requirements needed for learning on genetics concept / crossing?" The probed questions in post-PCK interview were constructed based on the data analysis of observation. For this reason, each teacher's post-PCK interview questions were different from other one.

The analysis of data and codes constructed according to available literature and data of the study revealed three common requirements of students to learn genetics topic and these requirements were harmonized with literature. The dimensions of the students' requirements are knowledge (Banet & Ayuso, 2000; Cavallo, 1996; Clark & Mathis, 2000; Dogru-Atay & Tekkaya 2008; Kindfield, 1991; Lewis, & Katmann, 2004; Longden, 1982; Pashley, 1994; Tekkaya et al., 2001; Yilmaz et al., 2011), skills (Banet & Ayuso, 2000; Hackling & Treagust, 1984; Slack & Stewart, 1990) and students' maturity level (Lawson & Thompson, 1988; Lewis & Kattman, 2004; Tobin & Capie, 1982).

The dimensions of students' requirements were formed by using the recurring patterns and themes obtained from analysis of interviews and observation data. In the results chapter, these dimensions were given with the examples of excerpts of participants teachers. All the dimensions are shown in Table 3.11. Knowledge dimension can be categorized into two sub-dimensions; science and mathematical knowledge.

Table 3.11. Codes of Knowledge of Students' Requirements to Learn Genetics

Dimension of requirements	Sub-dimension of requirements	Requirements
Knowledge	Science	Cell (DNA, Chromosomes, Gene) Cell division Fertilization
	Mathematics	Fraction, ratio, percentages Probability
Skills		Problem solving Graphic reading Prediction
Maturity		Formal-operational

3.5.2.2.2 Students' Difficulties While Learning Genetics

This knowledge refers to teachers' knowledge of the science concepts that students find difficult to learn and this knowledge includes source of the students' difficulties. The data of knowledge of students' difficulties for genetics were obtained through pre-PCK interview and post-PCK interview with the teachers. The probed question related to knowledge of students in pre-PCK interview for each genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous) and genetics crossing was "What are the difficulties of students while learning genetics concepts / crossing?" The probed questions in post-PCK interview were constructed based on the data analysis of observation. For this reason, each teacher's post-PCK interview questions were different from other one. For example, Nehir employed the activity of the preparing pedigree and frequency table of selected traits during observation. It was asked to teacher "What is your aim for the preparing pedigree and frequency table of selected traits while teaching?" in post-PCK interview.

The analysis of data and code construction were made according to related literature of genetics (Bahar et al., 1999; Banet & Ayuso, 2000; Cavallo, 1996; Clark & Mathis, 2000; Dogru-Atay & Tekkaya 2008; Knippers et al., 2005; Lewis, & Katmann, 2004; Lewis et al., 2000a, b, c; Marbach-Ad & Stavy, 2000; Rotbain et al., 2006; Saka, et al., 2006; Tatar & Cansungu-Koray, 2005; Tekkaya et al., 2001;

Yilmaz et al., 2011) and data analysis of the study. Based on the analysis of the data, teachers' knowledge on students' difficulties were grouped under two dimensions; difficulties related to students' understanding, and sources of difficulties (Table 3.12). The dimensions of difficulties and their sources were formed by using the recurring patterns and themes obtained from analysis of interviews and observation data. In the results chapter, these dimensions were given with the examples of excerpts of participants teachers.

Table 3.12. Codes of Students' Difficulties and Sources of Difficulties for Genetics

Difficulties	Examples
Understanding	Understanding meaning of the steps
Relationship	Constructing in relationship between genetics concepts category (sub-micro, micro, and macro) cell division, fertilization and continuity of genetics information
Crossing	Interpreting results
Sources	**Sub-dimension of sources**
Concept	New concepts Many concepts More than one usage for same concept
Representation	Alphabetic symbols Crossing symbols
Students' characteristics	Learning styles Cram school Having hereditary disease in the family

3.5.2.3 Data Analysis of Knowledge of Teaching Strategies

The participant teachers' knowledge of teaching strategies were presented as; description of teaching, representation, activities and employed strategies to overcome students' difficulties, respectively. Teacher's knowledge of teaching strategies was evaluated by the help of observation, the pre-PCK interview (see Appendix C) and the post-PCK interview.

The main question asked to the teachers in the pre-PCK interview for each genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous) and genetics crossing was “What kind of teaching strategies do you use to teach the genetics concepts / crossing?” The sub-question asked to the teachers in the pre-PCK interview for each genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous) and genetics crossing was “What kind of representation do you use to teach these concepts / crossing?” The term “representation” refers to teachers’ knowledge of ways to represent specific concepts or principles in order to facilitate students’ learning (Magnusson et al., 1999). This knowledge includes teachers’ ability to invent representation to aid students in developing an understanding of specific concepts or relationships. Teachers should also have knowledge about the relative strengths and weaknesses of a particular representation. Illustrations, examples, models, or analogies are the examples of representations. A topic specific example was about electricity circuit; water flowing through pipes and a bicycle chain (Magnusson et al., 1999).

Based on the analysis of the data, the representations employed by teachers while teaching genetics were grouped under three dimensions; illustrations, examples, and analogies. The dimensions of representations were formed by using the recurring patterns and themes obtained from analysis of interviews and observation data. In the results chapter, these dimensions were given with the examples of excerpts of participants teachers.

The sub-question “What kind of activities do you use to teach these concepts or crossing?” was asked to teachers in the pre-PCK interview for each genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous) and genetics crossing. The term “activities” refers to knowledge about activities that can be employed to help students comprehend specific concepts or relationships (Magnusson et al., 1999). This knowledge also includes knowledge of the conceptual power of a particular activity; it presents signals or clarifies important information about a specific concept or relationship. Problems, demonstrations, simulations, investigations, or experiments can be the examples of activities. For example, teachers should be able to decide what activities to use with middle school students to help them understand the distinction between temperature and heat energy; using a heat pulser and temperature probe (Magnusson et al., 1999).

In addition to the pre-PCK interview, teachers' observation in the classroom was another data source for this research question. All teacher observations were transcribed and teacher knowledge about teaching strategies was analyzed. Moreover, the observation data related to students' difficulties were analyzed and the question "What is the reason of using this kind of strategies to teaching this concept?" was asked to the teachers during the post-PCK interview. For example, during interview, teacher Nehir mentioned that students confused with use of letter for notation of dominant and recessive genes because some letters uppercase and lowercase are similar (like U-u, S-s) and researcher directed an additional question like "What would you do to overcome/prevent students' confusion about usage of these letters for the dominant and recessive genes?"

The analysis of the data was revealed that the teaching strategies employed by teachers to overcome students' difficulties and the activities employed by teachers while teaching genetics change for each teachers. This was actually results of nature of the PCK which unique the context and teachers. For this reason, each teacher's applications were separately given in each teacher's results.

The summary of all the data collection and analysis procedure was given in Table3.16.

Table 3.13. *Summary of the Research Design*

Research Question	Instrument	Data analysis
1. What are the science teachers' understandings of genetics?	Genetics test (Appendix A)	• Scientific Definition • Ontological categorization (Chi et al., 1994) • Crossing Answer Checklist
2. What is the nature of science teachers' pedagogical content knowledge in regard to topic of genetics?		
2.i. What is the science teachers' knowledge of curriculum in regard to topic of genetics?	Pre-PCK Interview Observation	• Data analysis of interview question (1. What are the objectives in curriculum for the concept of genetics / crossing?) with Curriculum Objectives Checklist for Curriculum Knowledge of Teacher • Objectives Checklist of Teachers' Teaching for Curriculum Knowledge of Teacher
2.ii. What is the science teachers' knowledge of students in regard to topic of genetics?		
2.ii.a. What is the science teachers' knowledge of the requirements of students to learn genetics?	Pre-PCK Interview Observation Post-PCK interview	• Data analysis of interview question (2.i. What are the requirements needed for learning on the concept of genetics / crossing?) ○ The probed questions related to knowledge of students requirements in post-PCK interview were constructed based on data analysis of observation. • The dimensions of students' requirements were formed by using the recurring patterns and themes obtained from analysis of interview and observation data.

Table 3.13. Summary of the Research Design (Continued)

Research Question	Instrument	Data analysis
2.ii.b. What is the science teachers' knowledge of the difficulties students experience while learning genetics?	Pre-PCK Interview Observation Post-PCK interview	• Data analysis of interview question (2.i. What are the requirements needed for learning on the concept of genetics / crossing?) ○ The probed questions related to knowledge of students requirements in post-PCK interview were constructed based on data analysis of observation. • The dimensions of students' requirements were formed by using the recurring patterns and themes obtained from analysis of interview and observation data.
2.iii. What kinds of strategies do science teachers employ to teach		
2.iii.a. What kind of representations do science teachers employ to teach genetics?	Pre-PCK Interview Observation Post-PCK interview	• Data analysis of interview question (3.i. What kind of representation do you use in order to teach the concept of genetics / crossing?) ○ The probed questions related to knowledge of students difficulties in post-PCK interview were constructed based on data analysis of observation and the probing questions were directed in the post-PCK interview . • Data analysis of observation and post-PCK interview

Table 3.13. Summary of the Research Design (Continued)

Research Question	Instrument	Data analysis
2.iii.b. What kind of activities do science teachers conducted to teach genetics?	Pre-PCK Interview Observation Post-PCK interview	• Data analysis of interview question (3.ii. What kind of activities do you use in order to teach the concept of genetics / crossing?) ○ The probed questions related to knowledge of students difficulties in post-PCK interview were constructed based on data analysis of observation and the probing questions were directed in the post-PCK interview. • Data analysis of observation and post-PCK interview
2.iii.c. What kind of strategies do science teachers employ to overcome the difficulties students experience while learning genetics?	Pre-PCK Interview Observation Post-PCK interview	• Data analysis of interview question (3.iii. What kind of strategies do you use in order to overcome students' difficulties of learning the concept of genetics / crossing?) ○ The probed questions related to knowledge of students difficulties in post-PCK interview were constructed based on data analysis of observation and the probing questions were directed in the post-PCK interview.

3.6 Trustworthiness

Patton asserted that researchers should take validity and reliability issues into account while designing a study, analyzing results, and judging the quality of the study (Patton, 2002). However, the understanding of concepts of validity and reliability in qualitative approach are different from those in quantitative approach (Yıldırım & Şimşek, 2006). For the reason that qualitative research is based on different assumptions about reality, qualitative researcher should consider validity and reliability from a perspective congruent with the philosophical assumption underlying the paradigm of qualitative research (Meriam, 1998). Based on this perspective, Lincoln and Guba (1986) defined credibility (as an analog to internal validity), transferability (as an analog to external validity), dependability (as an analog to reliability), and conformability (as an analog to objectivity) as signs of trustworthiness in qualitative studies (p. 76-77). In this study, the use of term trustworthiness was preferred instead the use of the term validity and reliability. Moreover, the amalgam of credibility, transferability, dependability, and conformability formed the trustworthiness of this study. The evidence in support of the trustworthiness of the study was described under the following titles.

3.6.1 Credibility

Lincoln and Guba (1985) claimed that the most important factor in establishing trustworthiness is confirming credibility. According to Meriam (1998), credibility in qualitative research seeks the answers of following questions of “how much do the research findings match the reality” and “how congruent are the findings with reality.” To increase the credibility of a study, Meriam (1998) offered six strategies: triangulation, member checks, long-term observation, peer-examination, participatory modes of research and clarifying biases of researcher. In addition to the aforementioned strategies, Shenton (2004) offered frequent debriefing sessions, peer scrutiny of the research, and examination of previous research findings as strategies to increase the credibility of the study.

The first method adopted to establish credibility is the triangulation. Triangulation is defined as a procedure where researchers search for convergence among multiple and different sources of information to form themes or categories in a study (Creswell & Miller, 2000). Moreover, Yin (2009) stated that when you really triangulate, the data facts of the case study are supported by more than a single source. By this way, validity has been established since multiple sources of data provide multiple measures of the same phenomenon. The triangulation has four types: data triangulation (the use of a variety of data sources in a study), investigator triangulation (the use of several different researchers or evaluators), theory triangulation (the use of multiple perspectives to interpret a single set of data, and methodological triangulation (the use of multiple methods to study a single problem or program) (Patton, 2002). In the present study, data triangulation was achieved by using multiple data sources including pre-PCK interview transcripts, observations, and post-PCK interviews.

The investigator triangulation was achieved by inviting another colleague to observe the teachers' teaching genetics topic. She was purposefully selected for the observation because she is knowledgeable on the construct of PCK, literature of PCK, its components, literature of genetics topic, and how to conduct observation. Co-observer observed 2 hours for each of the teachers' teaching and the duration of the observation of the all teachers' teaching was a total of 10 hours. These observations allowed her to gain experience about teachers' teaching. The co-observer was instructed on how to observe, to take notes about observation, to use a voice recorder, and to transcribe of the observation according to the obtained data. After observation, researcher came together with the co-observer and discussed the observations with the help of the obtained data. When the inconsistencies emerged between the researcher and the co-observer, they focused on these parts and tried to reach a consensus. All PCK components were discussed in these discussion sessions.

Along with triangulation, member check was another method employed to establish the credibility of the study. Member check refers to allowing the participants of the study check the data, categories, and interpretations (Yıldırım & Şimşek, 2006). The participants of the study viewed the raw data (genetic concept test, pre-PCK interview, post-PCK interview, etc.) and they were asked to comment on their accuracy. In other words, after each part of data collection, teachers were asked whether they agreed on what they stated and there was anything that they wanted to change or add. This process was followed throughout the investigation. In the analysis part, the participants were allowed to react to the interpretations of the data.

Long-term observation also helped the researcher to ensure credibility. The researcher spent about one and a half months in classroom observation and one semester with the participants for investigation. Meanwhile, the researcher observed their classes, spent time with them, and talked about teaching, learners, context, and science curriculum. Teachers' PCK for the topic of genetics was acquired as much as possible with the help of long-term observation.

Additionally, the low inference descriptors were employed in the analysis of the research findings. The researcher attempted to use the Latin phrases that were very close to the participants' wordings in Turkish and verbatim in reporting the analysis of the research findings.

Peer debriefing means requesting another researcher to review and comment on the findings of the study (Merriam, 1998). In this manner, another researcher who has experience in PCK and qualitative research was asked to comment on the findings of the study to increase credibility of the study by means of peer debriefing. In the light of her comments, the researcher refined the analysis, and the results of the study based on the analysis.

The researcher of the study met with his two advisors frequently and this frequent debriefing helped the researcher to widen his vision with the help of the advisors' experiences, perceptions, and valuable comments throughout the research. This process helped the researcher to develop new ideas about the investigation and to recognize the researcher’s own biases and preferences. Moreover, this process also gave him the opportunity to discuss and revise the findings of the study and elaborate the route of the analysis.

3.6.2 Dependability

Despite the fact that reliability is defined as the replication of findings in quantitative studies, it has a different meaning due to the nature of the qualitative studies (Yıldırım & Şimşek, 2006). In qualitative studies, dependability, as analog to reliability, means that readers of the study should acknowledge the consistency and dependability of the study results (Lincoln & Guba, 1985). Dependability does not mean finding the similar results and it, in qualitative study, also signifies whether the results of the study are congruent with the collected data of the study. Lincoln and Guba (1985) also claimed that there is a close tie between credibility and dependability, and the efforts for credibility mean to some extent the help to ensure dependability. In this way, the aforementioned strategies for credibility, such as; multiple data collection, investigator triangulation, peer debriefing, long term observation, etc., also helped to increase the dependability of the study.

The aim of dependability in a qualitative study is, according to Yin (2009), to decrease the errors and bias in the study. To prevent and decrease the possibility of errors and biases, the case study protocol was offered by Yin (2009) during data collecting and developing case study database. By means of the case study protocol, the researcher of the study helps to ensure if another researcher pursue the same protocol and s/he should get the similar result. Meriam (1998) similarly stated that in order to increase dependability of a study, the researcher of the study should give the detailed description of how data were collected, how categories were derived, how decision was made throughout the investigation. The case study protocol of this study is presented in the methodology part. This protocol describes the detail of the procedure of data collection, data collection tools, and analysis of obtained data.

Furthermore, a co-coder was employed for the data analysis so as to have consensus of findings and reduce the researcher bias. The co-coder was supported to sharpen his skills and insight on PCK and on genetics. The procedure of data analysis in the study was explained to co-coder in order to analyze the obtained data. In data coding, both of the coders identified the patterns and themes derived from data of the study and the coders compared codes emerged. In case inconsistencies emerged between co-coder and researcher of the study, two coders were tried to reach consensus.

3.6.3 Transferability

The term transferability is defined by Yin (2009) as the generalization of the findings beyond the given case study. Meriam (1998) used external validity instead of transferability and she defined external validity that is related to what extent the findings of a case study can be applied to other cases. The transferability is questionable issue in the case studies since sample and universe where the generalization is made, like in quantitative studies, is not the concern of case studies (Yin, 2009). The main aim of investigator in case study is to have analytical generalization from the particular set of the results to broader theories rather than the statistical generalization like in quantitative research. Under the light of this understanding, following strategies were employed to increase the transferability of the study.

The prepared case study protocol, data collection and analysis procedure, as aforementioned in dependability, is also employed to increase the transferability of the study. Another employed strategy for increasing of transferability is providing thick description on the case. In this manner five-science teachers and their physical and cultural environment of the middle schools, classrooms, students were described in detail. The study with more than one case is also another strategy to increase transferability of a study and this study was conducted with five science teachers.

Although the aim of the study was to investigate science teachers' content knowledge and PCK on genetics, the generalization of the findings was not concern of the study. On the other hand, the findings of this study could be shared with other science teachers having similar characteristics with this study to further understanding science teachers' content knowledge and PCK on genetics.

3.6.4 Confirmability

Quantitative approaches emphasized that research is relatively value-free, and therefore it should be objective. Qualitative approaches are based on interpretations, admittedly value bound and regarded as subjective. The term confirmability is preferred to term objectivity in qualitative studies and Lincoln and Guba (1985) underlined that confirmability is the degree to neutrality of researcher while interpreting of data. The confirmability (Shenton, 2004) is a researcher effort to ensure that findings of the study are based on the result of the experiences and ideas of participant of the study, rather than characteristics and preferences of researcher. Triangulation (Shenton, 2004), admission of researchers' bias, detailed methodological description (Miles & Huberman, 1994) are some of the strategies to promote the confirmability of an investigation. In this study, the applied strategies to increase the conformability were triangulation, the case study protocol, and admission of researcher's bias, peer debriefing and presence of the co-coder.

3.7 The Role of the Researcher

The role of the researcher in qualitative studies is different and more complex than in quantitative studies, as the nature of qualitative studies are open ended and less structured. Conducting qualitative studies is mainly based on the researcher, and the researcher is the primary data gathering and analyzing tool in qualitative studies (Meriam, 1998). Being a primary tool can affect the research process and research findings; thus, researcher should admit his role and bias to increase the understanding of the results of the study more clearly and to increase the trustworthiness of the study.

The concern for researcher existence in the context of the study was held by Patton (2002) by means of the researcher explanation of the degree of his participantness, revealedness, and extensiveness. The participantness ranges from full participant to complete observer and the participantness of the researcher of this study was a complete observer. The researcher did not participate in any teaching activity of the teacher and observed from back of the classroom.

As to the revealedness of the researcher, the participant teachers were informed about the observation and their permissions were obtained before collecting data. Observation was conducted during the teaching of genetics topic from the first week of October to the second week of the November in 2009. Observation started two weeks ago before the teaching of the genetics topic to make both teachers and students get used to the situation that is observed by a researcher. Moreover, there was not any data gathered before the observation of genetics topic. Field notes and voice recorder were employed to obtain genetics observation data.

Another concern for the role of researcher is intensiveness-extensiveness which Marshal and Roseman (2006) explained as the amount of the time daily used for investigation and the duration of the investigation. The aim of the first visit of the researcher in June 2009 was to invite teachers to participate in the study and the schedules of volunteer teachers were obtained during the first week of the for fall semester of 2009-2010 academic year. Afterwards, the demographic information of volunteer teachers were obtained during sampling procedure. The teaching observation of the topic of genetics and interviews were conducted and the data gathering process of this study took about one semester (about four months). The duration of time spent with teachers to obtain data both in the classroom and in other places helped to bring their PCK to light as much as possible. The role of the researcher was made clear and explained to the participants at the beginning of the study (Marshall & Roseman, 2006).

Before conducting this study, the researcher had some experiences in teacher education and PCK since 2004. In this manner, the researcher took graduate courses related to PCK. The researcher's master thesis was focused on content knowledge of science teachers on environment. The researcher also had an opportunity to meet weekly with Prof. Dr. Julie Gess-Newsome to discuss PCK between August 2010-August 2011. These meetings enriched the researcher's understanding on PCK and improved researchers' investigation skills. The researcher's personal conception of PCK was formed according to the aforementioned sources. In conducting the investigation, the researcher was aware of his bias.

3.8 Ethical Issues

The permission from Ministry of National Education was granted for this study in 2009-fall semester (Appendix E). These permissions are an official agreement that the study does not cause any potential harm to the participants and students. In the investigation, anonymity of participants and the schools were ensured. Moreover, teachers in the study accepted to participate voluntarily. Participants were informed about the purpose of the study. They were also informed they could quit the study, whenever they wish. To confirm confidentiality, pseudonyms were used to transcribing, analyzing, and presenting the data collected by observation, interviews and genetics test.

3.9 Limitation of the Study

There are some limitations in this study. Because this study is qualitative in nature, the transferability, in other words generalizability, of the findings of the study is limited with respect to quantitative studies. The participants are five science teachers, one male, and four females. The PCK was affected by factors related to teachers' characteristics (such as teaching experience, training on content knowledge and pedagogy they have received and similar background characteristics), students' characteristics, teaching context. The study focused on the genetics topics and some of the findings might not be generalized for the other topics in science. Besides, the study was conducted only in public schools and private schools were not included. The adopted PCK model in this study only included three components (knowledge of curriculum, knowledge of students, and knowledge of teaching strategies) out of five components of Magnusson et al.'s model (1999). Moreover, the PCK components were limited to the knowledge dimension and the other affective dimensions were not in the scope of this study. Each of these factors affected and limited the study findings to some extent, especially in transferability.

During observations, the presence of the researcher in the classroom is one of the limitations of the study. The observation was begun two weeks earlier than the actual data collection to minimize the effect of presence of observer in the classroom for teachers and students. Nevertheless, there might be influence of presence of observer inevitably. Observations of teachers' teaching were conducted for six weeks and whole data collections took around one semester. Since using video recorder in classrooms was not allowed by the school principals, observation was not conducted with video recorder and lack of videotaping of teachers' teaching is another limitation of the study. During observations, a voice recorder and field notes were employed to compensate the lack of video recording. The field notes included the visual aspects of the teaching environment such as the information on blackboard, classroom layout, and interaction between teacher-students and among students. The voice recordings were transcribed completely and transcription of voice recordings merged with field notes to provide more complete picture of observations. Thus, this kind of transcription helps to imagine how teaching occurred in the classroom.

Since participants' native language is Turkish, all data collection tools were prepared in Turkish and all data collection procedures were conducted in Turkish. For this reason, the used excerpts in the dissertations were translated into English from Turkish by the researcher. Translation procedure is another limitation of the study. To reduce this limitation, expert opinion was requested for the quality of the translation. Two experts both in qualitative research and in science education provided feedback during data analysis.

3.10 PCK Conceptualization in This Research

Due to the fact that there are different PCK models in the literature, the researcher have to select one or to form a hybrid model at the beginning of the study. Therefore, PCK conceptualization of the study was held.

In the conceptualization of the research, Magnusson et al.'s transformative PCK model was adopted with help of the literature (Abell, 2007; Grossman, 1990; Magnusson et al., 1999) and the data collected. Although Magnusson et al., (1999) mentioned both knowledge and belief in their PCK model only knowledge was focused on in this study. Moreover, I think that PCK is a new type of knowledge employed during planning and enacting. When trying to teach a topic to learners, a teacher reshapes and reorganizes content knowledge, pedagogical knowledge, and other knowledge types, which makes them a new form of knowledge that is PCK.

PCK model adopted in this study is modified version of Magnusson et al.'s model (Figure 2.5). As literature has said, although the boundaries between components are not clear, still using components helped researcher prepare the instruments, collect, and analyze the data. In Magnusson et al.'s model, the PCK components have five sub-components. In this study, only studied with three of components; knowledge of curriculum, knowledge of students, knowledge of teaching strategies. The orientations towards teaching science and knowledge of assessments components were not employed in the study.

The knowledge about science curriculum was the first subcomponents and it was named as briefly knowledge of curriculum in this study. This knowledge refer to the knowledge of goals and objectives for students in the subject they are teaching, besides the expression of those guidelines through the topics addressed during the educational year.

The second component was knowledge of students understanding of science and this component named as knowledge of students. Teachers' knowledge of students about genetics was analyzed under two dimensions in this study; namely knowledge of students' requirements and students' difficulties (Magnusson et al., 1999). The knowledge of students' requirements means that development of knowledge in a specific area needs prior knowledge and skills (Magnusson et al., 1999). A teacher should have this knowledge to help students to learn new topic appropriately. The knowledge of students' difficulties refers to teachers' knowledge of the science concepts that students find difficult to learn and this knowledge includes source of the students' difficulties (Magnusson et al., 1999).

The third component was knowledge of topic specific strategies. Knowledge of topic specific strategies is the strategies employed to help students comprehend specific science concepts. According to Magnusson et al.'s (1999) PCK model, this knowledge also has two categories: representations and activities. In this study these two categories represents knowledge of topic specific strategies.

The term "representation" refers to teachers' knowledge of ways to represent specific concepts or principles in order to facilitate students' learning (Magnusson et al., 1999). This knowledge includes teachers' ability to invent representation to aid students in developing an understanding of specific concepts or relationships. Teachers should also have knowledge about the relative strengths and weaknesses of a particular representation. Illustrations, examples, models, or analogies are the examples of representations. A topic specific example was about electricity circuit; water flowing through pipes and a bicycle chain (Magnusson et al., 1999).

The term "activities" refers to knowledge about activities that can be employed to help students comprehend specific concepts or relationships (Magnusson et al., 1999). This knowledge also includes knowledge of the conceptual power of a particular activity; it presents signals or clarifies important information about a specific concept or relationship. Problems, demonstrations, simulations, investigations, or experiments can be the examples of activities.

3.11 Timeline of the Study

A timeline indicating the order of events organized for the data collection is given in Table 3.14.

Table 3.14. Timeline of the Study

Date	**Events**
December 2008-March 2009	Design of the study
April 2009-September 2009	Development of the genetics test, Pre-PCK interview questions
May 2009- June 2009	Getting permission
June 2009- September 2009	Selection of the participants, Obtaining demographic data of the participants, Obtaining teaching schedule of the participants
July 2009-September 2009	Pilot study of genetics test, Pilot study of pre-PCK interview, Data analysis of pilot study, Evaluation of experts on instruments, Revision on the instruments in light of the pilot study, Preparation last version of instruments
September 2009-October 2009	Data collection of Genetics test and Pre-PCK interview,
September 2009-December 2009	Observation
September 2009-December 2009	Preparing observation data for post-PCK interview (transcription of voice recordings and field notes)
September 2009-August 2010	Preparing all data for analysis (transcription and using NVivo)
August 2010–December 2011	Data analysis
January 2012–January 2014	Writing results, conclusion, and discussion section

4. CHAPTER

FINDINGS

This chapter presents the results of the study regarding teachers' PCK components, namely, knowledge of curriculum, knowledge of students and knowledge of teaching strategies and their sub-components for each teacher. In this section, all of the data collected through genetics test, observations, and pre-PCK and post-PCK interviews were analyzed and presented.

In the following section, each case begin with the description of the teachers and description of each case includes teacher's main characteristics; such as area of undergraduate education, courses related to genetics and biology, pedagogy taken during undergraduate education, in-service education related to science and science education, their teaching experiences, professional experiences and other special experiences related to aim of this study. These characteristics of the cases were taken as the evidences about teachers' PCK and its components. Secondly, the cases were explained with their context in order to explain teachers' PCK components more clearly. For these reasons, there is also a need to mention other teaching context related factors like classroom size, students' general characteristics. The data for the description of the cases were combination of the interviews (see Appendix C) and observations (see Appendix B).

4.1 The Case of Beste

The description of Beste for PCK and the analysis of PCK components of Beste were presented.

4.1.1 Description of Beste

Beste had 22 years of teaching experience; 8 years as a biology teacher, 14 years as a science teacher. She graduated from biology department in the faculty of arts and sciences. Beste took biology and genetics courses during her undergraduate education. In order to get teacher certification, she took pedagogy courses from faculty of education while she was undergraduate student. After graduation, Beste took in-service education called "Studies on Biology Laboratory."

Beste had some experiences in her professional lifetime. One of her experiences was that she involved in science textbook writing committee of Board of Education (Talim Terbiye Kurulu) for writing of 6-8th grades science textbooks based on the 2000 and 2004 science curricula.

Beste described her book-writing experience as a two-year master education. She stated that:

> I was assigned to the Board of Education (Talim Terbiye Kurulu) to write science textbooks. It was really beneficial for me. I read many books on science and education both in Turkish and in English. It was a good experience for me; it was like a two-year master degree. We employed the Internet, even though the Internet sources were not widespread at that time. There were three teachers from the Turkish Education Association (Türk Eğitim Derneği) to help us and one teacher from the Students Selection and Placement Center (Öğrenci Seçme ve Yerleştirme Merkezi) in Turkey who checked the questions we prepared.
>
> My second book-writing experience was better than the first one. Some of the professors came from Gazi University and guided us while writing the book.

In addition, Beste had an experience on science textbook editing and she mentioned that this work helped her to gain editing skills. The related quotation was given below:

> I am still editing books on middle school science. Science textbook authors wrote and sent drafts of chapters to me for editing. I am also editing supplementary books (additional books to study science, not an official one). The editing process included the entire 6-8th grade science topics as well genetics. During book writing process at the Board of Education (Talim Terbiye Kurulu), we firstly worked on book writing and then we worked on editing the other books on middle school science written by private companies. Editing helps me to gain different capabilities such as criticizing or reviewing science content.

Her experiences also included teaching in cram school which is private teaching institution named Turkish as “dershane.” She explained her experience:

> I worked at cram school before the Board of Education (Talim Terbiye Kurulu) experience. Working at cram school contributed to my professional development. While working at there, I taught how to solve science problems in textbooks. Book writing makes you more knowledgeable; working as science teacher makes you experienced on teaching and working in cram school makes you an expert on problem solving. I also felt experienced on problem solving skill while teaching school, some of the students ask about science problems and you can solve their problems easily. You even recognize which the science problem belongs to which cram school. The Board of Education (Talim Terbiye Kurulu) experience contributed to my professional development with regard to improving in science content, and crams school contributed to increase in the aspect of teaching science problem solving.

When the physical classroom environment of Beste in public middle school was considered, her classroom had students’ desks, teacher’s desk, and whiteboard. School science laboratory had some technological devices including notebook, projector, and Internet connection. Student number in the classroom was 42. Beste mentioned that almost all of the students attended to cram school.

4.1.2 Beste’s Understanding about Genetics

In this section, the first research question “What is the science teacher’s understanding of genetics?” was analyzed. The science teachers understanding of genetics was evaluated with the help of genetics test (see Appendix A). The analysis of test presented with two main parts; understanding of genetics concepts and genetics crossing.

4.1.2.1 Understanding of Beste about the Genetics Concepts

The analysis of answers of Beste for the definition of seven genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous, see Appendix A) were given in Table 4.1.

Beste's definition of what a gene was "Gene is the hereditary information in the DNA of all living things specific to each character (the smallest genetics unit)." Her definition was considered as a reflection of partial understanding, and included matter within ontological category. The definition of Beste included only what a gene is "Gene is hereditary information…" however, her definition did not include information about the function of a gene for an organism according to scientific definition (see Table 3.5). In other words, although scientific definition of gene is in both matter and process category according to Chi et al. (1994), Beste's definition included only the information about matter category.

Table 4.1. Definition of the Genetics Concepts given by Beste

Concepts	Answer of Beste	Understanding of concepts		Ontological categorization	
		Partial	Sound	Matter	Process
Gene	Gene is the hereditary information in the DNA of all living things specific to each character (the smallest genetics unit).	✓		✓	
Dominant gene	The dominant gene prevents or masks the effect of other gene.	✓		✓	
Recessive gene	The recessive gene does not express its effect when exposed to dominant gene.	✓		✓	
Genotype	Genetics structure (for a character), gene composition.	✓		✓	
Phenotype	It is the reflection of one genetics trait possessed by the person.	✓			✓
Homozygous	If both of the gene characters affecting the gamete are same.	✓		✓	
Heterozygous	If one of the allele is recessive and the other is dominant, it is called heterozygous, or hybrid.	✓		✓	

Beste's definition of the dominant gene "The dominant gene prevents or hides of other gene effect." included some deficiency. In her definition, she mentioned dominant gene property as masking the recessive gene however, it is understood that dominant gene is defined as if it's role was to mask the effect of other gene. Her understanding of dominant gene was partial and the ontological categorization of her definition was considered, it is in matter category. In similar vein, the understanding for recessive gene was considered as partial. Her definition of recessive gene was "The recessive gene does not show its effect in the case of existence of dominant gene." Although she mentioned the effect of recessive gene masked by the dominant gene, the role of recessive gene and in which condition a recessive gene shows its effect were not included in her definition. Due to these deficiencies, the ontological categorization of Beste's definition of recessive gene was considered as matter category.

Beste's definition of genotype was "Genetically structure (for a trait), gene composition." Her understanding was accepted as partial for the concept of genotype. Because her definition only described the structure of genotype but it did not describe the role of genotype in determining the expression of a particular trait or trait phenotypes according to scientific definition (see Table 3.5). In other words, her definition of genotype did not include the information about function of genotype. For that reason, her definition was in matter category.

Beste's definition of phenotype was "It is reflection of outside appearance of a person for the owned genotype of a trait." Her definition of phenotype was reflection of a partial understanding because the expression of a phenotype depend on interaction of both genotype and environment, but her definition only focused on the genotype. Since the procedural explanation was included in her phenotype description, it was in the process category (Chi et al., 1994).

Beste defined homozygous as "If both of the gene characters affecting the gamete are same." She did not give any information about role of homozygous on phenotype. For this reason, the understanding of Beste according to scientific definition (see Table 3.5) was accepted as partial for homozygous and it was in matter category. She defined heterozygous as “If one of the allele is recessive and other is dominant, it is called as heterozygous, or hybrid.” Similar deficiency existed in her definition. For that reason, Beste’s understanding of heterozygous was accepted as partial. Her definition of heterozygous was also in matter category.

To sum up, Beste understanding about all genetics concepts was found as partial. Her ontological categorization results were generally revealed as matter category besides, phenotype concept definition was only in process category.

4.1.2.2 Beste’s Understanding about the Crossing

In the genetics test, the result of analysis related to a monohybrid-crossing question in genetics test was presented in this section. The result of Beste’s answers to crossing question was given in the Figure 4.1.

The answer of Beste for crossing question was considered as sound understanding according to expected answer of the crossing (see Figure 3.4 and Table 3.6). Beste correctly employed the information of dominant phenotype of the pea seed that has two-genotype probability. Beste thought that there could be two different genotype (homozygous dominant, AA and heterozygous, Aa) for dominant phenotype (yellow seed color for peas) and one genotype (homozygous recessive, aa) for recessive phenotype (green seed color for peas). Although Beste did not use genetics concepts like homozygous, heterozygous in her crossing, her answer included the correct usage of symbolization of genetics terms according to expected crossing answer.

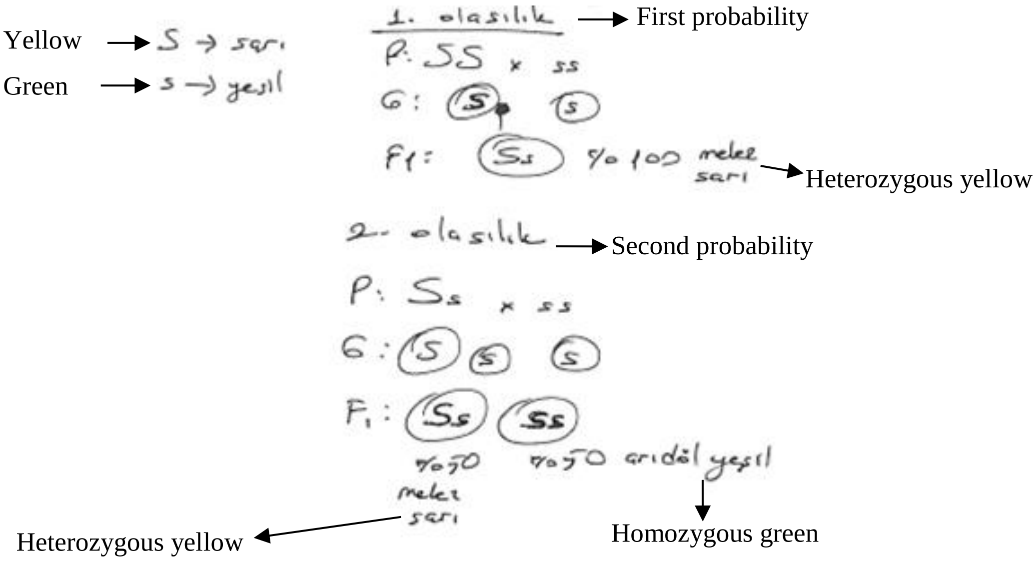


Figure 4.1. Beste's Answer for Crossing Question

4.1.3 The Nature of Beste's PCK Regarding the Topic of Genetics

In the second research question of the study "What is the nature of science teachers' PCK about genetics?" was investigated in this section. The result of the analysis of teachers' PCK was presented in three components with its sub-components.

i. Knowledge of curriculum,

ii. Knowledge of students

    a. Knowledge of students requirements
    b. Knowledge of students difficulties

iii. Knowledge of teaching strategies,

    a. Representations
    b. Activities
    c. Teaching strategies to overcome students' learning difficulties

4.1.3.1 Beste's Knowledge of Curriculum about Genetics

In this section, teachers' knowledge about the curriculum related to genetics concepts was investigated. Beste's knowledge of curriculum about genetics was evaluated with the help of pre-PCK interview (see Appendix C) and classroom observation. Result of pre-PCK interview about Beste's knowledge of curriculum was summarized in Table 4.2.

Table 4.2. Objectives Checklist for Beste's Answers for Curriculum Questions in the pre-PCK Interview

2006 Objectives Stated in Science Curriculum for Genetics Topic	Does teacher answer meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about the concept of gene.	✓		
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solve crossings problems related to inheritance of a single character.		✓	
2006 Limitations Stated in Science Curriculum for Genetics Topic			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	✓		
2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.		✓	
2006 Warnings Stated in Science Curriculum for Genetics Topic			
2.6. It should be stated that sex depends on sex chromosomes.	✓		

The results of interview with Beste revealed that she had sound curriculum knowledge. However, some of her answers for curriculum question in pre-PCK included non-curriculum parts. For example, her answer for the "What are the objectives related with crossing?" curriculum question in pre-PCK interview was

> …Students should learn inherited diseases such as colorblindness with XR and Xr by means of crossing. Students have difficulty in symbolizing with sex linked inherited diseases because students learn different symbolization during cram school (dershane), and school (pre-PCK Interview).

Her explanation not only included examples about inherited disease but also crossing about disease. She also mentioned sex-linked genetic disease during interview. However, neither curriculum nor science textbook includes anything related to sex-linked genetic disease. Only student textbook (Ministry of National Education, 2006) includes an example of sickle-cell disease once as an example of inherited disease crossing on page 17. Inherited disease example was only shown with AA (healthy person), Aa (carrier), aa (sick person) in the students textbook but does not include sex linked disease or X^RX^r. This finding displayed her deficiency in curriculum knowledge on regarding to objectives and limitations stated in the curriculum which are "2.6. Solves crossings problems related to inheritance of a single character." and about limitation "2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. are given as examples of inherited diseases."

On the other hand, in pre-PCK interview, Beste showed her knowledge about curriculum by categorizing the concepts, teaching strategies or activity as outside of the curriculum and she stated "it is not inside the curriculum" or similar sentences in her interview. The examples of Beste's curriculum knowledge statements were:

> I made detailed crossing, F1, F2, separate gametes etc. in my first years of teaching but I become aware of that it just makes difficult learning for students and it is not inside of the curriculum.
>
> Some students learn crossing like distributive property in mathematics from cram school (dershane) and this is neither inside of the curriculum nor in the textbooks.
>
> We never teach dihybrid, thrihybrid crossing in our lesson and curriculum did not emphasize them.

To conclude, Beste's knowledge of curriculum about genetics was also evaluated with classroom observation. The evaluation of curriculum knowledge for Beste's observation was given in Table 4.3.

Table 4.3. Objectives Checklist for Teaching of Beste's Observation

2006 Curriculum Objectives for Genetics Topic	Does teacher teaching meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene.	✓		
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solves crossings problems related to inheritance of a single character.	✓		
Limitation			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	✓		
2.6. Hemophilia, sickle cell anemia, color blindness, Down syndrome, etc. are given as examples of inherited disease.	✓		
Warning			
2.6. It should be stated that sex depends on sex chromosomes	✓		

According to Table 4.3, Beste showed sound curriculum knowledge for genetics topic in her teaching. Beste's teaching included 29 crossings problems and all of them were inside the curriculum. In addition, her teaching included some parts parallel to the teacher books content. She employed punnet square for crossing and gave human examples traits such as hair color, hair type in her teaching. These depicted that Beste was aware of teacher book's content. Moreover, one of the students employed "homozigot [as homozygous]" and "heterozigot [as heterozygous]" in the lesson and she corrected her students with "we do not employed these terms in our lesson but we use "arı döl" instead of "homozigot" [as homozygous] and melez döl instead of "heterozigot" [as heterozygous]." This explanation was a sign of Beste's knowledge of curriculum because neither curriculum nor textbook includes this terminology.

To conclude, Beste's knowledge of curriculum was found to be sound. Her interviews and observation data showed that some statements in interviews or implementations were not part of the curriculum. She had reasons for non-curriculum activities such as being able to meet students' curiosity.

4.1.3.2 Beste's Knowledge of Students about Genetics

In this section, teachers' knowledge about students in learning genetics concepts was investigated. Student knowledge was analyzed under two titles; requirements of students and difficulties of students while learning genetics topic.

4.1.3.2.1 Beste's Knowledge of Students' Requirements for Genetics

In this section, the requirements of students were presented with examples of teachers' responses. Teachers' knowledge of students' requirements for learning genetics was evaluated with the help of pre-PCK interview (see Appendix C). The dimensions appeared in data analysis of Beste's knowledge of students' requirements for genetics and examples of her response were shown in Table 4.4.

Beste emphasized that students require knowledge about meiosis and fertilization as scientific knowledge to understand the meaning of crossing symbols and crossing tasks. According to her, as a mathematical knowledge, students should know probability and fraction to explain crossing results. Moreover, she also mentioned that students should have prediction, problems solving and graphics reading skills for better understanding of genetics topic. Beste highlighted that some of the students were not mature enough to comprehend some genetics concepts clearly. In the literature of genetics (Lawson & Thompson 1988), it was highlighted this requirement and suggested that formal reasoning patterns were essential for sound understanding of genetics.

The results of data analysis of Beste depicted that she had sound knowledge of her students' requirements for genetics topic.

Table 4.4. Beste's Knowledge of Students' Requirements for Learning Genetics

Dimension of requirements	Requirements	Responses of Beste
Knowledge		
	Science	We taught genetics topic before teaching meiosis and fertilization. This causes a problem in teaching genetics. Because we could not mention that a germ cell produces gametes of an organism by means of meiosis. These gametes have only one pair of chromosomes. We have not taught meiosis and fertilization. Nevertheless, we have trouble in explaining crossing properly with this deficiency of basic knowledge. We could not explain clearly, what happens under the crossing and what the meaning of crossing symbols and steps are. We have to teach meiosis, fertilization prior to genetics unit. The curriculum topic sequence should be changed according to requirements of genetics (pre-PCK interview).
	Mathematics	The crossing results need knowledge about concepts of probability and fraction. If students do not know fraction or probability, they have trouble in understanding and writing result of crossing. When you said 2 over 4 equals to 1 over 2, student asks about how they are equal. On the other hand, you said 25 percent probability and they ask a similar question like why 25 percent. This causes difficulty in problem solving as well (pre-PCK interview).
Skills		
	Problem solving	Genetics was taught by problems. Students should know how to approach a problem to solve genetics problems as well (pre-PCK interview).
	Graphics reading	The curriculum developer wants to enable students to read graph. In genetics topic, students need to read graph (pre-PCK interview).
	Prediction	All genetics problem basically questioned what results is obtained after crossing or what kind of crossing should be made to obtain definite phenotype or genotype and both of them need prediction actually (pre-PCK interview).
Maturity		
	Formal-operational	When you tell the students "gene placed on DNA and has information about our phenotype." some of the students have difficulty in understanding because of abstractness of the concepts. I think some of them are even not mature enough to grasp for some genetics concepts (pre-PCK interview).

4.1.3.2.2 Beste's Knowledge of Students' Difficulties in Learning Genetics

In this section, the difficulties of students were presented with examples of teachers responses. Teachers' knowledge of students' difficulties while learning genetics was evaluated with the help of pre-PCK interview (see Appendix C) and observation of the course. The dimensions appeared in the data analysis of Beste's knowledge of students' difficulties while learning genetics and examples of her response were shown in Table 4.5.

Beste indicated that her students experience different kinds of difficulties while learning genetics. According to Beste, students had difficulty in understanding allele genes, in other words the same character having different dominant and recessive traits; for example, eye color is one character but it has two different traits; blue and dark. She stated: "Students confused about heterozygous genotype and hybrid person (mixed race or blood) [in Turkish both have same term "melez"]." The everyday experiences and usage of the terms were another sources of difficulties in learning biology (Tekkaya, 2002), it was similar usage of "fish" for dolphin in everyday language. Furthermore, Beste explained that students erroneously relate one character genotype with entire genotype of an organism, and they think that if a character is heterozygous, all character genotypes of that organism should be heterozygous. Moreover, this difficulty was noted in the literature (Knippels et al. 2005) as the students' difficulty in constructing relationship between different level of organism such as one part of a chromosome and entire organism.

Beste also mentioned that her students also had difficulty in the comprehending mechanism underlying the crossing. They thought the four result of crossing (e.g. AA, Aa, Aa, aa) representing the parents' order of their siblings and the first result of crossing (AA) should be born as the first and then so on.

Table 4.5. Beste's Knowledge of Students' Difficulties While Learning Genetics

Difficulties	Responses of Beste
Understanding	A character like eye-color has different traits, brown, and blue. Students think that if one character gene should be same for all how could be different type exist. For example, if it is an eye color gene, it should be only one type of gene such as brown, no other type of eye color should exist (pre-PCK interview).
Relationship	Students confused about heterozygous genotype and hybrid person (mixed race or blood) [in Turkish both has same term "melez"]. When we say melez, they also think that person all genotype is heterozygous, not one allele instead all the allele genes are heterozygous. For phenotype of melez [Turkish term of heterozygous], they think person should have shared character. For example, short plant has recessive and long plant has dominant genes and they think Aa heterozygous one should have middle length not long one (as dominant character). This also shows that dominant gene is not understood by students (post-PCK interview).
Crossing	Students interpret the crossing results differently. For example, we crossed two heterozygous brown-eyed and we got three brown and one blue-eyed child. Students think the first baby must be homozygous brown eyed child, the second and third one must be heterozygous brown eyed and fourth one must be blue eyed. They have a difficulty that the results showed just probability and each born baby has same probability to be blue eyed. May be the entire child, even four or five children, are blue eyed. One more thing, they think sometimes these take place in order. I mean first baby could not be blue eyed, and parents must wait to fourth baby to have blue-eyed one (pre-PCK interview).
Sources	
Concept	Students have never heard any one of the genetics concepts before. They did not know anything about heterozygous, homozygous etc. All of concepts are new for students. Moreover, there are many concepts. They did not hear anything previously and many new concepts cause difficulties for learning (post-PCK interview).
Representation	Students have difficulty to place on crossing arrows and I can say most of the students firstly write crossing results then put arrows. They confused arrow order. Sometimes they use arrow arbitrarily. They do not think it has meaning (post-PCK interview).
Students characteristics	Students or her/his relatives in classroom may have hereditary disease and you talked about hereditary disease or gave as an example. This may cause negative attitudes towards the topic. For this reason, I tried to be careful not hurt my students (pre-PCK interview).

Beste talked about the sources of these difficulties and she asserted that many new concepts should be learned in genetics topic, which causes difficulty for the students to understand. She explained in post-PCK interview another sources of students' difficulties that students could not use the arrows in crossing and they experienced the difficulty in following arrows to track crossing results and using arrows made the crossing procedure more complicated. In addition, Beste gave an example for students' characteristics as another source of difficulties. She explained this difficulty with an example that one of her students in her classroom had relative having hereditary diseases when she was teaching genetics. She felt her student became upset while giving examples about hereditary diseases. Based upon this experience, she suggested

> they should be very careful about students who might have relative having this kind of disease so as not to create negative attitude towards to the genetics topic, the teacher, and science as well.

The analysis and results of Beste's data depicted that she had sound knowledge of students' difficulties while learning genetics topic.

4.1.3.3 Beste's Knowledge of Teaching Strategies

Teacher knowledge about teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with two titles subject specific and topic specific teaching strategies.

4.1.3.3.1 Knowledge of Subject Specific Strategies

Beste did not use any noticeable subject specific teaching method such as learning cycle, discovery, inquiry or conceptual change oriented instruction, guided instruction, generative learning model and so on (Magnusson et al. 1999). She followed the sequence of the science textbook. She started with history of genetics with the help of a picture showing milestone developments in genetics. It was followed by a question “What are the similarities and dissimilarities in your family?” Then, Beste started to teach concepts of genetics and their representations or notations (homozygous, heterozygous, dominance, recessive, Aa). Afterwards, she explained crossing with systematically. She explained all representations and tasks comprehensively and answered each student’s questions while teaching crossing. She gave crossing examples and expected her students to solve the crossing questions. She or her students solved the questions on the blackboard. Beste’s sequence of the teaching continued with similar cycle of crossing questions and answers.

The main characteristic of Beste’s teaching was mostly teacher centered. On the other hand, she allowed her students to share their ideas and frequently asked topic related questions and she expected from her students to be active in the lesson, especially in problem solving, and giving ideas and examples about their lives however, these were not desired level.

4.1.3.3.2 Knowledge of Topic Specific Strategies

Teacher knowledge about topic specific teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with three headings as; representation, activities and employed strategies to overcome students’ difficulties, respectively. Teacher’s knowledge of teaching strategies was evaluated with the help of the pre-PCK interview (see Appendix C), observation of the course and the post-PCK interview.

4.1.3.3.2.1 The Representations Employed by Beste While Teaching Genetics

The data analysis for representation leads to three categories namely; "illustrations," "examples," and "analogies." The examples of employed representations by Beste while teaching genetics were shown in Table 4.6.

Beste employed Punnet square, one example of illustration of crossing in her lesson and she explained her preference with the students' difficulties as:

> Students have difficulty in matching crossing arrows with each other. Some of them even did not use any arrows in their crossings. They just wrote the results of the crossings… We do not use arrows in Punnet square…

For examples category, she preferred to use human traits to exemplify the genetic traits, and she said:

> [My] Students … live in urban areas … They have never seen any pea plants in their life, or flowers of pea plants. I prefer to use human traits to exemplify genetic traits.

Table 4.6. The Representations Employed by Beste While Teaching Genetics

Dimension of representations	Responses of Beste
Illustrations	Students have difficulty in matching crossing arrows with each other. Some of them even did not use any arrows in their crossings. They just wrote the result of crossing. I prefer to use Punnet square for crossing. We do not use arrows in Punnet square, and for this reason, it becomes less confusion. I asked them to draw 3x3 nine squares and we filled them with genotype of parents (post-PCK interview).
Examples	Students in our school live in urban areas and they have never seen different traits of peas such as yellow, or wrinkled. They have only seen green pea seed. They have never seen pea plant in their life, or flower of pea plant. I prefer to use human traits to exemplify genetic traits (post-PCK interview).
Analogies	I employed the analogy that genes are like pair of shoe. One piece of pair did not work well; you should have both of the shoe pair (post-PCK interview).

Beste also employed analogy in her teaching. For example, she employed shoe analogy to explain that genes should be in a pairs to work well correctly.

The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Beste has sound knowledge of representations to teach genetics concepts in order to facilitate students' learning.

4.1.3.3.2.2 The Activities Employed by Beste While Teaching Genetics

The activities employed by Beste while teaching genetics were problem solving about crossing, students' construction of their own pedigree, and using computer simulation for crossing (Table 4.7).

The problem solving about crossing was the main part of Beste's teaching of genetics. The problems employed by Beste were based upon the crossing type: (1) general crossing, (2) sex crossing, (3) hereditary disease, and (4) pedigree (see Table 4.7).

Beste assigned the homework of constructing own pedigree to her students. She expected from her students to select a trait and construct their own pedigree by tracking to this trait. Additionally, she employed computer simulation for crossing as an activity. This simulation activity was presented on the Vitamin website, offered by Ministry of National Education. For this activity, she brought all students to the science laboratory where computer, projector, and Internet connection existed. This activity enabled students to select the family and trait and then followed the generation traits. The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Beste had sound knowledge of activities to teach genetics concepts in order to facilitate students' learning.

Table 4.7. ***The Activities Employed by Beste While Teaching Genetics***

Type of activities	Observation data
Problem solving	General crossing problem - Cross two heterozygous brown eyed mother and father (brown eye color is dominant over blue eye color) (Observation). Sex crossing problem - A family is expecting a new baby, what is the probability of the sex of a baby, a girl or a boy? (Observation). Hereditary and pedigree problem - Determine phenotype and genotype of Mert's family on his pedigree. (Observation).
Pedigree construction	Select a trait and construct own pedigree (Observation).
Computer simulation	Computer simulation for crossing (Observation).

4.1.3.3.2.3 Teaching Strategies Employed by Beste to Overcome Students' Difficulties While Teaching Genetics

Teachers were asked what kind of strategies they employed to overcome students' learning difficulties while teaching genetics. Data on teaching strategies to overcome difficulties were obtained through drilling questions during pre-PCK and post-PCK interviews. The classification of learning difficulties and the respective teaching strategies employed by Beste were given in Table 4.8.

Beste stated that students had difficulties in understanding why the same trait had two different traits as dominant and recessive; dark and blue for eye color. When the employed strategy was asked during pre-PCK interview, she thought that it was not necessarily common difficulty. However, she employed the explanation to students that "dominant and recessive genes are totally different but are placed together in gene pairs which showed its effects on the eye colors." Beste just explained students' misconception about gene and allele.

For the heterozygous difficulties of students, Beste especially employed heterozygous-parents example to help students to understand the concept of heterozygous. The misconception source was everyday language and in the course teacher gave an explanation that

> In biology, we use heterozygous as a genotype including both dominant and recessive genes… Daily usage of melez [hybrid] did not correspond to the heterozygous in biology (Observation).

Table 4.8. Teaching Strategies Employed by Beste to Overcome Students' Difficulties While Teaching Genetics

Difficulties	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Understanding	Students have difficulty in understanding of same character having different dominant and recessive traits; for example, eye color is one character but it has two different traits, blue and dark. This difficulty comes from students who lack of knowledge or understanding of structure of chromosomes, gene pair, dominant gene and recessive genes… This is not so common difficulties… In my opinion, they think eye color controlled by a gene and how can be different color gene exists. One gene can control the eye color. This should be same for all people and same color for all people... This can remediate by helping them to understand dominant gene and recessive gene are different and placed together in gene pair while on body cell chromosomes, showed its effects on eyes (pre-PCK interview).
Relationship	Students wrongly relate one character genotype with entire genotype of organism and they think if a character is heterozygous, then all character genotypes of that organism should be heterozygous. I gave example of crossing both parents heterozygous to show them that it is possible to obtain recessive phenotype siblings from dominant phenotype parents by means of heterozygous genotype parents (post-PCK interview).
Crossing	Students have difficulty in mechanism underlying behind the crossing and they think the four result of crossing (e.g. AA, Aa, Aa, aa) represent the parents' order of their sibling and first result of crossing (AA) should be born as first then so on. When we cross and write all possibilities of new generation, students did not think these are the probabilities. They think they are children and order of the children. I explained that all of them happen again for a new baby and each of babies has the same probability to have genotype and phenotype probability (pre-PCK interview).

Table 4.8. Teaching Strategies Employed by Beste to Overcome Students' Difficulties While Teaching Genetics (Continued)

Sources	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Concept	Many new concepts should be learned in genetics topics this made difficult topic for students. We employed to teach in … homozigot [as homozygous], heterozigot [as heterozygous], dominant [as dominance] and other terms but in this curriculum these are not taught and we teach Turkish ones [arı döl as homozygous and melez döl as heterozygous]. However, students use heterozigot [as heterozygous] or other term in lesson because some students learn them during cram school (dershane) and they want to show their knowledge in the lessons… I correct students not to use these terms and say them we use Turkish term in our lesson (pre-PCK Interview).
Representation	Students could not follow the arrows in crossing and they experienced following arrows to find crossing results make more complicated the crossing procedure. Students have difficulty in matching crossing arrows with each other. Some of them even did not use any arrows in their crossings. They just wrote the result of crossing. I prefer to use Punnet square for crossing. We do not use arrows in Punnet square, and for this reason, it becomes less confusion. I asked them to draw 3x3 nine squares and we filled them with genotype of parents. If I did not ask them to draw nine squares, they would have difficulty in drawing. Otherwise, they would be counting the squares and this is time consuming... Moreover, Punnet square helps students to determine percentages of the result of crossing (post-PCK Interview).
Students characteristics	Students already have to learn many new concepts, knowledge, and laws. Students did not know the some plants and animals and their genetic traits. Unknown traits of animals or plants make the topic more difficult. I do not want to give pea traits as an example in the classroom. Students in our school live in urban area and they have never seen different traits of peas like yellow, or wrinkled. They only see green pea seed. They have never seen pea plant in their lives, or flower of pea plant. I prefer to use human traits as an example of genetic traits. In this crossing problem, I preferred to use eye color because our students are interested in eye color. Generally, they want to be blue eyed. Eye color attracts students' attention easily (post-PCK Interview).

Additionally, the heterozygous misconception was related to students' difficulty in constructing relationship between different level of organism such as one part of a chromosome and entire organism and she did not use any strategy for the students' difficulty to help them relate different level of organism.

Another students' difficulty that Beste mentioned was the interpretation of crossing results and probability in crossing. They thought the four result of crossing (e.g. AA, Aa, Aa, aa) representing the parents' order of their offspring. Her explanation to her students was that "For each new baby, the same process repeated and probability for a genotype and phenotype is same." In order to overcome students' misconception, Beste just explained about gene and allele and did not conduct any activity to explain the probability factor in crossing.

Being exposed to many new concepts in genetics at once was the one of the sources of learning difficulty for the students. She employed only the Turkish terms to lessen the confusion in concepts. She stated that her students found it difficult to follow crossing arrows and she preferred to use Punnet square instead of using arrows in her teaching of crossing. Other sources of difficulties were related to students' characteristics and she claimed that her students live in urban areas so they do not know genetic traits of many animals and plants. Accordingly, the use of unknown traits deepens the difficulty of students to learn genetics; therefore, she preferred to use human traits such as eye color. Moreover, she asserted that using eye color also attracted her students' attention to the topic.

To summarize; Beste generated and utilized special and different kinds of teaching strategies to help students to overcome difficulties while learning genetics topic. However, Beste showed limited knowledge on teaching strategies to overcome students' difficulties while teaching genetics.

4.2 The Case of Melis

The description of Melis for PCK and the analysis of PCK components of Melis were presented.

4.2.1 Description of Melis

Melis graduated from the chemistry department of science and arts faculty. Melis only took general biology and did not take any genetics courses during undergraduate education. During undergraduate education, Melis took pedagogy courses from faculty of educational as well. Her pedagogy course experience was as stated below:

> I took the pedagogy course in the faculty of education but I did not participate in this course properly. I did not learn anything about teaching during undergraduate education. All of my knowledge on teaching is based on 14-years of experiences and I learned this by doing.

Melis took two in-service courses named “Using Science Laboratory Tools and Equipment,” and “Science Education.” Moreover, Melis stated that she did not feel sufficient on experiments:

> Science teachers should be capable of experiments. I do not perceive myself as a capable one. For this reason, I attended the in-service education on Using Science Laboratory Tools and Equipment.

Melis had one and half years’ experience as an elementary teacher, twelve and half years as a middle school science teacher, a total of 14 years teaching experience. Her first teaching experience was on cram school as a chemistry teacher for one year before being assigned as an elementary teacher.

Melis’s classroom was not equipped with technology and it contained student’s desks, teacher’s desks, and blackboard. School had a well-equipped laboratory and the laboratory was equipped with technological devices: like notebook, projector, and Internet connection in addition to usual science laboratory equipment. She had 32 students and her students generally had low to middle level socio economic status. Around half of her students attended cram school education besides school education.

4.2.2 Melis's Understanding about Genetics

The analysis of understanding of genetics was presented with two main parts; understanding of genetics concepts and genetics crossing.

4.2.2.1 Understanding of Melis about the Genetics Concepts

The analysis of answers of Melis for the definition of seven genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous, see Appendix A) were given in Table 4.9.

Melis's definition of what a gene was "It is the part of chromosome carrying hereditary traits (Each one responsible for a particular trait.)." Her definition was considered as sound understanding according to scientific definition (see Table 3.5). Her definition of Melis included both structure of a gene by stating "It is the part of chromosome carrying hereditary traits." and function of a gene by stating "(Each one responsible for a particular trait)." Moreover, Melis's definition of the gene was the process category within the ontological category according to Chi et al. (1994) due to the presence of process explanation in her definition.

She defined dominant gene as "The gene that has more probability to emerge or to be reflected in phenotype." and recessive gene as "The gene that has less probability to appear in phenotype." In both definitions, she were focused on the probability. Although her definitions included some parts of scientific knowledge, her understandings of dominant and recessive genes were accepted as partial as a consequence of deficiencies which the trait of dominant gene such as masking effect and the trait of recessive gene such as the homozygous genotype conditions to appear in phenotype were not stated. Both of the definitions were also in matter category since they did not explain any function of dominant and recessive genes in conjunction with genotype and environment.

Table 4.9. Definition of the Genetics Concepts given by Melis

Concepts	Answer of Melis	Understanding of concepts		Ontological categorization	
		Partial	Sound	Matter	Process
Gene	It is the part of chromosome carrying hereditary traits. (Each one responsible for a particular trait)		✓		✓
Dominant gene	The gene that has more probability to emerge or to be reflected in phenotype.	✓		✓	
Recessive gene	The gene that has less probability to appear in phenotype.	✓		✓	
Genotype	Sequence of genes; the scientific statement of genes in the form of letters for homozygous or heterozygous.	✓		✓	
Phenotype	The appearance of a living being with the help of genes or environmental conditions.		✓		✓
Homozygous	It is any trait (coming from mother and father) that has the same feature. For example, a tall person getting tallness from both father and mother.		✓		✓
Heterozygous	These genes with the same trait but different attributes one coming from mother and the other from father. (For example; if a tall person got tallness from both mother and father, this trait is heterozygous.)	✓			✓

For genotype, Melis's understanding was considered as partial because her definition only included sequence of genes and notation of genes. Her definition was deficient about genotype trait, for example, genotype is the entire set of gene in an individual and has a role on determining phenotype of a trait. Since there was a deficiency to explain the function of genotype, her ontological categorization of genotype was in matter category. On the other hand, Melis's definition of phenotype was accepted as a reflection of sound understanding and the ontological category of her phenotype definition was process category because her definition included information of appearance as a result of the interaction of its genotype and the environment.

Melis defined both of homozygous and heterozygous concepts as the trait coming from father and mother. This explanation was related to the mechanism of hereditary. For this reason, ontological categorization of both concepts was process category. Although homozygous definition was considered as sound understanding, heterozygous definition included some deficiencies. For example, she stated different trait come from father and mother but she also stated same traits from both father and mother by providing example. For this reason, her understanding of heterozygous was considered as partial.

Briefly, Melis's understanding about three genetics concepts (gene, phenotype and homozygous) out of seven concepts was found as sound and the ontological categorization analysis of the concepts was resulted as four genetics concepts (gene, phenotype, homozygous and heterozygous) as in the process category.

4.2.2.2 Melis's Understanding about the Crossing

In the genetics test, the result of analysis related to a monohybrid-crossing question in genetics test was presented in this section. The result of Melis's answers to crossing question was given in Figure 4.2.

The answer of Melis for crossing question was considered as sound understanding according to expected answer for the crossing (see Figure 3.4 and Table 3.6). Melis correctly employed the information of dominant phenotype of the pea seed that has two-genotype probability. Melis thought that there could be two different genotypes (homozygous dominant, SS and heterozygous, Ss) for dominant phenotype (yellow seed color for peas) and one genotype (homozygous recessive, ss) for recessive phenotype (green seed color for peas). Although Melis did not use all genetics concepts like dominant, recessive, homozygous in her crossing, her answer included the correct usage of symbolization of genetics terms according to expected crossing answer.

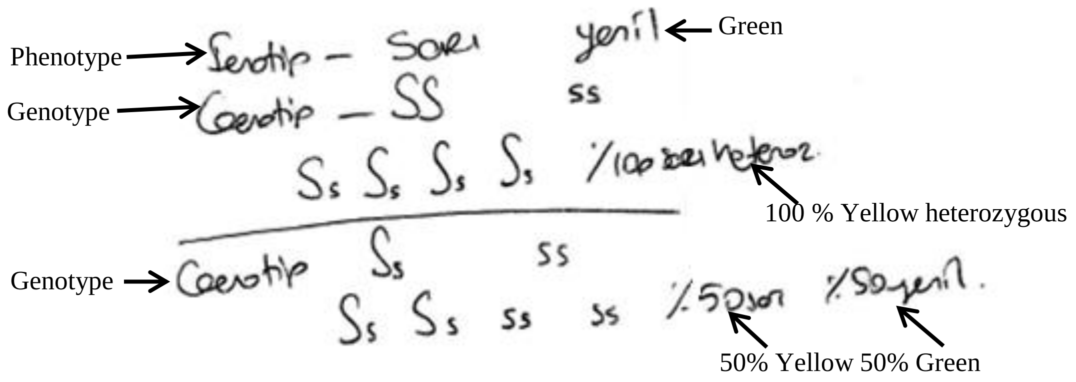


Figure 4.2. Melis's Answer for Crossing Question

4.2.3 The Nature of Melis's PCK Regarding the Topic of Genetics

The result of the analysis of Melis's PCK was presented in three components with its sub-components.

4.2.3.1 Melis's Knowledge of Curriculum about Genetics

In this part, teachers' knowledge about the curriculum related to genetics concepts was investigated. Melis's knowledge of curriculum about genetics was evaluated with the help of pre-PCK interview (see Appendix C) and classroom observation of the course. Result of pre-PCK interview about Melis's knowledge of curriculum was summarized in Table 4.10.

The results of interview with Melis revealed that she had limited curriculum knowledge. She did not have sound knowledge on curriculum objectives including "2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.", "2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.", "2.6. It should be stated that sex depends on sex chromosomes."

Table 4.10. Objectives Checklist for Melis's Answers for Curriculum Questions in the pre-PCK Interview

2006 Objectives Stated in Science Curriculum for Genetics Topic	Does teacher answer meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about the concept of gene.	✓		
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solve crossings problems related to inheritance of a single character.		✓	
2006 Limitations Stated in Science Curriculum for Genetics Topic			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.		✓	
2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.			✓
2006 Warnings Stated in Science Curriculum for Genetics Topic			
2.6. It should be stated that sex depends on sex chromosomes.		✓	

Her curriculum knowledge was mainly based on the textbooks and she could not directly address the curriculum objectives during the interviews. For instance, she stated that

> These concepts [genetics concepts] are in the curriculum because they are in the textbook. I am teaching these concepts in the classrooms and teaching genetics crossings.

She was also uncertain about the scope of the curriculum because her statements included some information that is not presented in the 8th grade science curriculum. For example, she thought that crossing on hereditary disease is presented in the curriculum but in reality, it is not. Her excepts was

> Crossing problems are taking important part in my teaching; I am teaching all types of crossings, not only sex crossing but also hereditary disease crossing…. I gave importance to teaching different types of crossings because students have to solve them in the national exam.

Similarly, she stated that she employed both Turkish and Latin genetics terms together ("arı döl" and "homozigot" for [homozygous]), and she was teaching Mendel laws, even though these were not presented within the scope of the curriculum.

Melis's knowledge of curriculum about genetics was also evaluated with classroom observation. The evaluation of curriculum knowledge for Melis's observation was given in Table 4.11.

According to Table 4.11, Melis showed limited curriculum knowledge for genetics in her teaching, since she taught her students both hereditary disease crossings and sex-linked genetic disease crossings. Her teaching included 37 crossings problems, nine of which were not stated in the science curriculum. She violated curriculum objectives of "2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.", "2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.", and "2.6. It should be stated that sex depends on sex chromosomes." She explained that

> How much they learn in school is beneficial for the students, even it is beyond the curriculum. I teach them so as to expand my students understanding as much as possible. In addition, I remember the exam [national exam] includes this kind of questions.

Table 4.11. Objectives Checklist for Teaching of Melis's Observation

2006 Curriculum Objectives for Genetics Topic	Does teacher teaching meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene.	✓		
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solves crossings problems related to inheritance of a single character.		✓	
Limitation			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.		✓	
2.6. Hemophilia, sickle cell anemia, color blindness, Down syndrome, etc. are given as examples of inherited disease.			✓
Warning			
2.6. It should be stated that sex depends on sex chromosomes		✓	

Melis's teaching included some other examples of non-curriculum implementations. For example, she followed the Mendel laws order while teaching the crossings, and she taught both Turkish and Latin terms for the same genetics concept (both “arı döl” and “homozigot” for [homozygous]).

Melis's knowledge of curriculum was found to be limited. Her interviews and observation data showed that some statements in the interviews or the classroom implementations were not related to the curriculum. On the other hand, since she followed same topic sequence as in the textbook in his teaching, her teaching was mainly appropriate to the curriculums.

4.2.3.2 Melis's Knowledge of Students about Genetics

In this section, teachers' knowledge about students in learning genetics concepts was investigated. Student knowledge was analyzed under two titles; requirements of students and difficulties of students while learning genetics topic.

4.2.3.2.1 Melis's Knowledge of Students' Requirements for Genetics

The dimensions appeared in data analysis of Melis's knowledge of students' requirements for genetics and examples of her response were shown in Table 4.12.

According to Melis, students require scientific knowledge about "DNA, genetic code, meiosis and fertilization to be able to explain genotype with mechanism of genetic code." She changed the order of textbook topics while teaching genetics to be able to meet students' science knowledge requirements. The book order and Melis's topic order were given in the Table 4.13.

Table 4.13. Unit Title Order

Textbook unit title plan	Melis unit title plan
Unit 1. Cell division and Genetic	Unit 1. Cell division and Genetic
1. Mitosis	1. DNA and genetic code
2. Genetics	2. Mitosis
3. Meiosis	3. Meiosis
4. DNA and genetic code	4. Genetics
5. Adaptation and evolution	5. Adaptation and evolution

According to Melis, students need to have mathematical knowledge about probability to solve crossing problems besides scientific knowledge. She underlined that graphical reading, prediction and problem-solving skills were a prerequisite to solve crossings problems especially in the national exam. As stated by Melis, particularly the abstract genetics concepts (e.g. genotype) and the steps of crossing were beyond the students' comprehension. The results of data analysis of Melis depicted that she had sound knowledge of her students' requirements for learning genetics.

Table 4.12. Melis's Knowledge of Students' Requirements for Learning Genetics

Dimension of requirements	Requirements	Responses of Melis
Knowledge		
	Science	Prior to learning genetics, students should know cell divisions and fertilization; otherwise students have difficulty in understanding genetics (pre-PCK interview). They need to know DNA, genetic code, meiosis and fertilization to be able to explain genotype with mechanism of genetic code and DNA (pre-PCK interview).
	Mathematics	Most of the crossing problems are related to the probability of a phenotype or a genotype and students should state the result of a crossing in probability terms to solve the problems. They have to know probability before learning genetics (pre-PCK interview).
Skills		
	Problem solving	To solve a crossing problem, students have to know not only scientific knowledge but also how to approach a problem. If they do not approach a problem appropriately, they cannot solve it (pre-PCK interview).
	Graphics reading	The exam committee likes to ask genetics problem in a pedigree. They have to learn how to read information from a pedigree to solve the pedigree problems in the exam (pre-PCK interview).
	Prediction	When problem asked for the dominant phenotype, students have to predict the probabilities of the genotypes (pre-PCK interview).
Maturity		
	Formal-operational	A 20-year-old man even cannot imagine what happens behind the steps of crossing. We are teaching 13/14-year-old students and they are not mature enough to comprehend concretely what happens during crossing (pre-PCK interview). I already mentioned about DNA, genetic code, meiosis and reproduction. Using this knowledge, I can explain genotype with mechanism of genetic code and DNA. Even this explanation for mechanism is a little too abstract for the age of the students (post-PCK interview).

4.2.3.2.2 Melis's Knowledge of Students' Difficulties in Learning Genetics

In this section, the difficulties of students were presented with examples of teachers responses. Teachers' knowledge of students' difficulties while learning genetics was evaluated with the help of pre-PCK interview (see Appendix C) and observation of the course. The dimensions appeared in data analysis of Melis's knowledge of students' difficulties while learning genetics and examples of her response were shown in Table 4.14.

Melis indicated that her students have different kinds of difficulties while learning genetics. According to Melis, students had difficulty in determining which traits are inherited characters. Melis stated that the steps of crossing do not have clear meaning for her students and transferring the result of crossings in daily life is another difficulty of her students. According to Melis, her students experience difficulty in comprehensive understanding of genetics concepts because students did not have prior experience with genetics concepts and these concepts are generally abstract and unfamiliar for her students. it is showed that formal reasoning patterns are essential for sound understanding of genetics concepts having abstract nature. Melis also stated that the learning style and students' preferences were the other factors influencing students learning of genetics.

On the other hand, there were other kinds of difficulties which students face while learning genetics (such as learning a great number of concepts in genetics topic, genotype, heterozygous genotype, hereditary disease crossings especially sex-linked one and so on) were not mentioned by Melis during her interviews. The analysis and results of Melis's data depicted that she had limited knowledge of students' difficulties while learning genetics topic.

Table 4.14. Melis's Knowledge of Students' Difficulties While Learning Genetics

Difficulties	Responses of Melis
Understanding	Students already have difficulty in differentiating which traits are inherited (pre-PCK interview).
	Students have difficulty to distinguish dominant and recessive concepts. For example, they think common traits should be dominant and rare traits should be recessive (post-PCK interview)
Relationship	Students experience a great difficulty in understanding the process of transition of genetic traits; they could not differentiate which relatives could be responsible in transfer of a specific trait among relatives. For example, they sometimes think spouses' maternal aunts are a genetic relative (post-PCK interview).
Crossing	During crossing, students have difficulty in giving meanings to steps of crossing. They do not think that we are actually talking about meiosis while we are separating gametes (pre-PCK interview).
	Some of the genes for traits are not reflected in a person's phenotype. You can carry some of genes of the traits as a heterozygous person and you do not need to be amazed when you see these gene characters from your offspring. For example, I experienced this. A father and a mother are brown-eyed people but they have a blue-eyed child. We may not interpret the situation differently. Nevertheless, children can interpret this differently in their life and misunderstand it (pre-PCK interview).
Sources	
Concept	Students can find some genetics concepts such as genotype as an abstract and an unfamiliar concept. When I explain phenotype, I mention phenotype can be seen by the eye. They can see and explain phenotype by looking at the any animal phenotype. They cannot see genotype outside by the naked eye. Genotype is a fact that you cannot see outside… by stating an unfamiliar concept, they have never heard genotype concept before. It is fact that they did not hear genotype in daily life. They can see phenotype by looking each other but I cannot show genotype to them visually and it is difficult to find it in their daily life (post-PCK interview).
Representation	Students have difficulty to distinguish homozygous and heterozygous notation in letter, especially homozygous one because there are two homozygous genotype; dominant [AA] and recessive [aa] one (post-PCK interview).
Students characteristics	These ages of students easily distracted from the lesson. The genetics topic is difficult topic and their attention was easily distracted from the lesson (post-PCK interview).
	The genetics topic is abstract and just telling the concepts and relationship is not enough in my opinion (post-PCK interview).

4.2.3.3 Melis’s Knowledge of Teaching Strategies

Teacher knowledge about teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with two titles subject specific and topic specific teaching strategies.

4.2.3.3.1 Melis’s Knowledge of Subject Specific Strategies

Melis, similar to Beste, did not use any noticeable subject specific teaching method such as learning cycle, discovery, inquiry or conceptual change oriented instruction, guided instruction, generative learning model and so on (Magnusson et al. 1999). In her teaching, she followed the sequence of the science textbook. She started with history of genetics with the help of a picture showing milestone developments in genetics. It was followed an assignment “What are the similarities and dissimilarities in your family?” Then, Melis started to teach concepts of genetics and their representations or notations (homozygous, heterozygous, dominance, recessive, Aa). Afterwards, she explained crossing step by step. She explained all representations and steps comprehensively and answer each student’s questions while teaching crossing. She gave crossing examples and expected from her students to solve the crossing questions. She or her students solved the questions on the blackboard. Melis’s sequence of the teaching continued with similar cycle of crossing questions and answers. She solved a total of 37 crossings problems while teaching genetics topic.

The main characteristic of Melis’s teaching was mostly teacher centered; but, she sometimes allowed her students to share their ideas and frequently asked topic related questions. Melis expected from her students to share their ideas, especially in problem solving, gave examples from their lives.

4.2.3.3.2 Melis's Knowledge of Topic Specific Strategies

Teacher knowledge about topic specific teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with three headings as; representation, activities and employed strategies to overcome students' difficulties, respectively. Teacher's knowledge of teaching strategies was evaluated with the help of the pre-PCK interview (see Appendix C), observation of her lesson and the post-PCK interview.

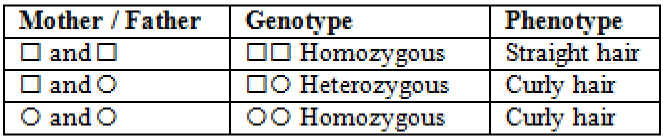
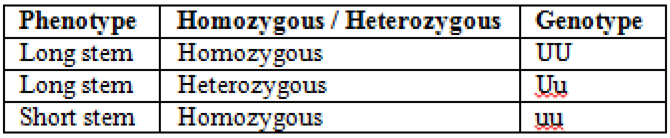
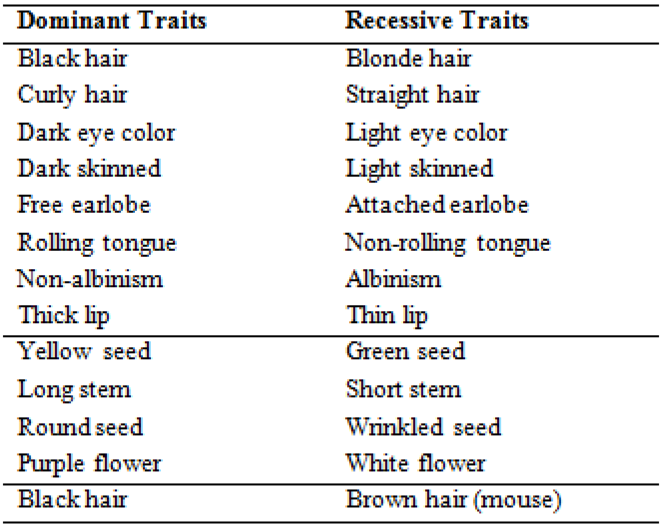
4.2.3.3.2.1 The Representations Employed by Melis While Teaching Genetics

The teaching strategies were covered under in three sub-titles, the first one related with representation, and the data analysis for representation lead to three categories namely; "illustrations," "examples," and "analogies." The examples of employed representations by Melis while teaching genetics were shown in Table 4.15.

Her illustrations was dominated by tables, she employed table in each part of her teaching. She stated: "I learn easily with table and my students, in my opinion, learn better with table." Most of the time, she employed letters for teaching genotype and crossings, but she employed circle and square for showing dominant and recessive traits respectively (Curly hair O, Straight hair □). She explained her aim as to reach different students who are visual learners. She also tabulated the notations of genotype of phenotypes and she employed this table to help students to see how to make notations of genotype and to see the probabilities.

In her lesson, she employed different living beings examples (pea, mouse, human and so on), and she drew a table to exemplify genetic traits to her students in the classroom. These traits were mainly related with human and human appearance. When selection of example was asked during the post-PCK interview, she responded:

Table 4.15. The Representations Employed by Melis While Teaching Genetics

<table>
<tr><th>Dimension of representations</th><th>Responses of Melis</th></tr>
<tr><td>Illustrations</td><td>She gave a table with different notation for genotype while teaching heterozygous and homozygous. Circle was employed for dominant and a square was employed for recessive traits. (Curly hair→ O, Straight hair→ ☐)

<table>
<tr><th>Mother / Father</th><th>Genotype</th><th>Phenotype</th></tr>
<tr><td>☐ and ☐</td><td>☐☐ Homozygous</td><td>Straight hair</td></tr>
<tr><td>☐ and ○</td><td>☐○ Heterozygous</td><td>Curly hair</td></tr>
<tr><td>○ and ○</td><td>○○ Homozygous</td><td>Curly hair</td></tr>
</table>
(Observation).
She presented homozygous-heterozygous genotype with following table

<table>
<tr><th>Phenotype</th><th>Homozygous / Heterozygous</th><th>Genotype</th></tr>
<tr><td>Long stem</td><td>Homozygous</td><td>UU</td></tr>
<tr><td>Long stem</td><td>Heterozygous</td><td>Uu</td></tr>
<tr><td>Short stem</td><td>Homozygous</td><td>uu</td></tr>
</table>
and she employed tables frequently in her teaching (Observation).</td></tr>
<tr><td>Examples</td><td>She drew the following table to exemplify genetic traits to her students in the classroom. The traits are mainly related with human appearance.

<table>
<tr><th>Dominant Traits</th><th>Recessive Traits</th></tr>
<tr><td>Black hair</td><td>Blonde hair</td></tr>
<tr><td>Curly hair</td><td>Straight hair</td></tr>
<tr><td>Dark eye color</td><td>Light eye color</td></tr>
<tr><td>Dark skinned</td><td>Light skinned</td></tr>
<tr><td>Free earlobe</td><td>Attached earlobe</td></tr>
<tr><td>Rolling tongue</td><td>Non-rolling tongue</td></tr>
<tr><td>Non-albinism</td><td>Albinism</td></tr>
<tr><td>Thick lip</td><td>Thin lip</td></tr>
<tr><td>Yellow seed</td><td>Green seed</td></tr>
<tr><td>Long stem</td><td>Short stem</td></tr>
<tr><td>Round seed</td><td>Wrinkled seed</td></tr>
<tr><td>Purple flower</td><td>White flower</td></tr>
<tr><td>Black hair</td><td>Brown hair (mouse)</td></tr>
</table></td></tr>
</table>

> the characters on the table were selected because student sees hair color, eye color, height etc., in their daily life. Students at this age generally give importance to their appearance and the traits related to appearance, then they were more interested in the topics.

She did not use any analogies while teaching concepts and crossing. The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that her representation generally dominated by tables. Melis had limited knowledge of representations to teach genetics concepts in order to facilitate students' learning.

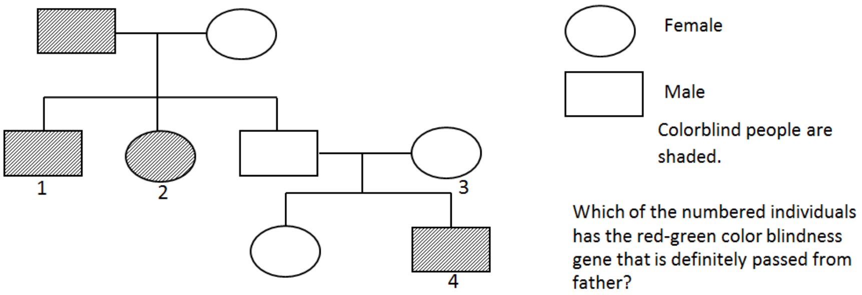
4.2.3.3.2.2 The Activities Employed by Melis While Teaching Genetics

The activities employed by Melis while teaching genetics were problem solving about crossing, students' construction of their own pedigree, and assignments (Table 4.16).

The problem solving about crossing dominated to the other teaching activities of Melis and her lesson included 37 genetics problems. The problems employed by Melis were composed of various crossing types: general crossing, sex, hereditary disease, and pedigree (Table 4.16).

During teaching phenotype, Melis described her phenotype and then she expected from her students to describe their phenotypes. This activity aimed to make concrete and familiarize the genetics concepts. In one of her assignment, she expected to from her students to make an observation to find out similarities and differences in their parents' phenotypes. This activity help students to identify the genetic traits. In other assignment students were required to make the Internet search about genetic disease and share their findings with classroom. The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Melis activities were dominated by problem solving and her knowledge of activities was limited.

Table 4.16. The Activities Employed by Melis While Teaching Genetics

Type of activities	Observation data
Problem solving	General crossing problem - When cross homozygous wrinkled peas and round peas (round pea is dominant over wrinkled pea), what fraction is expected to be round pea? (observation). Sex crossing problem – A family is expecting their third baby, what is the probability of the sex of a baby, a girl or a boy? (Observation) Hereditary disease and pedigree problem - Color blindness is an inherited trait as a sex-linked recessive. Which of the numbered individuals in the pedigree below has the red-green color blindness gene that is definitely passed from father? 
Description of my phenotype	Melis described her phenotype as "Middle height, brown hair, light eye color, light skin color, curly hair is my phenotype" while teaching phenotype. Then, she asked to students: "tell us about your phenotype"
Assignments	What similarities and differences do you have in your family? (Observation) Search the Internet to find out "What are the genetic diseases?" and share your findings in the classroom.

4.2.3.3.2.3 Teaching Strategies Employed by Melis to Overcome Students' Difficulties While Teaching Genetics

The classification of learning difficulties and the respective teaching strategies employed by Melis were given in Table 4.17.

Table 4.17. Teaching Strategies Employed by Melis to Overcome Students' Difficulties While Teaching Genetics

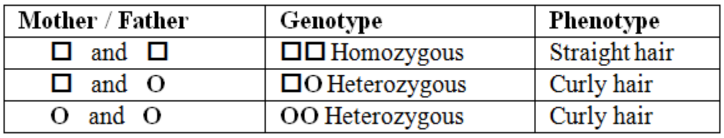
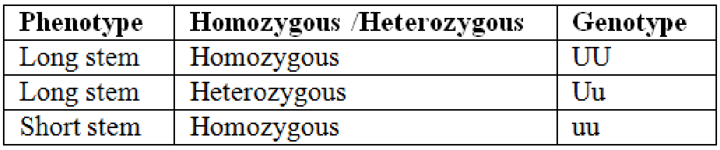
<table>
<tr><th>Difficulties</th><th>Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics</th></tr>
<tr><td>Understanding</td><td>Students have difficulty in differentiating which traits are inherited (pre-PCK interview).</td></tr>
<tr><td></td><td>Students already have difficulty in separation which character is inherited characters. I gave assignment "What similarities and differences do you have in your family?" and they share their genetic traits in classroom. With the help of this assignment, they can easily identify and differentiate genetic traits (post-PCK interview).</td></tr>
<tr><td></td><td>Students show confusion in differentiating of dominant and recessive. For example, they think common traits should be dominant and rare traits should be recessive (post-PCK interview)</td></tr>
<tr><td></td><td>The assignments "What similarities and differences do you have in your family?" also help students to overcome this difficulty. They can see there is no relationship between prevalence and dominancy. I also underlined this in my teaching (post-PCK interview).</td></tr>
<tr><td>Relationship</td><td>Students experience great difficulty in understanding the process of transition of genetic traits, they could not differentiate which relatives could be responsible in the transfer of a specific trait among relatives. For example, they sometimes think spouses' maternal aunts are a genetic relative (post-PCK interview).</td></tr>
<tr><td></td><td>I started teaching genetics with an assignment "What similarities and differences do you have in your family?" and this assignment may help them to recognize the genetic relative. I also teach my students how to read pedigree and we have to track genetic relative to reach the solution of each genetics problem asked in a pedigree (post-PCK interview).</td></tr>
<tr><td>Crossing</td><td>Students have a difficulty in giving meaning to steps of crossing and they cannot think the crossing tasks refer to meiosis or fertilization.</td></tr>
<tr><td></td><td>While I am teaching crossing, I teach each steps slowly try to explain the meaning of each steps. I also repeat the meaning of steps in almost every crossing problem. For example, the crossing Aa x Aa, I stated that we separated the gametes of them; many times I said this steps means to meiosis. One A came from father and one A came from mother to compose AA, each crossing I say this and this steps represent the fertilization (post-PCK interview).</td></tr>
<tr><td></td><td>She employed father and mother gene statements in following table.
Circle was employed for dominant and a square employed for recessive traits (Curly hair→ O, Straight hair→ ☐) She employed mother and father to compose genotype.
<table>
<tr><th>Mother / Father</th><th>Genotype</th><th>Phenotype</th></tr>
<tr><td>☐ and ☐</td><td>☐☐ Homozygous</td><td>Straight hair</td></tr>
<tr><td>☐ and O</td><td>☐O Heterozygous</td><td>Curly hair</td></tr>
<tr><td>O and O</td><td>OO Heterozygous</td><td>Curly hair</td></tr>
</table>(Observation).</td></tr>
</table>

Table 4.17. Teaching Strategies Employed by Melis to Overcome Students' Difficulties While Teaching Genetics (Continued)

<table>
<tr><th>Sources</th><th>Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics</th></tr>
<tr><td>Concept</td><td>The abstractness and unfamiliarity of genetics concepts especially genotype cause the difficulty while learning genetics (pre-PCK interview).

I already mention about DNA, genetic code, meiosis and reproduction. Using this knowledge, I explained genotype with mechanism of genetic code and DNA. Even this explanation of mechanism is a little abstract for the age of the students. I started the lesson with family traits and similarity and dissimilarity with family. I employed this for explanation of the genotype, especially with traits, which parents do not have, but other relatives (grandmother, grandfather) have may help to make it clear. I also have to give the dictionary definition of genotype to students (post-PCK interview).</td></tr>
<tr><td>Representation</td><td>Students experience difficulty in notation of a genotype of a person having dominant phenotype (pre-PCK interview).

The source of the problem was dominant phenotype (for example brown-eyed person) can have two different genotypes (homozygous dominant-AA, or heterozygous-Aa). Students may not think when see the dominant phenotype person may be a heterozygous or a homozygous dominant. When I asked the brown-eyed person genotype, they just stick one genotype and this is generally homozygous dominant-AA. To overcome this difficulty, I teach the phenotype-genotype notation in a table and I strictly underlined dominant phenotype has two different genotypes (post-PCK interview).

She presented homozygous-heterozygous genotype with following table

<table>
<tr><th>Phenotype</th><th>Homozygous /Heterozygous</th><th>Genotype</th></tr>
<tr><td>Long stem</td><td>Homozygous</td><td>UU</td></tr>
<tr><td>Long stem</td><td>Heterozygous</td><td>Uu</td></tr>
<tr><td>Short stem</td><td>Homozygous</td><td>uu</td></tr>
</table>
(Observation).

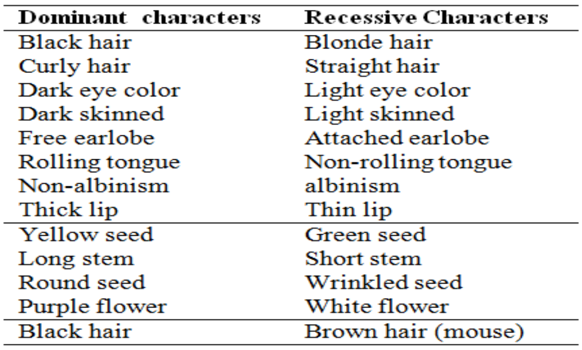
Students can confuse about homozygous and heterozygous notation in letter, especially homozygous one because there are homozygous dominant and homozygous recessive (post-PCK interview)

I teach the phenotype-genotype notation in a table. While teaching the table, I put emphasis on table content detailed and underlined each phenotypes, genotypes, notations, and probability. I insist on two homozygous and one heterozygous as well (post-PCK interview).</td></tr>
</table>

Table 4.17. Teaching Strategies Employed by Melis to Overcome Students' Difficulties While Teaching Genetics (Continued)

<table>
<tr><th>Sources</th><th>Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics</th></tr>
<tr><td>Students characteristics</td><td>Students at this age easily distracted from the lesson. The genetics is a difficult topic and their attention was easily distracted from the lesson… Students at this age generally give importance to their appearance and the traits related to appearance (eye color, hair shape, and so on). They were more interesting to take their attention to the topic (post-PCK interview).

She drew the following table to exemplify genetic traits to her students in classroom. The traits are mainly related with human appearance (Observation).


<table>
<tr><th>Dominant characters</th><th>Recessive Characters</th></tr>
<tr><td>Black hair</td><td>Blonde hair</td></tr>
<tr><td>Curly hair</td><td>Straight hair</td></tr>
<tr><td>Dark eye color</td><td>Light eye color</td></tr>
<tr><td>Dark skinned</td><td>Light skinned</td></tr>
<tr><td>Free earlobe</td><td>Attached earlobe</td></tr>
<tr><td>Rolling tongue</td><td>Non-rolling tongue</td></tr>
<tr><td>Non-albinism</td><td>albinism</td></tr>
<tr><td>Thick lip</td><td>Thin lip</td></tr>
<tr><td>Yellow seed</td><td>Green seed</td></tr>
<tr><td>Long stem</td><td>Short stem</td></tr>
<tr><td>Round seed</td><td>Wrinkled seed</td></tr>
<tr><td>Purple flower</td><td>White flower</td></tr>
<tr><td>Black hair</td><td>Brown hair (mouse)</td></tr>
</table>
(Observation).

The genetics topic is abstract. For this reason just telling the concepts and relationship is not enough in my opinion. Each student learns differently, in my opinion some of my students learn better with tables (post-PCK interview).</td></tr>
</table>

Melis's students had difficulty to distinguish which trait is inherited one. Moreover, they generally thought that dominant traits should be more common in a population. As a relationship difficulties, students experienced difficulty to distinguish genetic relatives from the relatives owing to marriages. To overcome these difficulties, teacher referred to her assignment about "What similarities and differences do you have in your family?" Although her approach to difficulty was seemingly meaningful, her observation data did not reveal any approach to overcome these three difficulties with stated assignment. In other words, she did not anything to overcome these difficulties. Furthermore, she gave explanation that the being common traits should not necessitate the dominant traits in her lesson to her students.

While teaching pedigree, she emphasized to track genetic relatives and she solved several pedigree problems. Her students thought that crossing composed of several meaningless steps. While teaching the first crossing, Melis explained the meaning of the steps in each crossing by stating, “one gene came from father and another gene came from mother to compose gene pair.” She also emphasized this with an example by using circle and square symbols to teach homozygous and heterozygous. In this example, she showed separately genes before composing gene pairs.

The abstractness and unfamiliarity of the concepts (e.g. genotype) were the main source of difficulties for students while learning genetics. Melis gave explanation about mechanism of genetics with DNA, genetic code, meiosis, and reproduction as the background knowledge for these difficulties. She accepted that underlying process and required knowledge were also abstract for this age of the students and then she preferred to use another strategy such as giving an assignment related to searching family traits. She referred to heterozygous parent or grandparents and their homozygous recessive siblings as an example of genotype, because people having same phenotype might have different phenotype siblings.

During classroom observation, it was seen that students faced a difficulty in notation of dominant phenotype (AA or Aa) and homozygous genotype (homozygous dominant-AA or homozygous recessive-aa) because both of them had two different notations. She taught all notations with a table and this table makes it more clear probabilities of all notations and types at a single glance for students.

Furthermore, during classroom observation, it was seen that students had a difficulty to pay attention to the topic and this was the case for particularly genetics as a demanding topic. This difficulty was based on students’ characteristics and Melis dealt with this difficulty by using students’ traits in her teaching because students at this age gave importance their appearance. She gave mainly human traits examples especially related to appearance of a person like hair color, eye color, and hair type. The learning of students was also affected by abstractness of genetics concepts. Then she preferred to use table to show all probabilities and notation of phenotype and genotypes.

Students' requirements of scientific knowledge (DNA, genetic code, cell divisions and fertilization) was cared by Melis and she changed the order of textbook topics while teaching genetics to be able to meet students requirements. The book order and Melis's topic order were given in the Table 4.18.

Table 4.18. Unit Title Order

Textbook unit title plan	Melis unit title plan
Unit 1. Cell division and Genetic	Unit 1. Cell division and Genetic
6. Mitosis	6. DNA and genetic code
7. Genetics	7. Mitosis
8. Meiosis	8. Meiosis
9. DNA and genetic code	9. Genetics
10. Adaptation and evolution	10. Adaptation and evolution

When asked the reason for this change, Melis answered;

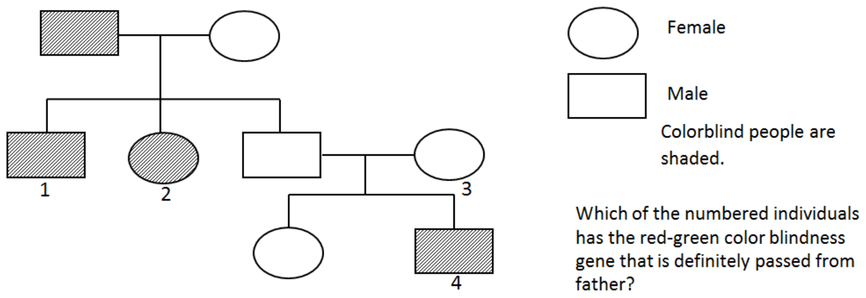
> The first time of the curriculum change and the next two-year, I followed the textbook title order. During teaching according to book topic order, I recognized some students had problems with relationships among the concepts and topics. Learning genetics topic needs good understanding of DNA, meiosis and reproduction. However, the book order is left behind meiosis, reproduction, and DNA after the genetic topic. I changed the topic order to help students construct more meaningful relationship among the concepts.

In contrast all of the above strategies targeting to overcome students difficulties, Melis did not pay attention other kinds of difficulties which students face while learning genetics (such as learning a great number of concepts in genetics topic such as genotype, heterozygous genotype, hereditary disease crossings especially sex-linked traits and so on). For example, although genetics has numerous new concepts, Melis taught both Turkish and Latin terms for the same genetics concept (both "arı döl" and "homozigot" for [homozygous]).

Another teaching example, Melis syllabified both terms as homo-zygous and hetero-zygous and focused on homo-hetero syllables while teaching homozygous and heterozygous. She related homo-hetero syllables with chemistry terms of homo-geneous and hetero-geneous and explained them with solution examples. This may be based on her chemistry background.

The third teaching strategy example, which makes worse the genetics difficulty of students, was using of sex-linked genetic disease on the pedigree. She asked the following question to the students (Figure 4.3).

Hereditary disease and pedigree problem - Color blindness is inherited as a sex-linked recessive. Which of the numbered individuals in the pedigree below has the red-green color blindness gene that is definitely passed from father?



Colorblind people are shaded.

Which of the numbered individuals has the red-green color blindness gene that is definitely passed from father?

Figure 4.3. Melis's Crossing Example of Sex-Linked Genetic Disease on Pedigree

None of the students answered this question, and teachers solved her problem on the blackboard. However, students stated that they did not understand the solution of the problem. Even teacher had to repeat the solution three times; many of the students again stated that they did not understand solution.

To summarize; Melis generated and utilized special and different kinds of teaching strategies to help students overcome their difficulties while learning genetics topic. However, Melis showed limited knowledge on teaching strategies to overcome students' difficulties while teaching genetics.

4.3 The Case of Mert

The description of Mert for PCK and the analysis of PCK components of Mert were presented.

4.3.1 Description of Mert

Mert graduated from the biology department of science and arts faculty. Mert took biology and genetics courses during undergraduate education. During undergraduate education, he took pedagogy courses from faculty of education as well. He also took in-service education on “Application and Development of Biology Laboratory” and “Introduction of New Curriculum” in 2004.

Mert had four and half years of teaching experience as an elementary teacher, 3 years as a biology teacher, one year both as a biology teacher and middle school science teacher, 9 years as an middle school science teacher; a total of 17 years teaching experience. He gave additional courses for the university entrance exam in his school for one year.

Mert’s distinctive characteristic was preparing and reviewing problems for the high school entrance exam for private book publishers. This helped him gain experience on content knowledge, curriculum knowledge, and problems. He described this experience as “I prepared problems and reviewed them according to the new curriculum, depending on the publisher demands.”

Mert’s different situation was that he did not work as a teacher for 5 years after graduation, and when he began teaching, he became an elementary teacher and worked for four and half years as well. He mentioned that “during first year of teaching in high school, I studied physics and chemistry even harder than students.”

Mert’s classroom was not equipped with technology, it contained only student’s desks, teacher’s desks, and blackboard. School had a well-equipped laboratory and the laboratory was equipped with technological devices: like notebook, projector, and Internet connection in addition to usual science laboratory equipment. He had 27 students and his students generally had low level socio economic status. Around half of his students attended to cram school education besides school education.

4.3.2 Mert's Understanding about Genetics

In this section, the first research question "What is the science teacher's understanding of genetics?" was analyzed. The science teachers understanding of genetics was evaluated with the help of genetics test (see Appendix C). The analysis of test presented with two main parts; understanding of genetics concepts and genetics crossing.

4.3.2.1 Understanding of Mert about the Genetics Concepts

The analysis of answers of Mert for the definition of seven genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous, see Appendix A) were given in Table 4.19.

Mert's definition of what a gene was "It is the DNA sequence which causes a trait to appear." His definition was considered as sound understanding according to scientific definition (see Table 3.5) because definition of Mert included both structure of a gene "It is the DNA sequence…" and function of a gene "the DNA sequence which causes a trait to appear." Moreover, due to the having process explanation in his definition, Mert's definition of the gene was categorized as process within the ontological category according to Chi et al. (1994).

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Table 4.19. Definition of the Genetics Concepts given by Mert

Concepts	Answer of Melis	Understanding of concepts		Ontological categorization	
		Partial	Sound	Matter	Process
Gene	It is the DNA sequence which causes a trait to appear.		✓		✓
Dominant gene	The gene which reveals its effect on appearance in all conditions.	✓		✓	
Recessive gene	This gene which shows its effects only when it is homozygous.	✓		✓	
Genotype	it is all of the genes on chromosomes, even though they do not emerge in appearance.		✓		✓
Phenotype	Although it includes different traits genes carrying on genotype, this gene emerges in the appearance.	✓			✓
Homozygous	~~Only one~~, the trait coming from mother and father that is same and expressing this trait in the next generations.		✓		✓
Heterozygous	The genes coming from mother and father having different traits, and this trait’s existing in the genotype of next generation.	✓		✓	

Mert defined dominant gene as "The gene which reveals its effect on appearance in all conditions." He probably implied the homozygous and heterozygous genotypes with "all conditions." Another point of his definition was that he did not mention the masking effect of dominant gene over recessive gene. It was a deficiency for both scientific definition and the role of the dominant gene. In this manner, Mert's understanding of dominant gene was accepted as partial and his definition of dominant gene was in matter category. The definition of recessive gene was "This gene which shows its effects only when it is homozygous." The similar deficiency exists in definition of recessive gene. He did not mention recessive gene was masked by dominant gene. Hence, his understanding of recessive gene was partial according to scientific definition (see Table 3.5) and recessive gene definition was in matter category according to Chi et al. (1994).

Mert defined genotype as "It is all of the genes on chromosomes, even though they do not emerge in appearance." Although it included small differences with the scientific definition (Table 3.5), the definition included both the structure and function of genotypes. For this reason, it was accepted as a reflection of sound understanding of genotype and it was in the process category according to Chi et al. (1994). For the definition of phenotype, it was in the process category due to the explanation of "…this gene emerges in the appearance." However, the definition only explains interaction with genotype and it did not include any information about interaction with the environment. Thus, his understanding was accepted as partial

Mert's definition of homozygous was "~~Only one~~, the trait coming from mother and father that is same and expressing this trait in the next generations." Mert employed traits instead of gene or gametes and stated its function as expressing in the next generation. The understanding of homozygous was accepted as sound and the ontological category was the process. His heterozygous definition was "The genes coming from mother and father have different traits, and this trait's exists in the genotype of next generation." The term of traits was employed also for the heterozygous. This definition was scientifically acceptable. However, the statement regarding heterozygous "…this trait's exists in the genotype of next generation" was not clear because this trait's is valid for both dominant and recessive gene and the dominant and recessive genes express themselves differently on the phenotype of next generation. Hence, his understanding of heterozygous was accepted as partial. This deficiency also related to ontological category and Mert's heterozygous definition was in matter category according to Chi et al. (1994).

To summarize, Mert's understanding about three genetics concepts (gene, genotype and homozygous) out of seven concepts were found as sound and the ontological categorization analysis of four genetics concepts (gene, genotype, phenotype, and homozygous) was resulted as in process category.

4.3.2.2 Mert's Understanding about the Crossing

In the genetics test, the result of analysis related to a monohybrid-crossing question in genetics test was presented in this section. The result of Mert's answers to crossing question was given in the Figure 4.4.

The answer of Mert for crossing question was considered as partial understanding according to expected answer of the crossing question (see Figure 3.4 and Table 3.6). Mert could not write the two crossings for the information of dominant phenotype of the pea seed that have two-genotype probability. He referred to the yellow color phenotype as homozygous dominant and solve with only one crossing. His answer included the correct usage of symbolization of genetics terms according to expected crossing answer. Although he employed the terms of genotype, phenotype, homozygous and heterozygous in the first and the last row of the crossing, he did not use all genetics concepts in each crossing tasks.

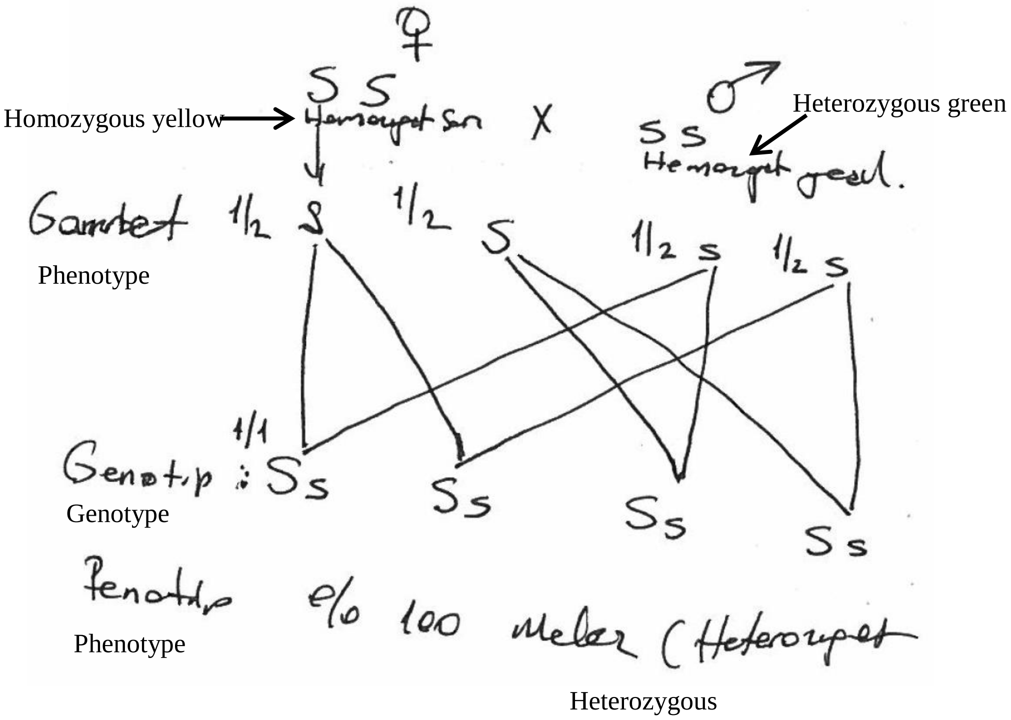


Figure 4.4. Mert's Answer for Crossing Question

4.3.3 The Nature of Mert's PCK Regarding the Topic of Genetics

In the second research question of the study "What is the nature of science teachers' PCK about genetics?" was investigated in this section. The result of the analysis of teachers' PCK was presented in three components with its sub-components.

i. Knowledge of curriculum,
ii. Knowledge of students
    a. Knowledge of students requirements
    b. Knowledge of students difficulties
iii. Knowledge of teaching strategies,
    a. Representations
    b. Activities
    c. Teaching strategies to overcome students' learning difficulties

4.3.3.1 Mert's Knowledge of Curriculum about Genetics

In this section, teachers' knowledge about the curriculum related to genetics concepts was investigated. Mert's knowledge of curriculum about genetics was evaluated with the help of pre-PCK interview (see Appendix C) and classroom observation of the course. Result of pre-PCK interview about Mert's knowledge of curriculum was summarized in Table 4.20.

The results of interview with Mert revealed that he had limited curriculum knowledge. For some of the curriculum questions, Mert could not directly refer the curriculum objectives during the interviews. He generally stated "These concepts are in the curriculum because they are in the textbook…. I am teaching these concepts in the classrooms."

Mert stated crossing objective as

> The teaching genetics requires the teaching crossing to help students understand the genetics topic better. On the other hand, I feel to prepare my students for the national examinations and crossing questions were asked in the examination. Our book [science course book] also includes crossing.

He was aware of the science textbook content, alongside he had the reason to teach crossing. Mert continued the answer of crossing objective questions with

> I also teach sex crossing, pedigree. I want to teach the hereditary disease crossing but I know textbook did not include these kinds of questions. I try to teach previously but hereditary disease crossings confused much more students' minds on the genetics topic. Even though I teach one or two examples of hereditary crossing because students have seen them in the cram school or in the supplementary books.

His answer indicated that he had knowledge on curriculum objectives "2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.", "2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.", "2.6. It should be stated that sex depends on sex chromosomes."

Table 4.20. Objectives Checklist for Mert's Answers for Curriculum Questions in the pre-PCK Interview

2006 Objectives Stated in Science Curriculum for Genetics Topic	Does teacher answer meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about the concept of gene.		✓	
2.5. Understand the relationship between phenotype and genotype.		✓	
2.6. Solve crossings problems related to inheritance of a single character.	✓		
2006 Limitations Stated in Science Curriculum for Genetics Topic			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	✓		
2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.		✓	
2006 Warnings Stated in Science Curriculum for Genetics Topic			
2.6. It should be stated that sex depends on sex chromosomes.	✓		

In contrast, some of his answers for curriculum question in pre-PCK included non-curriculum parts. Mert employed homozigot [arı döl] [homozygous], heterozigot [melez] [heterozygous], allele genes, dominant [baskın] [dominant], resesif [çekinik] [recessive]" in the interviews and these terms were not present in the curriculum and textbook [the first parenthesis are the Turkish terms textbook employed]. He explained the reason of this as

> They will learn Latin terms in high school. Latin terms help my students to prepare high school biology courses. Since the newspapers and documentaries use these terms, they easily recognize these concepts when they encounter in the media.

Mert's knowledge of curriculum about genetics was also evaluated with classroom observation. The evaluation of curriculum knowledge for Mert's observation was given in Table 4.21

Table 4.21. Objectives Checklist for Teaching of Mert's Observation

2006 Curriculum Objectives for Genetics Topic	Does teacher teaching meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene.		✓	
2.5. Understand the relationship between phenotype and genotype.		✓	
2.6. Solves crossings problems related to inheritance of a single character.	✓		
Limitation			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	✓		
2.6. Hemophilia, sickle cell anemia, color blindness, Down syndrome, etc. are given as examples of inherited disease.		✓	
Warning			
2.6. It should be stated that sex depends on sex chromosomes	✓		

According to Table 4.21, Mert showed sound curriculum knowledge for genetics topic in his teaching. He only taught monohybrid crossing in his teaching and for this reason; he had sound curriculum objectives regarding "2.6. Solves crossings problems related to inheritance of a single character." and "2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given."

The hereditary crossing in Mert's teaching was only textbook activity. Mert also employed the another textbook activities such as "Let's help the Mendel," "Learn the traits of your family," "Toss a coin for sex crossing," "What is the Mert and his family genotype and phenotype." These activities kept his teaching inside the curriculum.

Furthermore, Mert started to lesson with a drama related to Mendel's life. Some part of Mendel's life drama such as dihybrid crossing was not covered by the curriculum. When Mert recognized the parts were not covered in the curriculum, he warned his students by stating, "We do not learn these parts, you will learn this in the upper grades."

Another activity named Let's help Mendel was presented in the textbook. However, Mert employed this activity extraordinary to explain meiosis, gametogenesis, and fertilization concepts in the crossing. He stated that

> The meiosis, gametogenesis, and fertilization are held in the next topic and I feel to mention in crossing topic to increase my students understanding as much as not violated the curriculum boundaries.

On the other hand, Mert's teaching included some examples of implementations which were not part of the 8th grade science curriculum. For example, he followed the Mendel laws order and employed F_1, F_2 and P symbols for generations. In the post-PCK interview, he stated that "I want to teach in coherence of Mendel's life for this reason I prefer to teach crossing in Mendel law order."

While teaching genetics, Mert employed persistently "homozigot [arı döl] [homozygous], heterozigot [melez] [heterozygous], allele genes, dominant [baskın] [dominant], resesif [çekinik] [recessive]" and these terms were not stated in the curriculum and textbook.

He employed his knowledge of biology while answering students' questions in the lesson, even some of answer was not covered in the curriculum. For example, he explained the detail of blood types such as factor of Rh. Another example was on apoptosis which is programmed cell destruction in development of human embryo. This kind of information was not part of the curriculum.

Mert integrated the computer activities in his teaching and he allowed an hour for online genetics activities such as crossing, video explanations for homozygous and heterozygous concepts. On the other hand, video related to genetics included some parts were not covered by the curriculum such as Turner syndrome as hereditary disease, co-dominance in blood types and flower colors etc. The video was probably outdated and Mert did not think that this information out of the curriculum might confuse the students mind.

Mert's knowledge of curriculum was found to be limited. His interviews and observation data showed that some statements in the interviews or the implementations were not part of the curriculum. On the other hand, because he followed same topic sequence as in the textbook in his teaching, his teaching was mainly appropriate to the curriculums.

4.3.3.2 Mert's Knowledge of Students about Genetics

In this section, teachers' knowledge about students in learning genetics concepts was investigated. Student knowledge was analyzed under two titles; requirements of students and difficulties of students while learning genetics topic.

4.3.3.2.1 Mert's Knowledge of Students' Requirements for Genetics

In this section, the requirements of students were presented with examples of teachers' responses. Teachers' knowledge of students' requirements for learning genetics was evaluated with the help of pre-PCK interview (see Appendix C). The dimensions appeared in data analysis of Mert's knowledge of students' requirements for genetics and examples of his response were shown in Table 4.22.

Mert asserted that his students need to know cell, cell division prior to learn genetics topics. However, he underlined that so many times they forget the knowledge they learned in previous grades. Mert emphasized students should know fractions and operation on fractions such as adding two fractions. In the case of deficiency in fractions, Mert tried to teach in his lesson.

In the pedigree problems, students have to know how to follow the people in the family. This requires a kind of graphical reading skills. Some problem types need to predict genotype of children or parent according to given information. Students should have prediction skills to solve this kind problem according to Mert.

Table 4.22. Mert's Knowledge of Students' Requirements for Learning Genetics

Dimension of requirements	Requirements	Responses of Mert
Knowledge		
	Science	A meaningful genetic crossing necessitates genetics knowledge and crossing is not composed of routinized crossing algorithms. Students should be able to explain why they perform each crossing tasks. While teaching genetics, you have to mention about many [scientific-biological] concepts, which students should know such as cell, nucleus, chromosomes, cell division, fertilization…Most of the times, students forget what they have learnt. In this time, you have to handle this knowledge to be able to teach the genetics.
	Mathematics	The result of crossing was stated with fraction and problems produced the results in the form of fraction or percentages. Students have to know the fraction and percentages. However, students did not know even addition in ratios. I try to teach fraction in my lesson as far as possible.
Skills		
	Problem solving	In each topic including problems and genetics as well, I stated some issues about how to solve the problems. Problems should be read carefully and you should try to understand what requested in the problem and what was the given information related to solution of the problems. These are also valid issues for genetics problem and students should use the similar approach the genetics problem as well.
	Graphics reading	While teaching pedigree, they have to know how to follow the people in the family according to information in the problem. I do not ask frequently the pedigree problem because students find difficult this kind of problem.
	Prediction	Basic genetics problem gives the parent genotype and asked the children about genotypes. Some of the problem give the phenotype of parent and asked the children about genotypes… or problem gives the children genotypes and asked what the father or mother genotype is. Students have to predict in this kind of question.
Maturity		
	Formal-operational	The genetics topic is only visible in phenotype for the students. Gene, chromosomes, cell divisions, and genotype are the microscopic level concepts and they could not be seen with naked eye. We teach them [genetics concepts] as affecting their phenotype and the mechanism for relationship between genotype and phenotype could not be observable. They are calculating the ratios about these non-observable issues. Many students just followed the crossing tasks and they could not comprehend deeply to what they are doing in crossing due to the abstractness. Maybe they get better understanding in high school biology. We just build ground for some high school topic with teaching monohybrid crossing.

Mert stated that “Gene, chromosomes, cell divisions, and genotype are the microscopic level concepts and they could not be seen with naked eye.” Moreover, genetics topic includes abstract concepts and mechanism, and observable issues arise only in the concept of phenotype and this situation was an problematic issue for the understanding of 8th grade students and Mert believed that he prepared his students for the higher grade level topics and his students could have better understanding in the higher level grades. The results of data analysis of Melis depicted that he had sound knowledge of his students’ requirements for learning genetics.

The results of data analysis of Mert depicted that he had sound knowledge of his students’ requirements for genetics topic.

4.3.3.2.2 Mert’s Knowledge of Students’ Difficulties in Learning Genetics

The dimensions appeared in the data analysis of Mert’s knowledge of students’ difficulties while learning genetics and examples of his response were shown in Table 4.23.

Mert indicated that his students experience different kinds of difficulties while learning genetics. According to Mert, students had difficulty with essential knowledge on meiosis and fertilization. Mert stated that his students could define the genetics concepts however; they could not relate these concepts between each other. It was seem that students struggled with linking between the major genetics concepts because they are concurrently subjected to various concepts and processes at different levels of organization, which they cannot deal with them at the same time. Moreover, Mert highlighted to students’ difficulties of notation of genotypes of dominant phenotype because it has two different genotypes. Moreover, his students preferred to write homozygous dominant genotype.

Table 4.23. Mert's Knowledge of Students' Difficulties While Learning Genetics

Difficulties	Responses of Mert
Understanding	A hindrance of some of my students was their weak understanding of meiotic division such as gametogonium has diploid chromosomes and gamete has haploid chromosomes [with the help of meiosis]. Since, they have not learned yet meiosis before the genetics topic and they do not clearly understand one letter represents gametes genotype and two letters represent gametogonium or autosomal genotype.
Relationship	All students followed the task of separation of parent alleles during crossing. However, they could not relate this separation with meiosis and gamete formation. They just separate the letter pair to follow the algorithm of crossing.
Crossing	A meaningful genetic crossing necessitates genetics knowledge and crossing is not composed of routinized crossing algorithms. Students should be able to explain why they perform each crossing tasks. Some of my students do not base their crossing on genetics knowledge and they just followed the routinized algorithm.
Sources	
Concept	With few exceptions, most of my students were able to provide acceptable definitions of most genetics concepts. However, most of them have difficulty describing how concepts are related. Such as how dominant gene, heterozygous genotype, and phenotype concepts are related each other. Their difficulty with heterozygous is more than homozygous. The difficulty with heterozygous is observable especially problems stating the phenotypes [of a trait] because there is a two homozygous; dominant and recessive and homozygous genotypes are observable on phenotype [of an organism]. However, heterozygous phenotype was same with dominant homozygous and when they required writing the genotype of dominant phenotype they prefer to stick on the homozygous dominant. They have difficulty to write there is two genotype probabilities of dominant phenotype and there is another possibility of genotype; heterozygous other than the homozygous dominant.
Representation	Basically, crossing means pairing a maternal gamete and a paternal gamete in forms an offspring genotype. Actually, it represents the fertilization by means of combination of letters [gametes]. However, gamete pairing should be done completely-without omitting any gametes and correctly-done without any repetition to be able to represent correct probabilities [of offspring genotypes]. We employed the arrows in crossing to reach the correct results and not to cause any omits and repetition. Some of my students did not use any arrows and they write the result of crossing from their memory. This causes many times errors [in result of crossing] and I notified [my students] to use arrows when I saw them not use any arrows [during crossing]. Students could not understand that two letters represent gametogonium with diploid chromosomes and one-letter germ cell represents haploid chromosomes.
Students characteristics	Students at this age get easily bored in science lessons especially while teaching topics including abstract and condense information like genetics.

During his teaching, the crossing arrows showed fertilization through combination of gametes. However, the representational difficulty of Mert’s students was to follow the arrows order. The following order helped students correctly pair up gametes for genotype of offspring and probabilities of offspring genotypes were indicated if there was not repetition or any missing of gamete pairs. However, when his students did not use or followed the arrows this caused errors of crossing results. Other representational difficulty of Mert's students was that they did not understand the parent genotype representing maternal or paternal gametogonium with diploid chromosomes and one-letter represented gametes with haploid chromosomes. Mert stated that students at this age get easily bored in science lessons especially while teaching topics including abstract and condense information like genetics.

The analysis and results of Mert’s data depicted that he had sound knowledge of students’ difficulties while learning genetics topic.

4.3.3.3 Mert’s Knowledge of Teaching Strategies

Teacher knowledge about teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with two titles subject specific and topic specific teaching strategies.

4.3.3.3.1 Mert’s Knowledge of Subject Specific Strategies

Mert did not use any noticeable subject specific teaching method such as learning cycle, discovery, inquiry or conceptual change oriented instruction, guided instruction, generative learning model and so on (Magnusson et al. 1999).

Mert started his lesson with a drama related to Mendel’s life. He employed the examples and information in the Mendel’s life drama while teaching of genetics concepts and crossing. The pedigrees and problems were rarely employed and he stated that

> Students find pedigree difficult and the genetics topic is a difficult topic and I do not want to raise the difficulties by solving pedigree problems in the lesson.

He employed his knowledge of biology while answering students' questions in the lesson, even some of answers were not covered by the curriculum. For example, he explained the detail of blood types such as factor of Rh. Another example was on apoptosis which is programmed cell destruction in development of human embryo. Mert's sequence of the teaching was based on cycle of crossing questions and answers.

Even though, the main characteristic of Mert's teaching was generally teacher centered; he allowed his students to share their ideas and frequently asked topic related questions. Mert expected from his students to be active in the lesson, especially in the problem solving, and to give ideas and examples about their lives.

4.3.3.3.2 Mert's Knowledge of Topic Specific Strategies

Teacher knowledge about topic specific teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with three headings as; representation, activities and employed strategies to overcome students' difficulties, respectively. Teacher's knowledge of teaching strategies was evaluated with the help of the pre-PCK interview (see Appendix C), observation of the course and the post-PCK interview.

4.3.3.3.2.1 The Representations Employed by Mert While Teaching Genetics

The teaching strategies were covered under in three sub-titles, the first one was related with representation, and the data analysis for representation lead to three categories namely; “illustrations,” “examples,” and “analogies.” The examples of employed representations by Mert while teaching genetics were shown in Table 4.24.

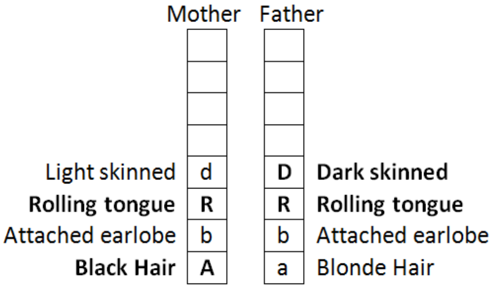
Some of Mert’s students thought that chromosomes have only one gene on it due to the application of monohybrid crossing or all genes should be same genotype such as homozygous or heterozygous. Mert employed the chromosome representation including different gene letters on it to help his students overcome these kinds of difficulties. He employed similar representation in sex chromosomes. He employed mainly pea traits examples. He thought that the activity regarding Mendel’s life helped his students focus on the topic and the Mendel studies helped his students to follow the topic easily. In addition, same traits helped students easily focus on the crossing, not traits phenotypes and genotypes. Mert employed transparency sheets for teaching of heterozygous person’s genotype and phenotype and he stated that

> This analogy helps students understand the case of phenotype of heterozygous genotype because this phenotype is dominated by dominant trait even including recessive trait.

The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Mert had sound knowledge of representations to teach genetics concepts in order to facilitate students’ learning.

Table 4.24. The Representations Employed by Mert While Teaching Genetics

<table>
<tr><th>Dimension of representations</th><th>Responses of Mert</th></tr>
<tr><td>Illustrations</td><td>

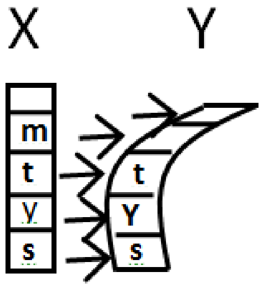


(Observation).

While teaching crossing, I am teaching only monohybrid crossing because curriculum limited us only crossing with monohybrid. In this grade, students see only one trait gene during crossing and they think that chromosomes have only one trait gene. I employed this representation in which homolog chromosomes have different trait genes, not only one-gene alleles.

On the other hand, we are studying with a person who has homozygous dominant genotype such as hair color [AA]. Students perceive that all alleles on homolog chromosomes should be homozygous dominant; rolling tongue [RR], dark skinned [DD], attached earlobe [BB] and so on are homozygous dominant. I employed this diagram to show my students that there is always a possibility that a chromosome is not identical with its counterpart. Homolog chromosomes may not have the same alleles.

Mert also employed this diagram to repeat the teaching of dominant, recessive, homozygous, heterozygous, genotype and phenotype concepts.



(Observation).

Mert also employed similar diagram for sex chromosomes of X and Y. In his teaching, he stated that they do not have similar shape and same genes.

</td></tr>
</table>

Table 4.24. The Representations Employed by Mert While Teaching Genetics (Continued)

Dimension of representations	Responses of Mert
Examples	The pea traits [flower color; seed color; seed shape; stem length, and so on] were generally give as genetic traits examples in his teaching. He explained this example preference as: I started genetics with the drama of Mendel's life and I want to continue my teaching with the scenario of Mendel by means of his studies on peas. In my opinion, this may help students imagine genetics on a complete picture without distracting one trait example to another one. If I employed different examples as entrance examples for crossing, each new example distracts students focused on crossing because they have to determine dominant, recessive traits and genotype of new traits. I employed different examples after recognizing students learn the crossing.
Analogy	Mert employed analogy of colored transparency sheets for dominant trait (A) and colorless transparency sheets for recessive trait (a) and he stated when paired colored for dominant and colorless recessive in heterozygous genotype (Aa), we see dominant paper color actually it includes recessive trait likewise in heterozygous. This analogy helps students understand the case of phenotype of heterozygous genotype because phenotype is dominated by dominant trait even it includes recessive trait.

4.3.3.3.2.2 The Activities Employed by Mert While Teaching Genetics

The activities employed by Mert while teaching genetics were problem solving about crossing, construction of pedigree, Let's help Mendel a probability activity and drama of Mendel's life (Table 4.25).

The Mert started to teach genetics drama of Mendel's life. He stated

> The life of scientist attracts the students' attention to the topics. Moreover, some of my students like to drama and give them the opportunity to dramatize the scientist life.

Although students mention briefly about genetics concepts and crossing in Mendel's life drama, Mert taught topic again and he referred the students' drama activity while he was teaching the concepts and crossing.

Table 4.25. The Activities Employed by Mert While Teaching Genetics

<table>
<tr><th>Type of activities</th><th>Observation data</th></tr>
<tr><td>Problem solving</td><td>General crossing problem - Cross two heterozygous green pea seeds (green pea seed color is dominant over yellow pea seed color) (Observation).
Sex crossing problem - A family has five girl children; they are expecting a new baby, what is the percentage of the sex of the sixth baby? (Observation).
Hereditary crossing problem – Determine phenotype and genotype of Mert family for sickle cell anemia disease on the following pedigree. (Observation).
Pedigree problem - Determine people having certainly heterozygous genotype of blue eyes on the following pedigree.</td></tr>
<tr><td>Pedigree construction</td><td>Mert gave an assignment to prepare a pedigree for teaching of the concept of heterozygous. He focused on parents both having dominant phenotype and recessive phenotype offspring on pedigree.</td></tr>
<tr><td>Let's help Mendel</td><td>Teacher divided classroom into six groups. Teacher asked students to prepare papers written 100-Dd heterozygous genotype on it. Students put 50 papers to mother's box (they employed pencil box as boxes) and 50 papers to father's box. Then they divided Dd letter pairs into two by cutting and there were 50-D and 50-d letters in each parent's box. During this process, Mert gave explanation that in the parent boxes, heterozygous genotype-Dd represents gametogonium, division of letters represents meiosis, and dividing of letters represent gametes of parents. In this steps, each parent's box had 100 gamete either dominant-D or recessive-d. One of the students picked up a letter from mother gamete box and another student picked up a letter from father ones. Third student wrote the pair of letters. Teacher underlined that pairing a letter from mother and a father represent fertilization. After finishing picking up the all letters and pairing them, students calculated the frequencies for each letter pairs; DD, Dd, dd and each group wrote their frequencies on the blackboard.
Data Table of Students for Let's help Mendel Activity
<table>
<tr><th></th><th>Group 1</th><th>Group 2</th><th>Group 3</th><th>Group 4</th><th>Group 5</th><th>Group 6</th></tr>
<tr><td>DD</td><td>18</td><td>28</td><td>22</td><td>25</td><td>27</td><td>23</td></tr>
<tr><td>Dd</td><td>58</td><td>52</td><td>48</td><td>54</td><td>56</td><td>51</td></tr>
<tr><td>dd</td><td>24</td><td>20</td><td>30</td><td>21</td><td>17</td><td>26</td></tr>
</table>
The interpretation of the result of crossing needs knowledge about probability. Some of my students have trouble in understanding of two gametes that were randomly paired in the fertilization. I [Mert] employed this activity to help students visualize how gametes are paired randomly [in fertilization].</td></tr>
<tr><td>Drama</td><td>Mert started the genetics lesson with drama of Mendel's life. Mert gave assignment to five volunteer students for preparing the life of Mendel to dramatize in the classroom.</td></tr>
<tr><td>Computer activity</td><td>Students like computer activities. … I reserve one course hour for computer activities for each topics and for genetics topic as well.</td></tr>
<tr><td>Science video</td><td>Mert employed a documentary Video CD related to fertilization, meiosis and genetics.</td></tr>
</table>

The main part of Mert's teaching of the genetics was based on problem solving. His teaching included (1) general crossing, (2) sex crossing, (3) hereditary disease, and (4) pedigree (see Table 4.25).

He employed the pedigrees only three times in his teaching. For example, he expected from his student to prepare the pedigree for the teaching of heterozygous concepts. Two of the pedigrees were for the genetics problems. Mert gave the hereditary disease problem by means of the activity named "the Mert sickle cell disease in his family." This activity was presented in the textbook.

The activity of Let's help Mendel was actually based on the textbook. However, Mert employed this activity to explain meiosis, gametogenesis, and fertilization in the crossing. Moreover, all students in the classroom were active during the activity. It seemed that this activity worked in parallel with Mert's purposes which was to help students visualize how gametes are paired randomly in crossing.

4.3.3.3.2.3 Teaching Strategies Employed by Mert to Overcome Students' Difficulties While Teaching Genetics

The classification of learning difficulties and the respective teaching strategies employed by Mert were given in Table 4.26.

Mert's students had difficulty with essential knowledge on meiosis and fertilization. He was aware of students' requirements of scientific knowledge and tried to compensate this deficiency with a brief explanation. Although meiosis and fertilization are the difficult topics for students to learn, he only briefly explained the meiosis and fertilization in the classroom. He also thought that these brief explanations were helpful for his students for their difficulty in understanding of what the mechanism of genetic crossing is.

Table 4.26. Teaching Strategies Employed by Mert to Overcome Students' Difficulties While Teaching Genetics

Difficulties	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Understanding	A hindrance of some of my students was their weak understanding of meiotic division, for example gametogonium has diploid chromosomes and gamete has haploid chromosomes [with the help of meiosis]. Since, they have not learned yet meiosis before the genetics topic and they do not clearly understand one letter represents gametes genotype and two letters represent gametogonium or autosomal genotype. The curriculum order forcse us to teach genetics before the meiosis [topic] but whenever I need to knowledge related to meiosis, I talk about briefly the meiosis. Otherwise, I believe that students do not understand why allele gene pairs split into gametes gene and gametes have one letter while gametogoniums have two letters.
Relationship	All students followed the task of separation of parent alleles during crossing. However, they could not relate this separation with meiosis and gamete formation. They just separate the letter pair to follow the algorithm of crossing. … whenever I need to knowledge related to meiosis, I talk about briefly the meiosis. This may help them to understand the mechanism of genetics crossing.
Crossing	A meaningful genetic crossing necessitates genetics knowledge and crossing is not composed of routinized crossing algorithms. Students should be able to explain why they perform each crossing tasks. Some of my students do not base their crossing on genetics knowledge and they just followed the routinized algorithm. In the first crossing, I teach crossing with tasks and I explained them to what is the biological meanings of each task to my students. The algorithm of crossing does not have meaning to my students without explanation.
Sources	**Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics**
Concept	…they required writing the genotype of dominant phenotype, they prefer to stick on the [writing only] homozygous dominant [genotype]. They have difficulty to write two genotype probabilities of dominant phenotype and there is another possibility of genotype; heterozygous other than the homozygous dominant. We employed the Demet's pedigree on textbook and I gave them an assignment to prepare pedigree on some traits. I focused on parents both having dominant phenotype and recessive phenotype offspring on pedigree. How can these parents have recessive phenotype offspring? I discussed all genotypes possibilities and their phenotypes with classroom. Then I write the genotype possibilities that have dominant phenotype and I matched the possibilities as parents' genotypes for crossings. Then I divided classroom in three groups [the desk order of the students] and ask them to cross three different parents' genotype possibilities. We made crossing for parents both homozygous dominant genotypes, one homozygous dominant and one heterozygous, and parents both heterozygous. We discussed the results. There is only one possibility and it was the parents both having heterozygous genotype who can have a recessive phenotype offspring.

Table 4.26. Teaching Strategies Employed by Mert to Overcome Students' Difficulties While Teaching Genetics (Continued)

Sources	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Concept	With few exceptions, most of my students were able to provide acceptable definitions of most genetics concepts. However, most of them have difficulty in describing how concepts are related. For example, how dominant gene, heterozygous genotype, and phenotype concepts are related to each other. I gave definitions with their relationships. For example, dominant gene suppresses the effect of recessive gene and shows its effect on phenotype.
Representation	Basically, crossing means pairing a maternal gamete and a paternal gamete to form an offspring genotype. Actually, it represents the fertilization by means of combination of letters [gametes]. However, gamete pairing should be done completely-without omitting any gametes and correctly- done without any repetition to be able to represent correct probabilities [of offspring genotypes]. We employed the arrows in crossing to reach the correct results and not to cause any omits and repetition. Some of my students did not use arrows and write the result of crossing from their memory. I notified [my students] to use arrows when I saw them not use of any arrows [during crossing]. Students could not understand that two letters was gametogonium with diploid chromosomes and one letter germ cells with haploid chromosomes. For this reason, I can draw a big circle to show the gametogonium and a little circle for ovum and a little circle with a waving tail for sperm. This may help them understand letter pair and one letter represents different type of cells.
Students characteristics	Students at this age get easily bored in science lessons especially while teaching topics including abstract and condense information like genetics. The life of scientist attracts students' attention to the topic easily. I knew some of my students like to play drama. I selected five students for preparing the life of Mendel to dramatize in the classroom. I started to lesson with this drama play and it makes the genetics topic enjoyable for students. Students like computer activities. I try to find out computer activities for each topic. The Vitamin website was really beneficial to find activities related to our science curriculum. For the genetic topics, the vitamin website has different activities and I reserve one course hour for computer activities for each topics and for genetics topic as well.

Mert stated that his students could define the genetics concepts. However, they could not relate these concepts between each other. He tried to overcome students' difficulty by defining concepts with their relationships.

Mert highlighted to students' difficulties of notation of genotypes of dominant phenotype because it had two different genotypes. Moreover, his students preferred to write homozygous dominant genotype. He employed a pedigree and focused on parent's dominant phenotype and recessive phenotype offspring. He discussed the possibilities of genotype of these parents. Then he divided classroom into three genotype possibilities of dominant phenotype parents and he asked each group to cross three different genotypes.

When he employed the crossing arrows to show fertilization through combination of gametes, his students had a difficulty to follow these arrows order. The following order helps students correctly pair up gametes for genotype of offspring and it showed probabilities of offspring genotypes if there was not repetition or any missing of gamete pairs. However, his students did not use or followed the arrows and this caused errors of crossing results. Mert overcame this difficulty with just notifying his students to use arrows.

Other representational difficulty of Mert's students was that they could not understand parent genotype representing maternal or paternal gametogonium with diploid chromosomes and one-letter representing gametes with haploid chromosomes. Mert employed a big circle for gametogonium, a little circle ovum and a circle with a tail for sperm cell while teaching crossing.

Mert tried to catch his students' attentions by the drama of Mendel because he had belief that the scientist life was attractive for his students and his students like drama and find it enjoyable. Moreover, Mert integrated the computer activities in his teaching and he allowed an hour for online genetics activities such as crossing, video explanations for homozygous and heterozygous concepts.

To summarize; Mert employed different kinds of teaching strategies to help students to overcome difficulties while learning genetics topic. However, Mert showed limited knowledge on teaching strategies to overcome students' difficulties while teaching genetics.

4.4 The Case of Nehir

The description of Nehir for PCK and the analysis of PCK components of Nehir were presented.

4.4.1 Description of Nehir

Nehir had approximately 30 years of teaching experience and all of the experience has occurred as a middle school science teacher. She worked in almost all regions of Turkey. Her education background was different in that she graduated from department of Physics-Chemistry-Biology as a science teacher from the institute of education that was basement of today's faculty of education in that time. The institute of education had different teacher education. Nehir talked about her education as:

> Physics, Chemistry, and Biology were our main courses. I graduated in Physics-Chemistry-Biology, and science. I graduated at an accelerated education and school only took three years. We had a regular education in the first year, and we took accelerated education for the 2nd and 3rd year. The accelerated education took only 45 days. For that reason, I could not remember anything other than physics, chemistry, and biology. I took an additional year to obtain a graduate certificate from university. This additional year, I did not take any courses. They sent books to us and I studied them. The books I studied were human biology, general biology, genetics, and general evaluation. In this education, biology was selected and genetics as a part of the other books. I remember this much.

Nehir did not take any in-service education on science. As an in-service education, she involved only in "Disabled Education." Nehir's the classroom was not equipped with technology, it contained only student's desks, teacher's desks, and blackboard. School had a little but a well-equipped laboratory and the laboratory was equipped with technological devices: like notebook, projector, and Internet connection in addition to usual science laboratory equipment. She had 15 students and her students generally had low-level socio economic status. Most of her students did not attend cram school education besides school education.

4.4.2 Nehir's Understanding about Genetics

In this section, the first research question "What is the science teacher's understanding of genetics?" was analyzed. The science teachers understanding of genetics was evaluated with the help of genetics test (see Appendix A). The analysis of test presented with two main parts; understanding of genetics concepts and genetics crossing.

4.4.2.1 Understanding of Nehir about the Genetics Concepts

The analysis of answers of Nehir for the definition of seven genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous, see Appendix A) were given in Table 4.27.

Table 4.27. Definition of the Genetics Concepts given by Nehir

Concepts	Answer of Melis	Understanding of concepts		Ontological categorization	
		Partial	Sound	Matter	Process
Gene	It is DNA parts that is included in the structure of chromosome and that enable genetic traits transfer to next generation.	✓		✓	
Dominant gene	The gen that shows its effects in all cases.	✓		✓	
Recessive gene	Recessive gene. The gene that shows its effect if dominant gene does not exist.	✓		✓	
Genotype	It is all the genes belonging to the living being. (It is the denotation of phenotype)	✓		✓	
Phenotype	It is the appearance of the living being. (it is reflection of genotype on appearance.)	✓			✓
Homozygous	It is offspring generated by the same trait or features. (homozygous) (AA or aa).	✓		✓	
Heterozygous	It is offspring generated by different traits or features.(heterozygous) (Aa)	✓		✓	

Nehir’s definition of what a gene is “It is DNA parts that is included in the structure of chromosome and that enables genetic traits to transfer to the next generation.” The definition of Nehir included sound information about structure of a gene. For the function of a gene, there was partial information given in the definition because she only stated that a gene was responsible for transfer of inheritance traits. However, a gene was also responsible for phenotype of an organism. For this reason, her definition was considered as partial understanding according to scientific definition (see Table 3.5) and it was accepted in the matter category according to Chi et al. (1994).

Nehir defined dominant gene as “The gen that shows its effects in all cases.” She probably implied the homozygous and heterozygous genotypes with “all cases.” In addition, she did not mention the masking effect of dominant gene over recessive gene. It was a deficiency for both scientific definition and the role of the dominant gene. In this manner, her understanding of dominant gene was accepted as partial and her definition of dominant gene was in matter category. The definition of recessive gene was “… The gene that shows its effect if dominant gene does not exist.” She did not give any information when it presents with dominant gene in heterozygous genotype and did not mention that recessive gene was masked by dominant gene. Hence, her understanding of recessive gene was partial according to scientific definition (see Table 3.5) her definition of recessive gene was in matter category.

Nehir’s genotype definition was “It is all the genes belonging to the living being (It is the denotation of phenotype).” This definition included the entire set of genes in the scientific definition. Instead of the genotype expression as a phenotype, she defined it as the denotation of phenotype. As a result, her understanding was accepted as partial and her definition was in matter category.

She defined phenotype was “It is the appearance of the living being. (it is reflection of genotype on appearance.)” The second part of her definition “it is reflection of genotype on appearance.” was related with the interaction of genotype and phenotype. In this manner, her phenotype definition was accepted in the process category according to Chi et al. (1994). For the scientific definition, her phenotype definition did not include the interaction of its genotype and the environment. Consequently, her definition was accepted as partial understanding of phenotype.

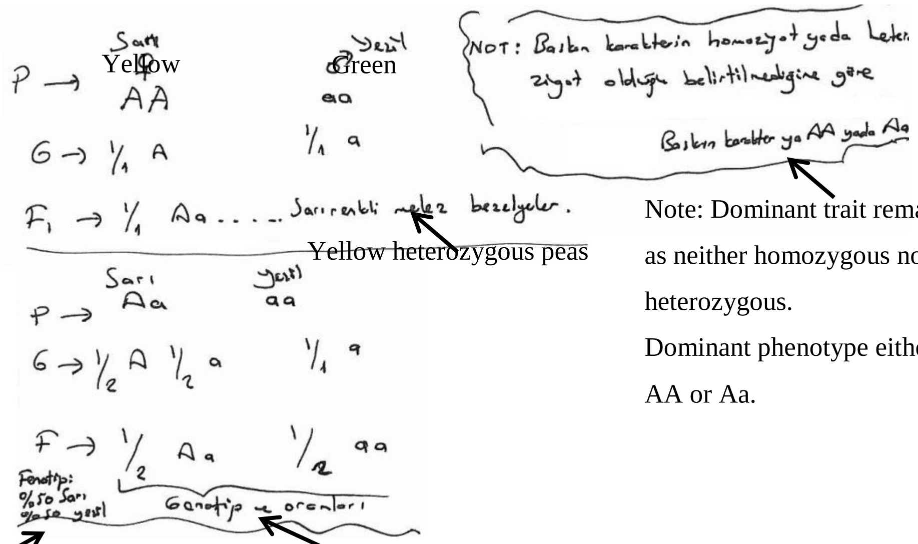
Definition of homozygous was “It is offspring generated by the same trait or features. (homozygous) (AA or aa).” and definition of heterozygous was “It is offspring generated by different traits or features (heterozygous) (Aa).” Nehir’s definition of homozygous and heterozygous shared similar characteristic. Both of the definitions were based on offspring and she just stated offspring generated by the same or different features. Both of her definitions explained just the structure of homozygous and heterozygous and she did not explain functioning part of the definition. Due to this deficiency, Nehir’s understanding of homozygous and heterozygous was accepted as partial. Moreover, her definitions of homozygous and heterozygous were categorized as in matter category.

To sum up, Nehir’s understanding about all genetics concepts was found as partial. Her ontological categorization results were six of genetics concepts in matter and only phenotype definition was in process category.

4.4.2.2 Nehir’s Understanding about the Crossing

In the genetics test, the result of analysis related to a monohybrid-crossing question in genetics test was presented in this section. The result of Nehir’s answers to crossing question was given in the Figure 4.5.

The answer of Nehir for crossing question was considered as sound understanding according to expected answer of the crossing (see Figure 3.4 and Table 3.6). Nehir correctly employed the information of dominant phenotype of the pea seed that have two-genotype probability. Nehir thought that there could be two different genotype (homozygous dominant, AA and heterozygous, Aa) for dominant phenotype (yellow seed color for peas) and one genotype (homozygous recessive, aa) for recessive phenotype (green seed color for peas). She wrote this information as a note on her crossing. Although she did not use genetics concepts like homozygous, heterozygous in her crossing, her answer included the correct usage of symbolization of genetics terms according to expected crossing answer.



Yellow

Green

Yellow heterozygous peas

Note: Dominant trait remarked as neither homozygous nor heterozygous.
Dominant phenotype either AA or Aa.

Phenotype
50% Yellow
50% Green

Ratio of genotypes and phenotypes

Figure 4.5. Nehir's Answer for Crossing Question

4.4.3 The Nature of Nehir's PCK Regarding the Topic of Genetics

In the second research question of the study "What is the nature of science teachers' PCK about genetics?" was investigated in this section. The result of the analysis of teachers' PCK was presented in three components with its sub-components.

i. Knowledge of curriculum,
ii. Knowledge of students
    a. Knowledge of students requirements
    b. Knowledge of students difficulties
iii. Knowledge of teaching strategies,
    a. Representations
    b. Activities
    c. Teaching strategies to overcome students' learning difficulties

4.4.3.1 Nehir’s Knowledge of Curriculum about Genetics

In this section, teachers’ knowledge about the curriculum related to genetics concepts was investigated. Nehir’s knowledge of curriculum about genetics was evaluated with the help of pre-PCK interview (see Appendix C) and classroom observation of the course. Result of pre-PCK interview about Nehir’s knowledge of curriculum was summarized in Table 4.28.

Table 4.28. Objectives Checklist for Nehir’s Answers for Curriculum Questions in the pre-PCK Interview

2006 Objectives Stated in Science Curriculum for Genetics Topic	Does teacher answer meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about the concept of gene.	✓		
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solve crossings problems related to inheritance of a single character.	✓		
2006 Limitations Stated in Science Curriculum for Genetics Topic			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	✓		
2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.	✓		
2006 Warnings Stated in Science Curriculum for Genetics Topic			
2.6. It should be stated that sex depends on sex chromosomes.	✓		

The results of interview with Nehir revealed that she had sound curriculum knowledge. Some of her statements in the interview also exemplified her knowledge of curriculum. Some examples of her excerpts were

> Students sometimes employed dominant and recessive in the classroom. They brought probably these terms from supplementary books or cram schools. For

> the reason that they [supplementary books writers or cram schools teachers] do not care much about the curriculum….
>
> Students bring some questions from supplementary books and some of them are not covered in the textbook or curriculum. For example, they asked hereditary disease crossings. I rejected to solve this kind of problems because exam committee stated that exam would assess the knowledge covered by the curriculum. …I warn my students these are not part of the curriculum whenever they employed the term or asked the question not covered by the curriculum.

Nehir’s given statements depicted that she was aware that the dominant and recessive terms should not be employed in the lesson and hereditary disease crossings should not be held in the genetics teaching.

Nehir’s knowledge of curriculum about genetics was also evaluated with classroom observation. The evaluation of curriculum knowledge for Nehir’s observation was given in Table 4.29.

Table 4.29. Objectives Checklist for Teaching of Nehir’s Observation

2006 Curriculum Objectives for Genetics Topic	Does teacher teaching meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene.	✓		
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solves crossings problems related to inheritance of a single character.	✓		
Limitation			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	✓		
2.6. Hemophilia, sickle cell anemia, color blindness, Down syndrome, etc. are given as examples of inherited disease.	✓		
Warning			
2.6. It should be stated that sex depends on sex chromosomes	✓		

According to Table 4.29, Nehir showed sound curriculum knowledge for genetics topic in her teaching. The characteristic of Nehir’s teaching was strictly science course textbook based. She followed the textbook activities, examples, and problems straightforwardly. Obviously, Nehir's teaching in the classroom generally was based upon the curriculum objectives. The question of "Why do you use generally the textbook examples and problems in the classroom?" was asked to Nehir in the post-PCK interview:

> I employed textbook examples and problem because it was easy for my students to repeat the course at home. If I employed the different examples from textbook, they have to write notebook, and I can admit that some of the students did not take good notes in their notebook. This causes problem of repeating the course at home and affect their study habit. This [not taking note in the classroom] is also time saver for me.

On the other hand, in some of the cases she changed the examples, and sex crossing was one of the examples for this case. Her problem was "A family has two children and they are expecting a new baby, what is the probability of the sex of a new baby, a girl or a boy?" and then students asked question of "what are sex of the previous children?" to her. Nehir explained:

> I asked this question intentionally because students have an idea that sex of previous child effect the following child sex. I want to teach them determination of sex was independent from previous child sex. You do not need to know sexs of previous children.

Another Nehir's additional activity was constructing pedigree based on observable traits and she employed this pedigree to increase understanding of students on genetic and acquired traits. She employed another pedigree to help students' understanding about dominant and recessive traits. Nehir also conducted a frequency table activity on dominant and recessive concepts. All of these activities were produced by Nehir for increasing the students understanding about genetics.

For the curriculum knowledge of Nehir, the some activities were missing in her teaching such as "Let's help the Mendel," and "Search the gene and dominant-recessive genes." She stated time limitation as a reason not to implement these textbook activities.

The evaluation of knowledge of curriculum about genetics with the help of pre-PCK interview and classroom observation revealed that Nehir has sound knowledge of curriculum.

4.4.3.2 Nehir's Knowledge of Students about Genetics

In this section, teachers' knowledge about students in learning genetics concepts was investigated. Student knowledge was analyzed under two titles; requirements of students and difficulties of students while learning genetics topic.

4.4.3.2.1 Nehir's Knowledge of Students' Requirements for Genetics

In this section, the requirements of students were presented with examples of teachers' responses. Teachers' knowledge of students' requirements for learning genetics was evaluated with the help of pre-PCK interview (see Appendix C). The dimensions appeared in data analysis of Nehir's knowledge of students' requirements for genetics and examples of her response were shown in Table 4.30.

According to Nehir, students thought only human can sexually reproduce. Prior to teaching of crossing in plant examples, students should have knowledge about fertilization of plants. This was also a misconception of students and previous studies (e.g. Tekkaya, 2002) stated this misconception as "Sexual reproduction occurs in animals but not in plants." Besides scientific knowledge, students should know how to represent different fraction and percentages related to crossing results. Nehir also mentioned about some skills require for learning genetics. For problems solving, she helped her students understand and detecting the information from problem statements. Students could not predict and think the possibilities genotype of dominant phenotype. Her students could not think that crossing results represents baby or immature offspring and these offspring needs time so as to animals or plants were mature enough to reproduce sexually. They probably could not think that the representation of crossing refer to an animal or plant. Students just algorithmically followed the crossing tasks and they did not think biological process in crossing.

Table 4.30. Nehir's Knowledge of Students' Requirements for Learning Genetics

Dimension of requirements	Requirements	Responses of Nehir
Knowledge	Science	I stated in the lesson pea reproduced sexually because some of my students think that only humans have sexually reproduce and plants do not. For this reason, I feel that there is a need to explain that plants sexually reproduce.
	Mathematics	When students study with different books, they see the different representation of fraction and they could not understand well these ratios. For this reason, you have to teach different fraction in classroom such as 1/1 equals to %100. The crossing problems asked generally the desired phenotype or genotype ratios or percentages. For this reason, while teaching I focused on that my students should be able to state the results in fraction or percentages the question required.
Skills	Problem solving	Teaching the genetics was based on the crossing problems. I teach how to solve this problem in my courses based on the crossing tasks. However, students face the difficulty with detecting the information from the problem statements. Even some of them could not detect which is the phenotype or genotype or some of them could not understand what the problem asked clearly. While solving problem, I help them in the blackboard or in their desks how to approach the problem statements.
	Prediction	When problem gives only information about dominant phenotype, students have to predict that it may have two different genotypes; homozygous dominant and heterozygous. However, many of the students prefer to use homozygous genotype, although it can be heterozygous.
Maturity	Formal-operational	I stated that we crossed parent and obtained offspring and these offspring should grow up to be mature enough to be able to sexually reproduce and I explain this for each different animal or plant example. I have to state the explanation otherwise; students can think that offspring directly can reproduce sexually. They could not think that following crossings include time to be mature. They bounded to representation firmly and these [representations] are abstract for these age students to comprehend deeply.

Nehir could not mention about any graphical reading skill as requirements of students for learning genetics. Above and beyond, Nehir mentioned about some knowledge about students for learning genetics. Nehir stated that girls find mouse examples as disgusting. Some students found the term of döl [offspring in Turkish] as funny and they did not know the meaning of döl as offspring in biology and Nehir feel has to explain the term of döl in the classroom. Some students even understand döl as a kind of insult in Turkish. Nehir stated that I have to talk about marriage while teaching hereditary disease and students are ashamed while talking about marriage. This information also can be taken into consideration while teaching genetics topic. The results of data analysis of Nehir depicted that she had sound knowledge of her students' requirements for genetics topic.

4.4.3.2.2 Nehir's Knowledge of Students' Difficulties in Learning Genetics

The dimensions appeared in the data analysis of Nehir's knowledge of students' difficulties while learning genetics and examples of her response were shown in Table 4.31.

Table 4.31. Nehir's Knowledge of Students' Difficulties While Learning Genetics

Difficulties	Responses of Nehir
Understanding	Students did not learn meiosis and therefore they have difficulty of how meiosis is related to genetics. …students were not cognizant of gamete formation and fertilization during crossing. I stated in the lesson pea reproduce sexually because some of my students do think that only humans sexually reproduce and plants do not. For this reason, I think it is necessary to explain that plants sexually reproduce.
Relationship	Even though the students who can relate the meiosis and fertilization with genetic crossing, some of them cannot clearly label the crossing tasks with these concepts.

Table 4.31. *Nehir's Knowledge of Students' Difficulties While Learning Genetics (Continued)*

Difficulties	Responses of Nehir
Crossing	Cram schools teach a method for solving monohybrid-crossing problems that was like a subtraction and addition of letters, a kind of algebraic solution based on distribution property of multiplication. It was like Aa x Aa = (½A + ½a) x (½A + ½a) = ¼AA + 2/4Aa + ¼aa Even though students always reach the successful solutions, this method make it difficult for the students to relate what they were doing while following to crossing tasks although they have given some information about meiosis and fertilization. In this algebraic method, students lost sight how their procedure could be accounted for meiosis and fertilization. This method just provides correct probability of letter pairs. It is important to point out that on multiple-choice [genetics-crossing] problem this erroneous model would never have shown up in their answers, which would have been correct.
Sources	**Responses of Nehir**
Concept	Students perceived that common traits should be dominant trait and uncommon one should be recessive trait. For example, I remember they stated straight hair as a dominant trait and curly hair as a recessive one. Students think that it is possible to inherit acquired trait. For example, if a sportsman has large muscles by means of hours of exercise, s/he will pass this trait to their offspring. Sometimes my students give different traits as genetic traits examples such as wound, music, or sportive talents.
Representation	I experience that students confused these (Uu, Ss, Iı, etc.) letters because their upper case and lower case letters are similar. Some of students even write similar size all letters of words whether upper or lower case in their writings. If they use similar letter of upper and lower cases in crossing, this causes big confusion to interpretation of result of crossing and learning genetics. For example, when Uu x Uu crossing is asked to students, the result is UU-Uu-Uu-uu. However, some of the students can write any kind of combination of this result because of similarity of upper cases, such as UU-UU-Uu-Uu; uu-uu-Uu-uu. Some of the students abuse also these letters for grading. S/he writes any kind of the results and when you said this is not correct answer, s/he state my upper U is u or lower u is also again U and I mean s/he tries to make you believe in her or his answer is correct.
Probability	They do not comprehend clearly the segregation and independent assortment. They even think the formation of gametes and fertilization of gametes are dependent on the sequence of the crossing results. They do not comprehend crossing results represent the probabilities [of genotypes] and all [genotype] probabilities are [independently] possible for each new offspring.
Students characteristics	Some of students can undervalue the risk of cousin marriage because they have some relative who married to a cousin and they have healthy children.

Nehir indicated that her students experience different kinds of difficulties while learning genetics. Some of the Nehir's students cannot relate and label the crossing tasks with some process such as fertilization, meiosis, gamete formation and gametes, gametogonium etc. Moreover, her students did not understand that gamete formation and fertilization happens while the crossing tasks represented. However, students could not relate that they were representation of these tasks. Besides, she stated one of the students' misconception that "…humans have sexually reproduce and plants do not." This misconception was addressed previous studies (e.g. Tekkaya, 2002).

Some of the Nehir's students had difficulty in crossing and the source of difficulty was the method taught by cram school. She named this method as algebraic method and this method seems like the distribution property of multiplication. Although students reached the correct solution, Nehir did not prefer to use this algebraic method in her lessons and she employed crossing with arrows. As the source of difficulty, Nehir's students had difficulty in concept of inherited traits because they were confusing inherited traits with acquired traits such as music or sportive talent.

In students' writing of the uppercase and lowercase, some letters (Uu, Ss, Iı, etc.) caused confusion because they wrote letter in similar size which make the differentiating the lower case and the uppercase letters from each other difficult. Another point was that her students had difficulty in understanding the independent probability of each new offspring. Moreover, her students could not correctly estimate probable negative effect of cousin marriage and they undervalue the risk of having a hereditary disease child.

The analysis and results of Nehir's data depicted that she had sound knowledge of students' difficulties while learning genetics topic.

4.4.3.3 Nehir’s Knowledge of Teaching Strategies

Teacher knowledge about teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with two titles subject specific and topic specific teaching strategies.

4.4.3.3.1 Knowledge of Subject Specific Strategies

Nehir did not use any noticeable subject specific teaching method such as learning cycle, discovery, inquiry or conceptual change oriented instruction, guided instruction, generative learning model and so on (Magnusson et al. 1999).

Nehir followed the science textbook closely in her classroom and gave direction to her students like open the page 22 and look at the historical developments in genetics. She applied and employed most of the textbook examples, homework, and activities. She explained the reason for using textbook as:

> Concerning the students working habit, it was easy for them to follow textbook while studying at home. Some students did not take good note in the course and if I want to give the different examples, they have to take notes in their notebook and study on it. This is time consuming as well.

She only made changes and insertions when she felt there is a need of students on the concept or the topic. She conducted first crossing with explaining task by task and then asked to students to use the same task order in their crossings. Same teaching pattern was seen on teaching sex crossing and pedigrees.

The main characteristic of Nehir’s teaching was mostly teacher centered. She allowed her students to share their ideas and frequently asked topic related questions. Nehir expected from her students to be eager to share their ideas in the classroom and promote her students to solve the crossing problems on the blackboard.

4.4.3.3.2 Knowledge of Topic Specific Strategies

Teacher knowledge about topic specific teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with three headings as; representation, activities and employed strategies to overcome students' difficulties, respectively. Teacher's knowledge of teaching strategies was evaluated with the help of the pre-PCK interview (see Appendix C), observation of the course and the post-PCK interview.

4.4.3.3.2.1 The Representations Employed by Nehir While Teaching Genetics

The teaching strategies were covered under in three sub-titles, the first one related with representation, and the data analysis for representation lead to two categories namely; "illustrations," and "examples." The examples of employed representations by Nehir while teaching genetics were shown in Table 4.32.

Nehir's representation application was mainly focus on crossing. However, she made five applications in the crossing. First one is the letter selection and she did not prefer to use letters which have similar upper and lower cases because of causing confusion. Second was using sex symbols (♀, ♂) and she supported her approach for the application by stating "using sex symbols (♀, ♂) helps my students to recognize that crossing means sexual reproduction and crossing includes meiosis and fertilization." Third is using different color in crossing enables students follow the gamete and this helped them to visualize meiosis and sexual reproduction in crossing. Fourth and fifth are not using arrows and x symbols in crossing. Nehir believed that more symbols cause confusion because genetics already have many new things. Nehir also thought that her students were probably affected from cram school teaching.

Table 4.32. The Representations Employed by Nehir While Teaching Genetics

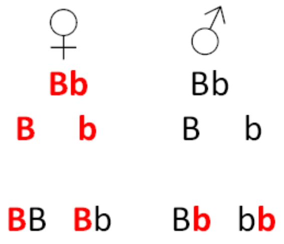
Dimension of representations	Responses of Nehir
Illustrations	Teacher Nehir wrote some letters (Uu, Ss, Iı, etc.) in blackboard and state “I do not use these letters in crossing traits. I expect not to use these letters in the exam.” I experience that students confused these (Uu, Ss, Iı, etc.) letters because their upper case and lower case letters are similar. Some of students even write similar size all letters of words whether upper or lower case in their writings. If they use similar letter of upper and lower cases in crossing, this causes big confusion to interpretation of result of crossing and learning genetics. For example, when Uu x Uu crossing is asked to students, the result is UU-Uu-Uu-uu. However, some of the students can write any kind of combination of this result because of similarity of upper cases, such as UU-UU-Uu-Uu; uu-uu-Uu-uu. Some of the students abuse also these letters for grading. S/he writes any kind of the results and when you said this is not correct answer, s/he state my upper U is u or lower u is also again U and I mean s/he tries to make you believe in her or his answer is correct. The following is an example of Nehir’s crossing (Observation) While teaching crossing,  Nehir employed sex symbols (♀, ♂), she explained that “sex symbols refer to mother and father and students can see the one gamete came from father and other gamete came from mother. This usage represents sexual reproduction and using sex symbols made it easier to explain meiosis and fertilization while teaching crossing.” She prefers to use red color pen for representing mother genotype, gametes, and offspring’s alleles. She stated “…different colors enable students to imagine that each offspring allele pair composed of both parents gametes. Moreover, meiosis, gametogenesis, and fertilization can be seen and taught more easily by means of following parents’ alleles while crossing. Besides, students especially girls like to use colors while taking notes.” She did not use arrows, because she thought that, “Some of my students use arrows without thinking, or following the crossing tasks. These students only draw the arrows and write the crossing results. Sometimes, they write crossing results different from what the arrows represents. They can learn some test techniques from cram schools and they mindlessly follow these techniques while solving problems. I want my students think what they are doing while crossing. For these reasons, I warn my students not to use arrows while crossing.” She did not use x symbols (like Bb x Bb). When asked, she stated “Basically, I see that the more symbols use in crossing, the more students mind confuse to learn genetics, because the topic of genetics already has many concepts and symbols. On the other hand, students think crossing is like an algebraic method such as distribution property of multiplication. For this reason, I do not want to use x symbols in crossing.”

Table 4.32. The Representations Employed by Nehir While Teaching Genetics (Continued)

Dimension of representations	Responses of Nehir
Examples	She gave cats, dogs, and other pets as example for observing the animal to see the resemblance between parents and their offspring. Her reason behind of the example selection was stated as "I want my students observe their environment which they live and I want them to generalize genetic rules for all living beings. Moreover, I know some of my students have pet in their home and this is a chance to observe their animals." Nehir follows textbook while teaching and her crossing examples was based on the textbook examples. Nehir explained her examples preferences as "In my opinion, different examples cause confusion in students' minds. Concerning the students working habit, it was easy for them to follow textbook while studying at home. Some students did not take good note in the course and if I want to give different examples, they have to take notes in their notebook and study on it. This is time consuming as well."

Nehir's example selection was based on textbook and students' experiences. Behind of the example selection from textbook was based on reasons that students could easily follow the textbook and each addition also increase the complexity of the genetics topics for students. By giving the pets as an example of genetics, she expected from her students to observe their pets and to see the genetics mechanism work in their daily life as well.

The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Nehir had sound knowledge of representations to teach genetics concepts in order to facilitate students' learning.

4.4.3.3.2.2 The Activities Employed by Nehir While Teaching Genetics

The activities employed by Nehir while teaching genetics were problem solving about crossing, students' construction of their own pedigree, probability, and frequency table (Table 4.33).

Table 4.33. The Activities Employed by Nehir While Teaching Genetics

Type of activities	Observation data
Problem solving	General crossing problem - Cross two heterozygous purple flower pea plant (purple flower color is dominant over white flower color) (Observation). Sex crossing problem - A family has two children and they are expecting a new baby, what is the probability of the sex of a new baby, a girl or a boy? (Observation). Hereditary and pedigree problem - Determine phenotype and genotype of Mert’s family on his pedigree. (Observation).
Pedigree construction	I gave them an assignment about preparing a pedigree for three observable traits on a poster. I gave assignment of preparation of pedigree and the frequency table of traits based on the pedigree. This assignment helped my students to have sound understanding of dominant and recessive traits that does not depend on the frequency in the populations.
Probability	I employed sex probability activity based on tossing two-coins. The first coin represents the father and it was written X letter on one side and Y was written other side. The second coin represents the mother and both side of the coin were written with X letter. We conducted this activity with all my students. This activity help students to understand that probability in sex crossing and the crossings results did no depend on the previous child sex or genotypes.
Frequency table	While teaching dominant and recessive, I draw a table on the black board and write some genetic traits such as attached-unattached earlobe, rolling tongue, dimples, freckles, etc., without stating which one is dominant or recessive. I asked classroom hang up if you have attached earlobe and for each genetic traits written on the table. One of the students filled the table with each traits frequency. These activities make the idea clear enough that frequency of a trait in population does not give information about whether it is dominant or recessive. That is, a dominant trait is not necessarily more common and a recessive trait is not necessarily rare in a population. The ratio is misleading to determine which trait allele is dominant or recessive. I exemplified the situation with classroom frequency table and known trait such as straight hair is more common than curly hair in our country.

Nehir’s main activity on teaching genetics was problem solving about genetic crossing. The characteristic point of her problems was strictly selected the textbook problems and almost all of the problems was on the textbook. She only produced sex crossing problems for her students. Her problem was

> A family has two children and they are expecting a new baby, what is the probability of the sex of a new baby, a girl or a boy? and students asked question “what are sex of the previous children?”

Teachers explained that:

> I asked this question intentionally because students have an idea that sex of previous child effect the following child sex. I want to teach them determination of sex was independent from previous child sex. You do not need to know previous children sex.

Another Nehir’s activity was constructing pedigree based on observable traits and she employed this pedigree to increase understanding of students on genetic and acquired traits. She employed another pedigree to help students’ understanding about dominant and recessive traits. Nehir also conducted a frequency table activity on dominant and recessive concepts. All of these activities were produced by Nehir for increasing the students understanding about genetics. The shared characteristics of her activities was one was that students were the active in her teaching. Another is the easiness of application of the activities all kind of classroom because there were no requirements of materials.

The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Nehir had sound knowledge of activities to teach genetics concepts in order to facilitate students’ learning.

4.4.3.3.2.3 Teaching Strategies Employed by Nehir to Overcome Students’ Difficulties While Teaching Genetics

The classification of learning difficulties and the respective teaching strategies employed by Nehir were given in Table 4.34.

Table 4.34. Teaching Strategies Employed by Nehir to Overcome Students' Difficulties While Teaching Genetics

Difficulties	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Understanding	Students did not learn meiosis and therefore they have difficulty about how it is related to genetics. Students were not cognizant of gamete formation and fertilization during crossing. I tried to relate each task of crossing with meiosis and fertilization during crossing. For example, when we are separating the parent genotypes I stated that the splitting of letters happens due to the meiosis. Moreover, the combination of letters to form offspring's genotype means fertilization to from zygote. We have to teach meiosis and fertilization after the genetics topic and this is a hindrance to teach students to relate genetics crossing with meiosis and fertilization.
Relationship	Even the students who can relate the meiosis and fertilization with genetic crossing, some of them cannot clearly label the crossing tasks with these concepts. During teaching the first crossing, I briefly explain each crossing tasks and the relationship with meiosis and fertilization. For example, dividing the letters of parents genotype, this represent the gamete formation and parents' allele pair represents diploid gametogonium, one allele represents gamete the and the process is meiosis. However, we have to teach meiosis and fertilization after the genetics topic because of the curriculum topics order.
Crossing	Cram schools teach a method for solving monohybrid-crossing problems that was like a subtraction and addition of letters, a kind of algebraic solution based on distribution property of multiplication. It was like $Aa \times Aa = (\tfrac{1}{2}A + \tfrac{1}{2}a) \times (\tfrac{1}{2}A + \tfrac{1}{2}a) = \tfrac{1}{4}AA + 2/4Aa + \tfrac{1}{4}aa$ Even though students always reach the successful solutions, this method make it difficult for the students to relate what they were doing while following to crossing tasks although they have given some information about meiosis and fertilization. In this algebraic method, students lost sight how their procedure could be accounted for meiosis and fertilization. This method just provides correct probability of letter pairs. It is important to point out that on multiple-choice [genetics-crossing] problem this erroneous model would never have shown up in their answers, which would have been correct. For these reasons, I do not prefer to use cram school method. Instead I prefer to use crossing with arrows because it enable us to show crossing tasks with their meaning as much as possible. Even I do not prefer to use punnet square because students also just behave like cramming the procedure to solution without thinking the meaning of what we are doing.

Table 4.34. Teaching Strategies Employed by Nehir to Overcome Students' Difficulties While Teaching Genetics (Continued)

Sources	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Concept	Students think that it is possible to inherit acquired traits. For example, if a sportsman has large muscles by means of hours of exercise, s/he will pass this trair to their offspring. Sometimes my students give different traits as genetic traits examples such as wound, music or sportive talents. I gave them an assignment required to prepare a pedigree for three observable traits on a poster to be able to show to classroom. Even most of the students select the genetic traits for their pedigree poster; some of the selected traits included acquired traits. Then we examined some of the poster in the extent of how traits pass from parents to children. This examination help me to show and explain that acquired traits is not a genetic traits. Students perceived that common traits should be dominant traits and uncommon one should be recessive traits. For example, I remember they stated straight hair as a dominant trait and curly hair as a recessive one. While teaching dominant and recessive, I draw a table on the black board and write some genetic traits such as attached-unattached earlobe, rolling tongue, dimples, freckles, etc., without stating which one is dominant or recessive. I asked classroom hang up if you have attached earlobe and for each genetic traits written on the table. One of the students filled the table with each traits frequency. These activities make the idea clear enough that frequency of a trait in population does not give information about whether it is dominant or recessive. That is, a dominant trait is not necessarily more common and a recessive trait is not necessarily rare in a population. The ratio is misleading to determine which trait allele is dominant or recessive. I exemplified the situation with classroom frequency table and known trait such as straight hair is more common than curly hair in our country. For this reason, I gave them the following assignment to increase their comprehension on dominance and recessiveness. This assignment includes preparation of pedigree and preparing the frequency table of traits based on the pedigree. This assignment helped also them to have sound understanding that frequency of a trait in population does not give information about whether it is dominant or recessive
Representation	…Some of students even write similar size all letters of words whether upper or lower case in their writing. Teacher Nehir wrote some letters (Uu, Ss, Iı, etc.) in blackboard and state "I do not use these letters in crossing traits. I expect not to use these letters in exam."

Table 4.34. Teaching Strategies Employed by Nehir to Overcome Students' Difficulties While Teaching Genetics (Continued)

Sources	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Probability	They do not comprehend clearly the segregation and independent assortment. They even think the formation of gametes and fertilization of gametes are dependent on the sequence of the crossing results. They do not comprehend crossing results representing the probabilities [of genotypes] and all [genotype] probabilities are [independently] possible for each new offspring. There was an activity on the book helping the Mendel. This activity focused on the probability of gene pairs. We might conduct this activity but I did not have time to do this activity. However, I applied sex probability activity based on tossing two-coins. The first coin represents the father and one side of it was written X letter and other side was written Y. The second coin represents the mother and both side of the coin was written with X letter. We conducted this activity with all students. This activity help students to understand that probability in sex crossing and the crossings results did no depend on the previous child sex or genotypes.
Students characteristics	Some of students can undervalue the risk of cousin marriage because they have some relative who married to a cousin and they have healthy children. The topic of hereditary disease is really important for me. Before teaching hereditary disease and cousin marriage, I asked each student sequentially the questions "Do you have any relative marry with another a cousin or a relative? Do cousin couples have any children having health problem? Is there any cousin couples have healthy children? Do you think that you can get married to a cousin?" I asked these questions to all of the students in the classroom and took their opinion. Then I started to teach hereditary diseases and warn them to possible disease if they make cousin marriage. I wanted them become aware of the possible risk of cousin couple marriage.

Some of the Nehir's students did not relate and label the crossing tasks with some process such as fertilization, meiosis, gamete formation and concepts gametes, gametogonium. Nehir overcame students' difficulties by explaining each crossing tasks with meiosis and fertilization and their related concepts. She also highlighted to teachers difficulties for teaching genetics by stating "…we have to teach meiosis and fertilization after the genetics topic because of the curriculum topics order." Students did not understand that gamete formation and fertilization happen while the crossing tasks represented. However, students could not referee them as representations of these tasks due to their knowledge deficiencies about gamete formation and fertilization. Teacher Nehir got through this difficulty by means of in depth explanation of the crossing tasks. Another source of difficulty of Nehir's students was the cram school method. She named this method as algebraic method and this method seems like a distribution property of multiplication. Although students reached the correct solution, Nehir did not prefer to use algebraic method in her lessons and she employed crossing with arrows.

Her students had difficulty with concept of inherited traits because they were confusing inherited traits with acquired traits such as music or sportive talent. She helped her students to get over this problem by constructing a pedigree on observable traits; some of the traits were acquired traits and some of them were genetic traits. Then Nehir examined students' pedigrees by tracking the traits transition through generations. Her students thought that dominant traits should be common traits. She employed the activity of the preparing pedigree and frequency table of selected traits to help her students for overcoming this difficulty.

According to her, students' writing of the uppercase and lowercase some letters (Uu, Ss, Iı, etc.) caused confusion because they wrote letter in similar size which made the differentiating the lower case and the uppercase letter from each other difficult. As to get over this difficulty, she did not prefer to use these letters while teaching crossing and warn them about not to use in the exam.

Students had difficulty in understanding the independent probability of each new offspring. Actually Nehir did not apply any strategy to overcome this difficulty for normal crossing, she employed tossing a coin activity by each students for helping understanding the probability of sex crossing.

Students could not correctly estimate probable negative effect of cousin marriage and they undervalued the risk of having a hereditary disease child. Nehir took all students' opinion about cousin marriage by asking the questions. She warned verbally the possible effect of cousin marriage.

To summarize; Nehir generated and utilized special and different kinds of teaching strategies to help students to overcome difficulties while learning genetics topic. However, Nehir showed limited knowledge on teaching strategies to overcome students’ difficulties while teaching genetics.

4.5 The Case of Seda

The description of Seda for PCK and the analysis of PCK components of Seda were presented.

4.5.1 Description of Seda

Seda graduated from the department of chemistry education in the faculty of education. Furthermore, she took biology education as a minor. Seda took the entire pedagogy course in the faculty of educational. During undergraduate education, she took genetic courses. She explained this as follows:

> I graduated in 1985 and at that time there was not much input about genetics in that time. That is to say, genetics was not broad like today. We took genetics last year of teacher education program as two semesters and two courses.

Seda did not take any in-service education on science. She took in-service education on “Assessment and Evaluation,” and “Drama Education.”

One of the different characteristic of Seda was that she worked for 6 year on pharmacy laboratory and had gained good laboratory skills. Another Seda’s distinctive characteristic was that she had 15 years of teaching experience as a middle school science teacher. Additionally, Seda worked as a problem writer on science and biology in the Ministry of National Education for two years. After this experience, she also sent questions to National Education Question Bank.

Seda’s the classroom was not equipped with technology, it contained only student’s desks, teacher’s desks, and blackboard. School had a well-equipped laboratory and the laboratory was equipped with technological devices: including notebook, projector, and Internet connection in addition to usual science laboratory equipment. She had 15 students and her students generally had low to moderate level socio economic status. Around half of her students attended cram school education besides school education.

4.5.2 Seda's Understanding about Genetics

In this section, the first research question "What is the science teacher's understanding of genetics?" was analyzed. The science teachers understanding of genetics was evaluated with the help of genetics test (see Appendix A). The analysis of test presented with two main parts; understanding of genetics concepts and genetics crossing.

4.5.2.1 Understanding of Seda about the Genetics Concepts

The analysis of answers of Seda for the definition of seven genetics concepts (gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous, see Appendix A) were given in Table 4.35.

Seda's definition of what a gene was "It is the smallest unit of DNA carrying hereditary information." Her definition was considered as partial understanding according to scientific definition (see Table 3.5). The definition of Seda included deficiencies in function of a gene. The definition of Seda included sound information about structure of a gene "It is the smallest unit of DNA carrying hereditary information" this was accepted because a gene is the smallest meaningful unit of a DNA.

Table 4.35. Definition of the Genetics Concepts given by Seda

Concepts	Answer of Melis	Understanding of concepts		Ontological categorization	
		Partial	Sound	Matter	Process
Gene	It is the smallest unit of DNA carrying hereditary information.	✓		✓	
Dominant gene	They are the traits revealed in the appearance.	✓			✓
Recessive gene	It appears, if it is homozygous recessive.		✓		✓
Genotype	The gene composition of a living being.	✓		✓	
Phenotype	The trait related to appearance.	✓		✓	
Homozygous	It is the situation where both of the allele genes are dominant or recessive.	✓		✓	
Heterozygous	it is the situation where dominant or recessive trait existing together.	✓		✓	

On the other hand, the function part of her definition had deficiency because she only referred the “carrying hereditary information.” However, a gene also is responsible for phenotype of an organism. For this reasons, her definition was accepted as partial understanding according to scientific definition (see Table 3.5). Regarding the ontological category of Seda’s definition of a gene, it was in the matter category according to Chi et al. (1994).

Seda’s definition of dominant gene was “They are the traits revealed in the appearance.” This definition had a deficiency that it did not include any information about the masking effect of dominant gene according to scientific definition (see Table 3.5). In this regard, the understanding of Seda for the dominant gene was accepted as partial. The definition part was “revealed in the appearance” was related to function of dominant gene and her definition of ontological category was in process. Her definition of recessive gene was “It appears, if it is homozygous recessive.” This definition implied the masking effect of dominant gene by means of “…if it is homozygous.” It was accepted as sound understanding for the recessive gene. The definition part “it appears…” related to function of recessive gene and in this regard, it was in the process category.

Seda definition of genotype was “The gene composition of a living being.” Her definition was deficient especially genotype role in expression of a trait. For this reason, Seda’s understanding of genotype was accepted as partial understanding and ontological category of her definition was in matter category. Similar deficiency was seen in the definition of phenotype and she defined it as “The trait related to appearance.” She did not give any information about the interaction of its genotype and the environment. According to scientific definition (see Table 3.5), her understanding was accepted as partial. This deficiency also related the mechanism of phenotype and the ontological categorization of phenotype was in matter category.

Definition of homozygous was “It is the situation where both of the allele genes are dominant or recessive.” and definition of heterozygous was “it is the situation where dominant or recessive trait existing together.” Seda definition of homozygous and heterozygous shared similar trait. In both of the definitions, she explained the situation where same alleles or different alleles are existing together. These definitions did not explain the roles of homozygous and heterozygous. For this reason both of the homozygous and heterozygous definition was accepted as partial understanding and they were in matter category according to Chi et al. (1994).

In briefly, Seda's understanding about six genetics concepts was found as partial and only recessive gene was found as sound understanding. Her ontological categorization results indicated that five of genetics concepts were in matter and two concepts (dominant and recessive gene) definitions were in process category.

4.5.2.2 Seda's Understanding about the Crossing

In the genetics test, the result of analysis related to a monohybrid-crossing question in genetics test was presented in this section. The result of Seda's answers to crossing question is given in the Figure 4.6.

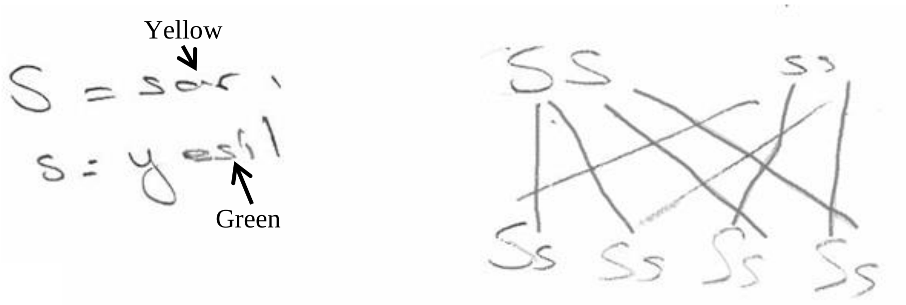


Figure 4.6. Seda's Answer for Crossing Question

The answer of Seda for crossing question was considered as partial understanding according to expected answer of the crossing question (see Figure 3.4 and Table 3.6). Seda could not write the two crossings for the information of dominant phenotype of the pea seed that have two-genotype probability. She referred to the yellow color phenotype as homozygous dominant and solve with only one crossing. Although, she did not use all genetics concepts in each crossing task, her answer included the correct usage of symbolization of genetics terms according to expected crossing answer.

4.5.3 The Nature of Seda's PCK Regarding the Topic of Genetics

In the second research question of the study "What is the nature of science teachers' PCK about genetics?" was investigated in this section. The result of the analysis of teachers' PCK was presented in three components with its sub-components.

i. Knowledge of curriculum,
ii. Knowledge of students
    a. Knowledge of students requirements
    b. Knowledge of students difficulties
iii. Knowledge of teaching strategies,
    a. Representations
    b. Activities
    c. Teaching strategies to overcome students' learning difficulties

4.5.3.1 Seda's Knowledge of Curriculum about Genetics

In this section, teachers' knowledge about the curriculum related to genetics concepts was investigated. Seda's knowledge of curriculum about genetics was evaluated with the help of pre-PCK interview (see Appendix C) and classroom observation of the course. Result of pre-PCK interview about Seda's knowledge of curriculum was summarized in Table 4.36

The analysis of Seda interview revealed that she had limited curriculum knowledge. Seda employed homozigot [arı döl] [homozygous], heterozigot [melez] [heterozygous], allele genes, dominant [baskın] [dominant], resesif [çekinik] [recessive]" in the interviews and these terms helpedwere not included in the curriculum and textbook [the first parenthesis are the Turkish terms textbook employed].

When asked Seda, “What are the objectives related with crossing?” in pre-PCK interview, Seda answered that:

> … I teach crossing for hereditary disease. Teaching the hereditary diseases and hereditary disease crossing is the most important issue in genetics topic for me. Because our school families are poor families …many of parents are relatives each other. … on the other hand, many of my students’ families had cross-cousin marriage and even hereditary disease offspring in their family as well. I want to protect them …I strictly warn them about the probable risk factors of cousin marriage and having hereditary disease children. I teach them sex linked hereditary disease crossing as well. …some of the students in our schools do not continue to education after middle school… They may have no other chance to learn these issues... Their families are not thinking that cross-cousin marriages have an issue, I heard this from my students, they stated in the classroom.

Table 4.36. Objectives Checklist for Seda’s Answers for Curriculum Questions in the pre-PCK Interview

2006 Objectives Stated in Science Curriculum for Genetics Topic	Does teacher answer meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about the concept of gene.	✓		
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solve crossings problems related to inheritance of a single character.		✓	
2006 Limitations Stated in Science Curriculum for Genetics Topic			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	✓		
2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.		✓	
2006 Warnings Stated in Science Curriculum for Genetics Topic			
2.6. It should be stated that sex depends on sex chromosomes.		✓	

Moreover, during pre-PCK interview, Seda mentioned sex crossing in the crossing. However, she added the sex linked hereditary disease “…I teach sex crossing and they employed sex crossing knowledge in sex linked hereditary disease. Otherwise, they could not solve sex linked hereditary disease problem." She also mentioned about blood type crossing in the interview. Her excerpts was given below:

> Knowledge about blood type is essential for me because in the case of emergency they have to know their blood type. They generally curious and learn their blood type. On the other hand, sometimes students misinterpret what they hear around them. For example, an A blood type mother and a B blood type father have an O blood type child. They think this is impossible but when we teach the blood types crossing. They can see the possibilities of blood type in a family.

Seda's knowledge of curriculum about genetics was also evaluated with classroom observation. The evaluation of curriculum knowledge for Seda's observation was given in Table 4.37.

Table 4.37. Objectives Checklist for Teaching of Seda's Observation

2006 Curriculum Objectives for Genetics Topic	Does teacher teaching meet the curriculum objective?		
	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about concept of gene.			✓
2.5. Understand the relationship between phenotype and genotype.	✓		
2.6. Solves crossings problems related to inheritance of a single character.		✓	
Limitation			
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.		✓	
2.6. Hemophilia, sickle cell anemia, color blindness, Down syndrome, etc. are given as examples of inherited disease.		✓	
Warning			
2.6. It should be stated that sex depends on sex chromosomes		✓	

According to Table 4.37, Seda showed limited curriculum knowledge for genetics in her teaching. First of all, Seda started to teach genetics with genetics concepts; dominant, recessive, homozygous, and heterozygous and she bypassed the textbook introduction part activities such as "Do we resemble each other?" "Search the gene and dominant-recessive genes." Moreover, she missed some of the activities on the science textbooks such as; "The resemblance of animals," "Lets help the Mendel," "Learn the traits of your family," "Toss a coin for sex crossing," "What is the Mert and his family genotype and phenotype." She rationalized this by stating time considerations and she said that "we do not have enough time to apply these activities."

Secondly, Seda employed "homozigot [arı döl] [homozygous], heterozigot [melez] [heterozygous], allele genes, dominant [baskın] [dominant], resesif [çekinik] [recessive]" and these terms were not included in the curriculum and textbook [the first parenthesis are the Turkish terms textbook employed].

Thirdly, Seda gave information about Mendel's life and studies order and she employed P, F_1, F_2 representations by stating Mendel studies order. She requested students apply this study order when you were crossing. This kind of approach did not part of the science curriculum and the science textbook.

Fourth is the blood type crossing and Seda mentioned about how blood type is genetically transferred, drawing a table for alleles of blood types, and co-dominancy of A and B. She asked a crossing question and students could not solve the problem. The blood types, co-dominancy, and blood types were not covered in the curriculum.

Lastly and the common curriculum violation of Seda is that although the curriculum did not cover the hereditary disease crossing, her teaching was dominated by hereditary disease crossings. Her teaching included 25 crossing problems, eleven of which were not stated in the science curriculum. Moreover, she likes to use pedigree for hereditary disease. She employed generally hereditary disease pedigree for crossing problem and this was also not inside the curriculum. She violated curriculum objectives regarding "2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.", "2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.", "2.6. It should be stated that sex depends on sex chromosomes." She explained that

> “About 80% of my students come from cousin marriage family and even some of them have hereditary disease offspring. They have to learn hereditary disease in detail.”

Moreover, Seda prepared a text about hereditary disease and she made students write this text to their notebooks. This text included information about genetic counseling, genetic screening, raising awareness of public about hereditary diseases etc. These were out of the scope of the curriculum. Her reasoning was based on the following idea:

> I prepared the text to help my students to learn how to overcome or minimize the problem of hereditary diseases in public. In my opinion, student should be able to state if I do not want to have hereditary disease problem when I planning to marry with a cousin, I have to applied genetic screening. My text included this kind of information.

She partially applied the “2.6. It should be stated that sex depends on sex chromosomes” objectives. Mainly, she focused on sex-linked genetic disease instead of teaching the concepts of sex and sex chromosomes. She started to teach sex linked hereditary disease and she taught sex chromosomes and sex crossing at fast pace.

4.5.3.2 Seda’s Knowledge of Students about Genetics

In this section, teachers’ knowledge about students in learning genetics concepts was investigated. Student knowledge was analyzed under two titles; requirements of students and difficulties of students while learning genetics topic.

4.5.3.2.1 Seda’s Knowledge of Students’ Requirements for Genetics

In this part, the requirements of students were presented with examples of teachers’ responses. Teachers’ knowledge of students’ requirements for learning genetics was evaluated with the help of pre-PCK interview (see Appendix C). The dimensions appeared in data analysis of Seda's knowledge of students' requirements for genetics and examples of her response were shown in Table 4.38.

According to Seda, the genetics topic is necessary for scientific knowledge about gametogonium, diploid-haploid chromosomes, meiosis, and fertilization. The literature of genetics studies (Banet & Ayuso, 2000; Lewis & Wood-Robinson, 2000, Lewis et al., 2000c) also highlighted these students' requirements for learning genetics topics. To help students to understand different representation of ratios in crossing results, Seda stated that student should know mathematical expression of ratios. In concerning with, Seda highlighted the importance of mathematics in the classroom:

> Mathematics and Science are brother branches and they are so closer. To be able to learn many things in science, you have to know mathematics well…. The probability in mathematics and science are same. I do not teach different probability in science.

She believed that students find problem solving as difficult with respect to reading the information and following the crossing tasks for the problems. Moreover, she believed that students develop problem skills by solving problems. She particularly employed pedigree in hereditary disease, and she gave importance to reading pedigree and read each one of the family member with their relatives by stating blood ties and not. The skill of prediction was also concern of Seda while teaching genetics. She stated that students have to use prediction skills to solve some genetics problem. Seda also stated

> They confused the hereditary disease and contagious disease or some of the disease such as poliomyelitis, because they can see both of them in the family.

Moreover, Seda also stated as one of the students requirements as:

> Some of the students think that two cousins are healthy and when they married, they also have healthy children but they could not think that they have greater possibility of having hereditary disease child than non-cousin marriage couple.

Table 4.38. Seda's Knowledge of Students' Requirements for Learning Genetics

Dimension of requirements	Requirements	Responses of Seda
Knowledge	Science	The genetics topic was presented before the meiosis and fertilization topics. However, the genetics topic was requiring this knowledge and students did not clearly comprehend what is the mechanism of inheritance. The writing two alleles were based on diploid chromosome of body cells and gametogonium. Separation of allele genes pairs refer to meiosis and gamete formation and writing one allele refers to haploid chromosomes and germ cells.
	Mathematics	The results of crossing were represented with percentages or ratios. Some of the [supplementary] books requested the results of the study in both cases. I taught different version of them such as ¼ and 0.25 are different ways of representing the same fraction. Otherwise, any representation of ratios confused the students' minds.
Skills	Problem solving	When students see the problems in genetics, they assume it is difficult, because they have to read problem carefully, write genotype and follow the crossing tasks appropriately and then they find the solution of the problem. They learn how to approach a problem in genetics in time with many exercises.
	Graphics reading	The pedigrees are the best representation of relationship of generations. For the first pedigree, I teach how to read pedigree. Otherwise, students cannot find which people have the blood tie.
	Prediction	Some of the problem asked parent genotype from the offspring's genotype. For this kind of question, students have to predict the possible genotype of parents…. I asked additional questions to help my students predict the genotype possibilities. For the dominant phenotype, students consider that it may have two different genotype [homozygous dominant and heterozygous]. However, many of my students could not think both of the genotype possibilities and stick to one of them.
Maturity	Formal-operational	You expect that student can comprehend the things you teach easily. However, sometimes they have difficulty with genetics topic. They confused the hereditary disease and contagious disease or some of the disease such as poliomyelitis, because they can see both of them in the family. You have to highlight the hereditary disease come from genetic material and when you born with hereditary disease, you have it for lifelong time. ….Some of the students think that two cousins are healthy and when they married, they also have healthy children but they could not think that they have greater possibility of having hereditary disease child than non-cousin marriage couple. Students could not correlate the genetic material and phenotype relationship easily. Maybe, the abstractness [of the concepts and relationships] affect their comprehension… they need time.

Additionally, students could not comprehend genetics due to the abstractness and teachers stated that students need time to be more mature to more comprehend the genetics. The results of data analysis of Seda depicted that she had sound knowledge of her students' requirements for genetics topic.

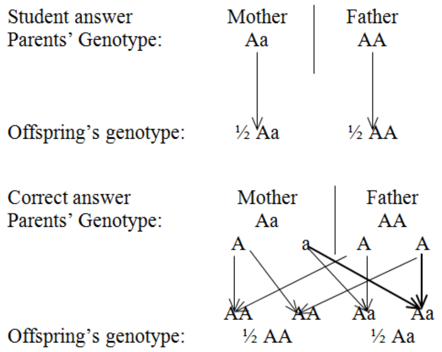
4.5.3.2.2 Seda's Knowledge of Students' Difficulties in Learning Genetics

The dimensions appeared in the data analysis of Seda's knowledge of students' difficulties while learning genetics and examples of her response were shown in Table 4.39.

Table 4.39. Seda's Knowledge of Students' Dificulties While Learning Genetics

Difficulties	Responses of Seda
Understanding	The genetics topic was taught before the meiosis and fertilization. However, the genetics topic was requiring this knowledge and students did not clearly comprehend what is the mechanism of inheritance. The writing two alleles were based on diploid chromosome of body cells and gametogonium. Separation of allele genes pairs refer to meiosis and gamete formation and writing one allele refers to haploid chromosomes and germ cells.
Relationship	Our phenotype example was generally chosen from observable traits such as hair type, hair color, and eye color. However, genotype is related to chromosomes [microscopic level] and phenotype is related to observable body part [macroscopic level]. Students could not relate cell part with body part. They could not imagine how they are related to each other or what the mechanism between genotype and phenotype is because we do not teach protein synthesis in this level and we could not explain how a cell product affect body part [organism level traits].
Crossing	Some of the student confused the algorithm of crossing and they cross gametes inappropriately to form the pairs of alleles without following the sequence to represent the probability. Cram school teachers teach crossing by subtraction and addition of letters. Crossing is just like a meaningless routinized algorithm to reach the answer. This kind of teaching effects students approach to crossing. They reach the answer but they do not care what the meaning of the crossing is. Although they could easily perform the routinized algorithm of crossing, they do not meaningful reference to segregation, meiosis, independent assortment, and fertilization. Students do not identify segregation of parent genotype allele as gamete formation.

Table 4.39. Seda's Knowledge of Students' Difficulties While Learning Genetics (Continued)

Sources	Responses of Seda
Concept	Some of students' brothers or sisters have hereditary disease. For this reason, I have focused on the hereditary disease. When I talked with my students, they generally oversimplify having hereditary disease because they have difficulty in understanding of carrier. They did not think that they may be a carrier of a hereditary disease and may have a hereditary disease baby if s/he marries with another carrier.
Representation	Other difficulty was employed by students when solving monohybrid-crossing problems. For example, some students attempt to cross as [given below diagram]. They apparently know that each offspring must contain two symbols, but the process that could be employed to explain this was not understood. These students probably do not have adequate knowledge of how meiotic division related to Mendelian genetics. These kinds of answer were given especially by genotype heterozygous with homozygous (dominant or recessive) genotypes; such as AaxAA, Aaxaa. 
Students characteristics	Some of students' brothers or sisters have hereditary disease. I try not to cause my students feel sad.

Seda indicated that her students experience different kinds of difficulties while learning genetics. According to Seda, her students had deficiency of knowledge about meiosis and fertilization and this caused the problem in understanding the mechanism of genetics. Moreover, her student also confused with the pairs of alleles due to fact that some of theme disordered the algorithm and they employed the algorithm of crossing as meaningless routinized pattern. They could not refer what the meaning of crossing tasks. Moreover, her students experienced difficulty to relate different biological levels such as gene and organism level traits because they could not imagine and they had knowledge deficiency about biology especially protein synthesis and cell divisions.

Seda also mention about some sources of difficulties. For example, students experienced difficulty with the concept of carrier and they could not estimate the possible risks of being a carrier such as probability of having a hereditary disease child if marry with another carrier. Aforementioned, Seda stated that some of the students in her classroom had relatives having hereditary disease and this probably affect her students' beliefs.

Seda's students had difficulty in following and understanding the algorithm of crossing tasks. She drew the below diagram for this difficulty (look at the representation difficulty in Table 4.39). According to diagram, her students do not have knowledge about meiotic division of gametogonium and gamete formation. Instead, parents transfer directly their genetic information through their children and it cannot be said mitosis as well. The analysis and results of Seda's data depicted that she had sound knowledge of students' difficulties while learning genetics topic.

4.5.3.3 Seda's Knowledge of Teaching Strategies

Teacher knowledge about teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with two titles subject specific and topic specific teaching strategies.

4.5.3.3.1 Knowledge of Subject Specific Strategies

Seda did not use any noticeable subject specific teaching method such as learning cycle, discovery, inquiry or conceptual change oriented instruction, guided instruction, generative learning model and so on (Magnusson et al. 1999). On the other hand, she did not strictly follow the science textbook. She had a different teaching sequence. She started the lesson with the definitions of genetic concepts and she dictated her own notes to students. After the writing of the definitions, she directly started to teach first crossing. She followed to Mendel study order in each crossing. In other words, firstly two homozygous and then two heterozygous genotypes were crossed in her teaching. She requested her students to follow this order in her homework.

Her teaching focused on hereditary diseases. Seda stated that cousin marriages were common in her school families and some of her students were children of cousin marriages. She desired to warn her students about the hereditary diseases. Her examples, problems, and explanations were commonly focused on hereditary disease. She went beyond the curriculum such as problem on sex linked hereditary disease and blood type. Furthermore, some of her explanations was affected her laboratory experiences. For examples, when students asked her “sex of baby inside the womb can be changed, cannot it?” she replied that “it cannot be possible, sex selection should be done before in vitro fertilization by selecting the sperm having Y chromosome.”

The main characteristic of Seda’s teaching was mostly teacher centered; even though, she stated in the interview that she wants her students to share their ideas and her students should be active in the lesson, especially in problem solving, and giving ideas and examples about their lives.

4.5.3.3.2 Knowledge of Topic Specific Strategies

Teacher knowledge about topic specific teaching strategies about genetics was investigated in this section. The knowledge of teaching strategies of the participant teachers was presented with three headings as; representation, activities and employed strategies to overcome students’ difficulties, respectively. Teacher’s knowledge of teaching strategies was evaluated with the help of the pre-PCK interview (see Appendix C), observation of the course and the post-PCK interview.

4.5.3.3.2.1 The Representations Employed by Seda While Teaching Genetics

The examples of employed representations by Seda while teaching genetics were shown in Table 4.40.

For the illustration, from the teaching of first crossing, Seda employed the sex symbols (♀, ♂) in crossing to represent father and mother and she highlighted students difficulty in understanding that plant can sexually reproduce by means of sex symbols in crossing. She also supported the usage of sex symbols with explanation of the crossing tasks in the classroom such as crossing represents meiosis, and fertilization. She taught the sex crossing with 44+XX-44+XY and she expected from students to separate the autosomes and sex chromosomes. This illustration also may help students to think broader than there are only two alleles in a living being and instead they can think that many other traits included in the other chromosomes. Seda allowed her students select the letters whatever they want for crossing. On the other hand, she preferred to use F_1, F_2 letters to represent generations in crossing. These representations regarding to generation order was not presented in neither curriculum nor textbooks. She also gave importance to hereditary disease and she stated that she likes to use pedigree for hereditary disease. She employed generally hereditary disease pedigree for crossing problem and this was not inside the curriculum.

Seda began teaching with examples of pea traits and followed the examples of textbooks. Moreover, she selected examples that help student imagine and get their interest such as use of famous singers in the examples. She gave importance to hereditary disease and her examples were dominated by hereditary disease examples because some of the students in her classroom came from cousin marriage families.

She gave albinism and Down syndrome examples due to fact that students can easily see in everyday life and in neighborhood. Another kind of example Seda employed in her classroom was news. She employed hereditary disease news especially due to the getting students' attention to the topic.

Table 4.40. The Representations Employed by Seda While Teaching Genetics

Dimension of representations	Responses of Seda
Illustrations	Seda employed sex symbols (♀, ♂) in crossing to represent father and mother; she stated, "some of my students did not recognize the [crossing] process as sexual reproduction especially for the peas [plants]. Sex symbols were reminder for them as crossing happens between different sex and it is a kind of sexual reproduction." Seda represented parents as 44+XX, 44+XY and gametes as 22+X, 22+Y in sex crossing. She explained that "students should be able to separate the autosomes and sex chromosomes. Students know that humans have 46 chromosomes but they have to know 46 chromosomes are not same. We can teach these differences with sex chromosomes. On the other hand, we cross two alleles all the time and this repetition may result in students' thinking that there are only two traits on the chromosomes. I think the 44+XX and 22+X representation help students to think that there is another chromosome and traits taking role in crossing.
Examples	I select crossing example that students can easily imagine. I gave pea traits; fur color of mouse etc. and other traits students interested in. I selected examples sometimes from supplementary books [which are generally employed by cram school]. …Yes, I asked blood type crossing about the famous singer. Students like to listen music and they generally know the all singer. This kind of examples easily takes their [students] attention. I gave albinism as an example of hereditary disease because they can easily see albino people in the street. Moreover, I gave first grade students having a down syndrome as example of hereditary disease in the classroom. Students believe that hereditary diseases are not in neighborhood. Students think that they [hereditary disease people] could not be their relatives, friends, and neighbors. I want them to realize hereditary disease is not far away them and they should be cautious about it [hereditary disease] because many of them have born in family having cross-cousin marriages. She gave examples from news on the newspaper or TV. …Yes, I gave a couple has thalassemia which they meet in hospital during treatment on thalassemia. Families of couples allow them not to have a baby because all of their children will be thalassemia disease. News grab their attention easily on the topic and news are also give them the idea about the daily life example of the [genetics] topic.

The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Seda had limited knowledge of representations to teach genetics concepts in order to facilitate students' learning.

4.5.3.3.2.2 The Activities Employed by Seda While Teaching Genetics

The activities employed by Seda while teaching genetics were problem solving about crossing, reading hereditary disease in a pedigree, and using computer simulation for crossing (Table 4.41).

Seda started to teach crossing with pea examples from textbook. She preferred to follow the same pattern while crossing pea examples; firstly, she crossed two homozygous peas and then she crossed two heterozygous peas that are obtained from first generations. She stated that "same pattern make learning easy for students."

Table 4.41. The Activities Employed by Seda While Teaching Genetics

Type of activities	Observation data
Problem solving	General crossing problem - Cross two homozygous purple flower pea plant (purple flower color is dominant over white flower color) (Observation). Sex crossing problem - A family is expecting a new baby, what is the probability of the sex of a baby, a girl or a boy? (Observation). Blood type problem What are the possible blood types of the offspring of a cross between a woman with type AB blood and a man with heterozygous type A blood? Sex linked hereditary disease problem - In a cross between a carrier female and color blindness male, what percent of the female offspring will have color blindness? (Color blindness is X-linked and recessive)
Reading a pedigree	Teacher prepared a special pedigree representing hereditary disease in a family and having cousin marriages. Students are required to examine this pedigree with respect to hereditary diseases transformation through the generations.
Computer simulation	Seda utilized the animations and videos on the Internet to visualize the genetic mechanism especially genotype and phenotype relationships.

Although blood type crossing due to the including co-dominancy is not covered by the curriculum, blood type crossing was involved in Seda's teaching and she explained this as "students learn blood and bloods type in 6th grade and genetics topic is a chance to learn blood type crossing (post-PCK interview)." Another point was that she gave an example related to specifying three children's family from given three family blood types. Although in her problem, it was requested to find exactly which child belongs which family, it cannot be reached precisely the children families. Instead, the solution comes with probability of the families. For this reason, students could not solve the problem. Seda tried to solve instead of students. She only reached the probability. Therefore, students found the solution as "confusing," and they asked different questions about the solution.

Seda emphasized the hereditary disease in her teaching by means of problems, reading special pedigree, and homework. She explained her season as:

> about 70% of my students come from cousin marriage family and even some of them have hereditary disease offspring. They have to learn hereditary disease in detail (post-PCK interview).

For this reason, hereditary disease and sex linked hereditary disease took place in her teaching. However, these were not inside the curriculum. Moreover, her students expressed some signs of difficulty to their teacher while solving hereditary disease and sex linked hereditary disease such as asking similar question, unsolved problems. Then in most of the time, Seda explained the solution of the problems. Besides, she gave homework related to hereditary disease. She begun with homework required to make a research on hereditary disease on the Internet, news on newspaper and hospitals. After the topic of hereditary disease was held in the classroom, she asked to students to examine their or close families on the hereditary disease including sick children life. The last homework related to hereditary disease was about searching a person life born with hemophilia and her/his difficulties due to hereditary disease. She believed that these homework help her students became more aware of "the hereditary disease", "potential risk of cross-cousin marriages" and "difficulties of caring a hereditary disease person." She prepared a special pedigree representing hereditary disease in a family and this family had cross-cousin marriages. She allowed her students to examine whole family especially their relationship among the relatives and inbred children. Then she asked students to calculate the probability of having a baby with hereditary disease in these families. She notified her students about risk on hereditary disease for the close cousin marriages.

Seda utilized the animations and videos on the Internet and she stated that student had difficulty to imagine the mechanism of genetics and genotype-phenotype relationship.

She did not do some of the activities on the science textbooks such as; “Do we resemble each other?,” “The resemblance of animals,” “Lets help the Mendel,” “Search the gene and dominant-recessive genes,” “Learn the traits of your family,” “Toss a coin for sex crossing,” “What is the Mert and his family genotype and phenotype.” Her rationalization was based on time considerations.

The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Seda had limited knowledge of activities to teach genetics concepts in order to facilitate students’ learning.

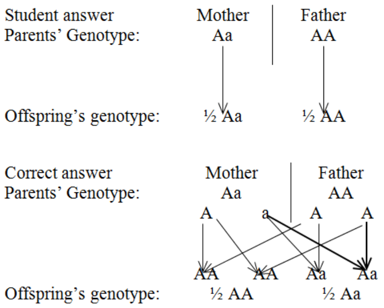
4.5.3.3.2.3 Teaching Strategies Employed by Seda to Overcome Students’ Difficulties While Teaching Genetics

The classification of learning difficulties and the respective teaching strategies employed by Seda were given in Table 4.42.

Table 4.42. Teaching Strategies Employed by Seda to Overcome Students' Difficulties While Teaching Genetics

Difficulties	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Understanding	The genetics topic was taught before the meiosis and fertilization. However, the genetics topic was requiring this knowledge and students did not clearly comprehend what is the mechanism of inheritance. The writing two alleles were based on diploid chromosome of body cells and gametogonium. Separation of allele genes pairs refer to meiosis and gamete formation and writing one allele refers to haploid chromosomes and germ cells. I strictly try to explain what the meaning of crossing [task] is regarding to biologically meaning of it.
Relationship	Our phenotype example was generally chosen from the observable traits such as hair type, hair color, and eye color. However, genotype is related to chromosomes [microscopic level] and phenotype is related to observable body part [macroscopic level]. Students could not relate between cell part and body part. They could not imagine how they are related to each other or what the mechanism between genotype and phenotype is because we do not teach protein synthesis in this level and we could not explain how a cell product affect body part [organism level] traits. The curriculum limited us to teach protein synthesis and RNA etc. We could not explain the genotype-phenotype relationship in detail. I got help from some of the animations and videos on the Internet even though most of them need to know about protein synthesis, RNA and DNA. These sites partially were helpful for students' understanding.
Crossing	Some of the student confused with the algorithm of crossing and they crossed gametes inappropriately to form the pairs of alleles without following the sequence to represent the probability. Cram school teaches crossing like subtraction and addition of letters. Crossing is just like a meaningless routinized algorithm to reach the answer. This kind of teaching effects students approach to crossing. They reach the answer but they do not care what the meaning of the crossing is. Although they could easily perform the routinized algorithm of crossing, they do not meaningful reference to segregation, meiosis, independent assortment, and fertilization. Students do not identify segregation of parent genotype allele as gamete formation. I teach briefly meiosis and fertilization while teaching crossing. Otherwise, I believe that the crossing will be just like meaningless algorithm to find just the probabilities of letter pairs. Whenever I feel to need explanation related to meiosis and fertilization, I stop teaching the crossing and try to explain the relation of the tasks or representation of tasks with segregation, meiosis, independent assortment, and fertilization. Maybe, I do not firmly follow to curriculum order but I feel I ought to teach meiosis and fertilization to explain crossing better to my students. Actually, I taught meiosis and fertilization exhaustively in their title after the genetics topic.

Table 4.42. Teaching Strategies Employed by Seda to Overcome Students' Difficulties While Teaching Genetics (Continued)

Sources	Employed Teaching Strategies to Overcome Students' Difficulties While Teaching Genetics
Concept	Some of students' brothers or sisters have hereditary disease. For this reason, I have focused on the hereditary disease. When I talked with my students, they generally oversimplify having brother with hereditary disease because they have difficulty in understanding of carrier. They did not think that they may be a carrier of a hereditary disease and may have a hereditary disease baby if s/he marries with another carrier. I want all students to participate to activity sheet that requires examining a special pedigree represent hereditary disease in a family and this family has cousin marriages. All students important because if I just asked to only to students who has hereditary disease relative they will feel to shame and they probably regret to participate in this activity. This activity starts after completing all hereditary disease in the textbook. The activity begins with a question that "please examine the pedigree with respect to hereditary diseases transformation through the generations." You should follow earlier generation to intersect with a mother and a father and earlier grandparents. Students inspect a pedigree and follow the hereditary disease pattern in this family and I ask especially person who is healthy but carrier of the disease. Then I ask them to calculate probabilities to have hereditary disease children if some of the cousins will marry each other.
Representation	Other difficulty was employed by students when solving monohybrid-crossing problems. For example, some students attempt to cross as given below diagram. They apparently know that each offspring must contain two symbols, but the process that could be employed to explain this was not understood. These students' probably do not have adequate knowledge of how meiotic division related to Mendelian genetics. These kinds of answer were given especially genotype heterozygous with homozygous (dominant or recessive) genotypes; such as AaxAA, Aaxaa.  When I saw my students cross like this, I corrected them by emphasizing the following crossing tasks, which I teach from the first crossing and explain each crossing tasks repeatedly.
Students characteristics	Some of students' brothers or sisters have hereditary disease. I try not to cause my students feel sad. When I teach the hereditary disease, I prefer to focus such hereditary diseases that my students' relatives do not have. I do not directly ask any hereditary disease question to students having sick relatives.

Her students had deficiency of knowledge about meiosis and fertilization and this caused the problem in understanding the mechanism of genetics. Seda tried to handle this hindrance by giving explanations about the meaning of crossing tasks.

Students experienced difficulty to relate different biological levels such as a gene and an organism level because they could not imagine and they had knowledge deficiency about biology especially protein synthesis and cell divisions. Teacher took advantage of the animations and videos on the Internet, although she was aware that they required extra knowledge to comprehend the theme of videos.

Students had difficulty with the pairs of alleles due to fact that some of theme confused with the algorithm and they employed the algorithm of crossing as meaningless routinized pattern. They could not refer what the meaning of crossing tasks. Seda tried to teach meiosis and fertilization while teaching crossing to help her students understand the underlying meaning of the algorithm of crossing tasks. She explained meaning of crossing tasks whenever she felt that there is a need to explanation. She highlighted the necessity to teach meiosis and fertilization before teaching the Mendelian genetics and crossing.

In addition, students had difficulty with the concept of carrier and they could not estimate the possible risks of being a carrier such as probability of having a hereditary disease child if there is marriage with another carrier. Teachers employed a special pedigree representing transition of hereditary diseases and cousin marriages. Students were assigned to examine this pedigree and calculate probability of having hereditary disease children when two people in pedigree marry to each other.

Students had also another difficulty in following and understanding the algorithm of crossing tasks. Students, according to diagram, did not have knowledge about meiotic division of gametogonium and gamete formation. Instead, parents transferred directly their genetic information through their children and it cannot be said mitosis as well. In order to help her students for this difficulty, Seda only reminded her students to follow the crossing tasks as which she taught.

Seda selected example of hereditary disease that the relatives of any students did not have and she did not direct any questions related to hereditary disease to these students.

To summarize; Seda generated and utilized special and different kinds of teaching strategies to help students to overcome difficulties while learning genetics topic. However, Seda showed limited knowledge on teaching strategies to overcome students' difficulties while teaching genetics.

4.6 Summary of the Findings

In this section, the findings of the study were reviewed according to research questions. In the first section, the nature of the science teachers' content knowledge about genetics was summarized. In the second section, the nature of the science teachers' pedagogical content knowledge was summarized in terms of science teachers' knowledge of curriculum, knowledge of students, and knowledge of teaching strategies and their sub-dimensions.

4.6.1 The Nature of Science Teachers' Content Knowledge

To investigate science teachers' content knowledge on genetics topic, the content test was applied (Appendix A). The genetics test consisted of two open-ended questions; one is genetics concepts question and the other one is genetics crossing question.

In the concept question section, seven genetics concepts including gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous were asked to science teachers. Summary of the analysis of definitions of teachers' genetics concepts was given in Table 4.43.

Table 4.43. Summary of Analysis of Definitions of Teachers' Genetics Concepts

	Understanding of concepts		Ontological categorization	
Concepts	Partial	Sound	Matter	Process
Gene	Beste, Nehir, Seda	Melis, Mert	Beste, Nehir, Seda	Melis, Mert
Dominant gene	Beste, Melis, Mert, Nehir, Seda		Beste ,Melis, Mert, Nehir	Seda
Recessive gene	Beste, Melis, Mert, Nehir	Seda	Beste, Melis, Mert, Nehir	Seda
Genotype	Beste, Nehir, Seda	Mert	Beste, Melis, Nehir, Seda	Mert
Phenotype	Beste, Mert, Nehir, Seda	Melis	Seda	Beste, Melis, Mert, Nehir
Homozygous	Beste, Nehir, Seda	Melis Mert	Beste, Nehir, Seda	Melis, Mert
Heterozygous	Beste, Melis, Mert, Nehir, Seda		Beste, Mert, Nehir, Seda	Melis

Regarding definition of gene, Melis and Mert defined gene as scientifically accepted but other participant teachers defined it partially according to scientific definition. When ontological categorization was considered, it was found that Melis's and Mert's definition was in process category and the rest of the teachers' definition was in matter category according to Chi et al. (1994).

All of the participant teachers defined dominant gene partially according to scientific definition. Only Seda's definition was in process category and the rest of the teachers' definition was in matter category.

Regarding definition of recessive gene, Seda's definition was accepted as sound understanding and in process category. The rest of the teachers' definition was accepted as partial and in matter category.

Regarding the definition of genotype, Mert's definition was accepted as sound understanding and in process category. The rest of the teachers' definition was accepted as partial and in matter category.

Regarding the definition of phenotype, Melis's definition was accepted as sound understanding. The rest of the teachers' definition was accepted as partial understanding. For the ontological categorization, Seda's definition was in matter category, all of the other participants' definition was in process category.

Regarding the definition of homozygous, Melis and Mert's definition was accepted as sound understanding and in process category. The rest of the teachers' definition was accepted as partial and in matter category.

Regarding the definition of heterozygous, all of the participant teachers defined partially according to scientific definition and only Melis's definition of heterozygous were in process category according to Chi et al. (1994).

The analysis of the results revealed that teachers' knowledge of concepts was found as partial for the most of the teachers. In descending order of the results of the genetics concept analysis was revealed that teachers had sound knowledge on concept of gene (2 teachers), homozygous (2), phenotype (1), genotype (1), recessive gene (1), dominant gene (0), and heterozygous (0) (Table 4.43).

The similar order was also found for the ontological categorization and the definition of teachers was in the process category for phenotype (4 teachers), gene (2), homozygous (2), genotype (1), recessive gene (1), dominant (1), and heterozygous (1) (Table 4.43). Teachers had difficulties in defining genetics concepts in process category with respect to ontological categorization according to Chi et al. (1994) and teachers' definitions generally were in the matter category.

In the crossing question section, a monohybrid-crossing question was asked to evaluate teacher knowledge about crossing. It was an open-ended question:

> It is known that the yellow seed color character is dominant over green seed color for peas. What would happen, if you cross yellow and green seed plants?

Responses of teachers revealed that Beste, Melis, and Nehir correctly symbolized and solved the problem. Mert and Seda partially answered the crossing problem. In the crossing question, science teachers experienced difficulty in understanding two different (homozygous and heterozygous) genotype probabilities according to given dominant character phenotype. Beste, Melis, and Nehir solved correctly the crossing question, since they represented their knowledge on symbolizing and solved both of the probabilities. These teachers did not have any hesitation in choosing and applying the correct tasks and probabilities. On the other hand, two teachers only made crossing for the dominant phenotype. Interestingly, this was stated as the students' difficulty by Nehir and Mert during the pre-PCK interview. However, Mert also had this difficulty along with the participant Seda. The results of crossings also supported findings in the genetics concepts definitions of teachers that teachers did not have adequate conceptual understanding.

4.6.2 The Nature of Science Teachers' Pedagogical Content Knowledge

The summary of the findings of teachers' PCK was presented in three components with its sub-components.

i. Knowledge of curriculum,
ii. Knowledge of students
    a. Knowledge of students requirements
    b. Knowledge of students difficulties
iii. Knowledge of teaching strategies,
    a. Representations
    b. Activities
    c. Teaching strategies to overcome students' learning difficulties

4.6.2.1 Teachers' Knowledge of Curriculum about Genetics

Knowledge about the curriculum related to genetics concepts was summarized. Teachers' knowledge of curriculum about genetics was obtained with the help of pre-PCK interview and classroom observation of the course. Result of pre-PCK interview and results of observation of teachers about teachers' knowledge of curriculum was summarized in Table 4.44.

The results of the study revealed that teachers' curriculum knowledge was mainly based on the textbooks and they could not directly refer the curriculum objectives during the interviews. However, their teachings were mainly based on the topic sequence in the textbook. For this reason, their teaching was mainly appropriate to the science curriculum. The result also revealed that Beste and Nehir had sound curriculum knowledge and Melis, Mert, and Seda had limited curriculum knowledge.

Table 4.44. Objectives Checklist for Teachers' Answers for Curriculum Questions

2006 Objectives Stated in Science Curriculum for Genetics Topic	Does teacher's answer meet the curriculum objective?			Does teacher's teaching meet the curriculum objective?		
	Yes	Partial	No	Yes	Partial	No
2.4. Be aware of dominance and recessiveness by collecting information about the concept of gene.	Beste Melis Nehir Seda	Mert		Beste Melis Nehir	Mert	Seda
2.5. Understand the relationship between phenotype and genotype.	Beste Melis Nehir Seda	Mert		Beste Melis Nehir Seda	Mert	
2.6. Solve crossings problems related to inheritance of a single character.	Mert Nehir	Beste Melis Seda		Beste Mert Nehir	Melis Seda	
2006 Limitations Stated in Science Curriculum for Genetics Topic						
2.3. Only monohybrid crossings should be given as an example, dihybrid crossing should not be given.	Beste Mert Nehir Seda	Melis		Beste Mert Nehir	Melis Seda	
2.6. Hemophilia, sickle cell anemia, color blindness, down syndrome, etc. should be given as examples of inherited diseases.	Nehir	Beste Mert Seda	Melis	Beste Nehir	Mert Seda	Melis
2006 Warnings Stated in Science Curriculum for Genetics Topic						
2.6. It should be stated that sex depends on sex chromosomes.	Beste Mert Nehir	Melis Seda		Beste Mert Nehir	Melis Seda	

According to curriculum, teachers were expected to give example about hereditary disease (2.6. Hemophilia, sickle cell anemia, color blindness, Down syndrome, etc. should be given as examples of inherited diseases.). Moreover, student textbook (Ministry of National Education, 2006) includes an example of sickle-cell disease as an inherited disease crossing on page 17. Inherited disease example is only shown with AA (healthy person), Aa (carrier), aa (sick person) in the students textbooks.

However, participant teachers Seda and Melis exceeded the curriculum border on the hereditary disease topic. For example, Seda solved eleven and Melis solved nine hereditary disease crossings, some of them were even sex linked hereditary diseases. Teacher Seda explained the reason of teaching hereditary crossing as students' having hereditary disease relatives. While, Seda taught blood type crossing, she mentioned about how blood type genetically is transferred and drew a table for alleles of blood types, and co-dominancy of A and B in her teaching. Beste and Mert did not teach the hereditary disease crossing, although they stated the importance of solving hereditary disease during pre-PCK interview.

Another curriculum deficiency related to crossing was Mendel study. In other words, they taught in their lesson detail information about Mendel's life, Mendel study and they employed F_1, F_2 and P symbols for generations and then followed the homozygous, heterozygous crossings order in their teaching. This sequence was not presented neither in curriculum nor in science textbooks. Mert, Seda, and Melis represented this kind of curriculum knowledge deficiency in their teaching. The previous science curriculum included these kinds of information and probably they did not aware that 2006 curriculum did not cover this information.

Mert, and Seda graduated from biology department in the faculty of arts and science and it was seen that they employed their knowledge of biology while answering students' questions in the lesson, even some of answer was not covered in the curriculum. For example, Mert and Seda explained the detail of blood types such as factor of Rh. Another example of Mert was about apoptosis which is programmed cell destruction in development of human embryo. Seda gave information about how sexual determination in vitro fertilization and test tube baby cane be done in her teaching. These kinds of information did not section of the curriculum.

Teachers' curriculum knowledge deficiency could be seen on the usage of biology term on two languages; Latin and Turkish. They employed homozigot [arı döl] [homozygous], heterozigot [melez] [heterozygous], dominant [baskın] [dominant], resesif [çekinik] [recessive]" in the interviews and these terms were not presented in the curriculum and textbook [the first parenthesis are the Turkish terms employed in the textbook employed]. The previous science curriculum included these terms. It seemed that probably they did not aware that new curriculum did not allow using of Latin terms for this grade level. Seda, Mert, and Melis employed these terms in their teaching. Nehir and Beste were aware that these kinds of usages were not section of the curriculum.

Mert, Melis, and Seda did not apply some activities in their lesson such as "Do we resemble to each other?" "Search the gene and dominant-recessive genes.," "Lets help the Mendel," "Learn the traits of your family," "Toss a coin for sex crossing," "What is the Mert and his family genotype and phenotype?" They rationalized this by stating time considerations and they stated that they did not have enough time to apply these activities even though Seda and Melis gave great amount time to solving hereditary disease crossing.

Another point for the curriculum knowledge of teachers was that they integrated the computer activities in their teaching and they employed online genetics activities such as crossing, video explanations for homozygous and heterozygous concepts. On the other hand, some parts of the video showed by the teachers in the classroom were not covered by the curriculum such as Turner syndrome as hereditary disease, co-dominance in blood types and flower colors etc.

As an alternative use for crossing, Punnet square was employed only by Beste and other participant did not use in their teaching even though it covered in the teacher book.

4.6.2.2 Teachers' Knowledge of Students about Genetics

In this section, teachers' knowledge about students in learning genetics concepts was summarized. Student knowledge was summarized under two titles; requirements of students and difficulties of students while learning genetics topic.

4.6.2.2.1 Teachers' Knowledge of Students' Requirements for Genetics

Teachers' knowledge of students' requirements for learning genetics was obtained with the help of pre-PCK interview (see Appendix C). All of the participant science teachers had sound knowledge of students' requirements for genetics. Participant teachers stated that students require the scientific knowledge prior to learning genetics such as cell, cell parts, DNA, genetic code, chromosome, diploid-haploid chromosomes, germ cells, sperms, ovum, gametogonium, cell division, meiosis and fertilization. As a specific example of students' requirement, Nehir stated that students thought that only human can sexually reproduce. Before teaching crossing in plant examples, students should have knowledge about fertilization in plants. This was also a known misconception of students in the literature (Tekkaya, 2002).

Teachers were generally aware of science knowledge requirements of students. Moreover, they stated that there was a need to change the topic order in the curriculum for teaching genetics because genetics code, meiosis, and fertilization were held after genetics topic. This caused difficulty in learning genetics topic and all participant teachers highlighted that the curriculum topic order should be change to be able to supply solid knowledge basement for learning genetics. To compensate scientific knowledge requirements of students for learning genetics topic, four of the participants just tried to give brief information about meiosis, fertilization, and genetics code when they felt necessitate for explanation, especially in crossing. Besides, Melis changed the order of textbook topics before teaching genetics to be able to meet students' science knowledge requirements. The book order and Melis's teaching order were in the Table 4.46. The genetics code, meiosis and fertilization topics were also stated as difficult topic for students' learning and they cannot be compensate the requirement of students with brief explanation. For this reason, curriculum and textbook topic order should be changed as Melis's order in order to meet students' requirements.

4.6.2.2.2 Teachers' Knowledge of Students' Difficulties in Learning Genetics

Teachers' knowledge of students' difficulties while learning genetics was obtained with the help of pre-PCK interview (see Appendix C) and observation of the course. The dimensions appeared in the data analysis of participant teachers' knowledge of students' difficulties while learning genetics were difficulties, and sources.

The dimensions appeared in the data analysis of participant teachers' knowledge of students' difficulties while learning genetics were understanding, relationship, and crossing. These were summarized in the following titles.

According to Beste and Seda, students had difficulty in understanding of allele gene and Beste's students had also difficulty with the same character having different dominant and recessive traits; for example, eye color is one character but it has two different traits; blue and dark. Seda's students also confused about the pairs of alleles due to fact that some of them disordered the algorithm and they employed the algorithm of crossing as meaningless routinized pattern. They dragged the pair of allele without separating the gametes. It was seen that students did not think gametogonium, gametogenesis procedure with meiosis and fertilization that are underlying mechanisms of genetics crossing. According to Mert and Seda, students had difficulty with essential knowledge on meiosis and fertilization and this caused the problem in understanding the mechanism of genetics. Moreover, Nehir stated known misconception of students that "…humans have sexually reproduced and plants do not" similarly. Beste also indicated similar confusion of her students about heterozygous. She stated that "Students confused about heterozygous genotype and hybrid person (mixed race or blood) [in Turkish both have same terms "melez"]." Another understanding difficulty of students stated by Nehir was the independent probability of each new offspring.

One of the students' difficulties in understanding according to Beste was that students erroneously relate one character genotype with entire genotype of an organism, and they thought that if a character was heterozygous, all character genotypes of that organism should be heterozygous. Mert stated that his students could define the genetics concepts however; they could not relate these concepts between each other. Moreover, Mert's and Nehir's students did not relate and label the crossing tasks with some process such as fertilization, meiosis, gamete formation and gametes, gametogonium etc. Moreover, students did not understand that gamete formation and fertilization happen during the crossing. However, students did not relate that they are doing representation of crossing. Moreover, Seda's students experienced difficulty to relate different biological levels such as a gene and an organism level traits because they could not imagine and they had deficiency about biology especially protein synthesis and cell divisions.

According to Melis, the steps of crossing did not have clear meaning and transferring the result of crossings in daily life was another difficulty of her students. Moreover, Mert pointed out to students' difficulties of notation of genotypes of dominant phenotype because it had two different genotypes. Moreover, his students preferred to write homozygous dominant genotype. Beste also mentioned that her students also had difficulty in the comprehending mechanism underlying the crossing. They thought that the four result of crossing (e.g. AA, Aa, Aa, aa) represent the parents' order of their siblings and the first result of crossing (AA) should be born as the first and then so on. In addition, Nehir pointed out different sources of students' difficult. She thought that the method taught in the cram school cause difficulty in crossing among students. She named this method with algebraic method and this method seems like distribution property of multiplication. Although students reached the correct solution, Nehir did not prefer to use algebraic method in her lessons and she employed crossing with arrows.

Concept, representation, students' characteristics were dimensions appeared in the data analysis of participant teachers' knowledge of students' difficulties while learning genetics as sources of difficulties. They were summarized in the following titles.

One of the students' difficulties in understanding according to Beste was that many new concepts should be learned in genetics topic, which was a source of difficulty for the students to learn genetics. According to Melis, her students experienced difficulty in comprehensive understanding of genetics concepts because students did not have prior experience with genetics concepts and these concepts are generally abstract and unfamiliar for her students. According to Melis and Nehir, students had difficulty with concept of inherited traits because Nehir's students were confusing inherited traits with acquired traits such as music or sportive talent. Another difficulty was that her students thought that dominant traits should be common traits. One of difficulties of Seda's students was that students experienced difficulty with the concept of carrier and they did not estimate the possible risks of being a carrier such as probability of having a hereditary disease child if carrier marries with another carrier. She stated as the sources of students' ideas about inheritance as their own ideas, teachers, and their communities.

Nehir stated that students' writing of the uppercase and lowercase some letters (Uu, Ss, Iı, etc.) caused confusion because they write letter in similar size which makes the differentiating the lower and the uppercase letters from each other difficult. Beste's students did not use the arrows in crossing and they experienced the difficulty in following arrows to track crossing results. She thought using arrows made the crossing procedure more complicated. Moreover, these crossing arrows showed fertilization through combination of gametes. The representational difficulty of Mert's students was to follow the arrows order. The following order helped students correctly pair up gametes for genotype of offspring and it showed probabilities of offspring genotypes if there was not repetition or any missing of gamete pairs. However, his students did not use or follow the arrows and this caused errors of crossing results. Seda's students had difficulty in following and understanding the algorithm of crossing tasks. She drew a diagram for this difficulty. According to diagram, her students did not have knowledge about meiotic division of gametogonium and gamete formation. Instead, student dragged the parents' genotypes and wrote directly parents genotypes as offspring genotypes. Other representational difficulty of Mert's students was that they did not understand parent genotype representing maternal or paternal gametogonium with diploid chromosomes and one-letter representing gametes with haploid chromosomes.

All of the participant teachers highlighted that students at this age get easily bored in science lessons especially while teaching topics including abstract and condense information like genetics. Concrete and observable concepts, examples, and relationships were can be employed for capturing students' interest. Beste and Seda emphasized that students' characteristics was one of the sources of difficulty. Their classrooms had students having hereditary disease relative. Therefore, they were careful about their examples, description, and explanation about hereditary disease because they did not want to make those students upset in the classroom. Moreover, Seda's students did not correctly estimate probable negative effect of cousin marriage and they undervalued the risk of having a hereditary disease child.

4.6.2.3 Teachers' Knowledge of Teaching Strategies

Teacher knowledge about teaching strategies about genetics was summarized in this section. The knowledge of teaching strategies of the participant teachers was presented with two titles subject specific and topic specific teaching strategies.

4.6.2.3.1 Teachers' Knowledge of Subject Specific Strategies

Participant teachers did not use any noticeable subject specific teaching method such as learning cycle, discovery, inquiry or conceptual change oriented instruction, guided instruction, generative learning model and so on (Magnusson et al. 1999).

They generally followed the sequence of the science textbook. They explained crossing with systematically. They explained all representations and tasks comprehensively and answered each student's questions while teaching crossing. They gave crossing examples and expected from their students to solve the crossing questions. Teacher or students solved the questions on the blackboard. Teachers' sequence of the teaching continued with similar cycle of crossing questions and answers. The numbers of crossing problems teachers solved in classroom were varied from 20 to 37 and the problem types were monohybrid crossing, pedigree, sex, hereditary disease crossing, and sex linked hereditary disease crossing.

One of the teachers, Nehir followed the science textbook closely in her classroom and gave direction to her students like "open the page 22 and look at the historical development in genetics." She applied and employed most of the textbook examples, homework, and activities. On the other hand, Mert started to his lesson with a drama related to Mendel's life. His teaching of genetics concepts and crossing based on the Mendel's life drama. Seda did not strictly follow science textbook. She had a different teaching sequence. She started the lesson with the definitions of genetic concepts and she dictated her own notes to the students. After the writing of the definitions, she directly started to teach first crossing. She followed to "Mendel study order" in each crossing. In other words, firstly two homozygous and then two heterozygous genotypes were crossed in her teaching. She requested her students to follow this order in her homework. Seda's teaching was concentrated on hereditary diseases. As a reason, Seda stated that cousin marriages were common in her school families and some of her students were children of cousin marriages.

The main characteristic of all participant teachers' teaching was mostly teacher centered. On the other hand, they allowed their students to share ideas and frequently asked topic related questions and in certain times they expected from their students to be active in the lesson, especially in problem solving, and giving ideas and examples about their lives.

4.6.2.3.2 Knowledge of Topic Specific Strategies

Teacher knowledge about topic specific teaching strategies about genetics was summarized in this section. The knowledge of teaching strategies of the participant teachers was presented with three headings as; representation, activities and employed strategies to overcome students' difficulties, respectively. Teacher's knowledge of teaching strategies was obtained with the help of the pre-PCK interview (see Appendix C), observation of the course and the post-PCK interview.

4.6.2.3.2.1 The Representations Employed by Teachers While Teaching Genetics

The teaching strategies were covered under in three sub-titles, the first one was related with representation, and the data analysis for representation lead to three categories namely; "illustrations," "examples," and "analogies."

The illustrations that teachers employed generally were similar to textbooks' illustrations in genetics topics. On the other hand, Beste employed Punnet square as an example of illustration of crossing in her lesson. Melis usage of illustrations was dominated by tables, and she showed tables in each section of her teaching. She gave her learning preferences as a reason. She explained her aim as to reach different students who were visual learners. She also tabulated the notations of genotype of phenotypes and she employed this table to help students see how to notations of genotype was made and to see the probabilities. Some of Mert’s students thought that chromosomes have only one gene on it due to the application of monohybrid crossing or all genes should be same genotype such as homozygous or heterozygous. Mert employed the chromosome pair representation which including different gene letters on it to help his students to visualize. He employed similar representation in sex chromosomes X and Y. Nehir’s representation application mainly focused on crossing. However, she made five applications in crossing. First was one letter selection and she did not prefer to use letters which have similar upper case and lower case because of causing confusion. Second was using sex symbols (♀, ♂) and she supported her approach by stating that these symbols helped the students to recognize crossing represents sexual reproduction, meiosis and fertilization. Third was using different color in crossing enabled students to follow the gamete and this helped them to visualize meiosis and sexual reproduction in crossing. Fourth and fifth were not using arrows and x symbols in crossing. Nehir believed that more symbols caused confusion because genetics already have many new things. However, it seemed that students were affected by cram school teaching and her students employed x symbols and arrows in crossing like a meaningless repetitive action in crossing. Seda taught the sex crossing with 44+XX-44+XY and she expected from students to separate the autosomes and sex chromosomes. She stated that the crossing representation of two letters resulted students thinking that living beings hereditary units composed by two letter and they do not have any other genes or chromosomes.” This illustration also may help students to think broader than there were only two alleles in a living being in crossing and instead many other traits may have the other chromosomes. Seda allowed her students select the letters whatever they want for crossing. On the other hand, she preferred to use F_1, F_2 letters to represent generations in crossing. She also gave importance to hereditary disease and she preferred to use pedigree for hereditary disease. She employed generally hereditary disease pedigree for crossing problem.

The participant of the study generally preferred to use textbook example in their genetics teaching. Alternatively, Beste preferred to use human traits to exemplify the genetic traits. In her lesson, Melis employed different living beings examples (pea, mouse, human and so on), and she drew a table to exemplify genetic traits to her students in classroom. These traits were mainly related with human and human appearance. In his teaching, Mert employed mainly pea traits examples. He thought that Mendel drama helped his students focus on the topic and similarly, Mendel studies helped them follow the topic easily. Same traits helped students easily focus on the crossing, instead of learning each new trait's phenotypes and genotypes. Nehir's example selection was based on textbook and students' experiences. Her example selection from textbook was based on reasons that students can easily follow the textbook. She also thought that each addition of new example also increase the complexity of the genetics topics for students. By giving the pets as an example of genetics, teachers wanted their students observe their pets and their experiences to see the genetics mechanism work in their daily life as well. Seda began her teaching with examples of pea traits and followed the examples of textbooks. Moreover, she selected examples that student can imagine and be interested such as use of famous singers. She gave importance to hereditary disease and her examples were dominated by hereditary disease examples because some of the students in her classroom came from cousin marriage families. In addition, she gave albinism and Down syndrome examples due to fact that students can easily see in everyday life and in neighborhood. Another kind of example Seda employed in her classroom was news. The selected example was on hereditary disease news and according to her, by the way students' attention was caught to the topic.

Only Beste and Mert employed analogy in their lessons. While Beste employed shoe analogy to explain that genes should be in a pairs to work well correctly, Mert employed transparency sheets for teaching heterozygous person genotype and phenotype.

The analysis of data from pre-PCK and post-PCK interviews and classroom observation indicated that Beste, Mert, and Nehir had sound knowledge of representation and Melis and Seda had limited knowledge of representations to teach genetics concepts in order to facilitate students' learning.

4.6.2.3.2.2 The Activities Employed by Teachers While Teaching Genetics

The central activities employed by teachers while teaching genetics were problem solving about crossing, students’ construction of their own pedigree, using of computer, Internet, and assignments.

The main activities of the participant teachers was problem solving; Beste solved 29 problems, Melis solved 37 problems, nine of which were not stated in the science curriculum, Mert solved 22 problems, Nehir solved 20 problems, Seda solved 25 problems, eleven of which were not stated in the science curriculum. There were four main types of problem employed in teaching genetics: (1) general crossing, (2) sex crossing, (3) hereditary disease, and (4) pedigree.

Participant teachers mostly employed the textbook problems, besides they also employed the supplementary books. On the other hand, they sometimes employed problems which were not section of the curriculum. This problems were generally hereditary disease or blood type problems and students were confronted with difficulties in these kind of problems. Teachers also chose their problems in their teaching according to students’ needs. For example, Seda selected hereditary disease examples because of her students having cross-cousin marriages. Participant teachers also developed their genetics problem.

Another activity employed by teachers while teaching genetics was construction of pedigree. Beste gave the homework of constructing own pedigree to her students. She expected from her students to select a trait and constructed their own pedigree by tracking to this trait. A similar pedigree activity was employed by Nehir, and she sought their students to construct pedigree based on observable traits. She employed this pedigree to increase their understanding on genetics and acquired traits. Nehir also employed another pedigree to help students’ understanding about dominant and recessive traits. Mert wanted student to prepare the pedigree for the teaching of heterozygous concepts. Seda prepared a special pedigree representing hereditary disease in a family and this family had cross-cousin marriages. She allowed her students to examine whole family especially their relationship among the relatives and inbred children. Then she asked her students to calculate the probability of having a baby with hereditary disease in these families. She notified her students about risk on hereditary disease for the close cousin marriages.

Other employed activities by participant teachers in teaching genetics were videos and Internet activities. Beste employed computer simulation for crossing as an activity. This simulation activity was presented on the Vitamin website, offered by Ministry of National Education. Seda utilized the animations and videos on the Internet and she stated that student had difficulty to imagine the mechanism of genetics and genotype-phenotype relationship.

Teachers also gave their students some assignments based on Internet search or observation of their family. Melis gave assignment about identifying similarities and differences in their parents. This activity helped students to identify the genetic traits. Melis also gave another assignment based on the Internet search on genetic disease and expected from her students to share their findings in the classroom. Seda gave homework related to hereditary disease. She begun with homework required to students make a research on hereditary disease on the Internet, news on newspaper and hospitals. Seda's another homework related to hereditary disease was on searching a person life born with hemophilia and her/his difficulties due to hereditary disease. She believed that these homework helped her students became more aware about "the hereditary disease", "potential risk of cross-cousin marriages" and "difficulties of caring a hereditary disease person." After the topic of hereditary disease was held in the classroom, Seda asked to her students to examine their or close families regarding hereditary disease including patient life.

There were some activities employed by one teacher for some pedagogical purposes. During teaching phenotype, Melis described her phenotype and then she expected from her students to describe their phenotypes. This activity aimed to concrete and familiarize the genetics concepts to her students. Mert started to teach genetics drama of Mendel's life to attract grab the students' attention to the topics. The activity of Let's help Mendel was actually based on the textbook. However, Mert employed the activity to explain meiosis, gametogenesis, and fertilization in crossing. Moreover, Mert's purpose was to help students visualize how gametes are paired randomly in crossing. Nehir also conducted a frequency table activity on dominant and recessive concepts.

On the other hand, textbook included some activities for teaching genetics such as "Do we resemble each other?," "The resemblance of animals," "Lets help the Mendel," "Search the gene and dominant-recessive genes," "Learn the traits of your family," "Toss a coin for sex crossing," "What is the Mert and his family genotype and phenotype." The participant teachers' rationalization were based on time considerations and stated that they did not have enough time to apply all textbook activities. Some of them gave these activities as homework and some of them just skipped them.

4.6.2.3.2.3 Teaching Strategies Employed by Teachers to Overcome Students' Difficulties While Teaching Genetics

Teachers were asked what kind of strategies they employed to overcome students' learning difficulties while teaching genetics. Data on teaching strategies to overcome difficulties were obtained through drilling questions during pre-PCK and post-PCK interviews. Even tough, the employed strategies to overcome students changed by teachers, teachers' strategies depicted some commonalities. In this manner, the employed strategies were given in the following titles.

In order to lessen the difficulty while learning genetics, teacher applied some teaching strategies. There were many new concepts in genetics and this was stated as a hindrance for students' learning by the teachers. Although all participant teachers clarified this difficulty, three of the participants taught additionally the Latin terms of genetics like homozygous [homozigot]. This addition was probably sourced from deficiency of curriculum knowledge because previous curriculum included the Latin genetics terms. However, the current science curriculum merely employed the

Turkish terms. Other sources of teacher' usage of Latin genetics term, they stated in the interviews, were cram schools' teachers and supplementary books. They feel that they have to teach Latin genetics terms because some students brought these terms from their cram school or supplementary books. On the other hand, Beste and Nehir stressed up on using the only Turkish genetics terms. They notified their students frequently about using the Turkish terms even when students asked question from supplementary textbooks. On the other hand, Melis tabulated the all genetics terms with Latin and Turkish ones to be able to visualize all the genetics concepts for her students to make learning of genetics term easier for her students. The algebraic method for crossing, using some letters in crossing (Uu, Ss, Iı, etc.), using x letter between the genotypes caused difficulty in students' learning in genetics and then Nehir warned her students about not to use them. On the other hand, Mert and Seda added some applications such as sex symbols (♀, ♂), and P, F_1, and $F_{2.}$ These were not covered by the curriculum. According to Nehir, each addition to crossing caused difficulties in learning genetics.

Another common difficulty of students related to representation was the arrows in crossing. Arrows represent transition of gametes from parents to offspring. Arrow helped to follow the probable combinations of gamete pairs and it limits the possible faulty while combining the gamete pairs. Some of the students did not use the arrows and some of them confused the order of the combinations. As expected, this affected negatively the result of the crossing and students reached the wrong results from crossing. For this reason, teachers employed some of the strategies for overcoming students' difficulty about the usage of the arrows. Beste taught her students Punnet square as an alternative of the crossing with arrows. Moreover, Nehir did not allow her students using arrows in crossing because some of her students firstly wrote the results of crossing and then added arrows, besides some of them did not care the arrows or drew arrow unordered way. Melis, Mert and Seda only reminded their students to use arrows correctly or notified them to care the order of the arrows when encountered the incorrect usages of arrows.

Especially Melis employed tables as teaching strategies to make the genetics concepts clearer and more observable for her students. Her students faced a difficulty in notation of dominant phenotype (AA or Aa) and homozygous genotype (homozygous dominant-AA or homozygous recessive-aa) due to having two different notations. She taught all conversion and notations with a table and this table made it more clear the probabilities of all notations and types at a single glance for students. Moreover, she gave all genetics traits with dominant and recessive on a table. She utilized table in every opportunity in genetics teaching and she stated table usage came from her learning styles. Beste preferred to use Punnet square her students in the case of visual sign of difficulty with crossing represented with arrows. Moreover, Nehir's students thought that dominant traits should be common traits in the population and she asked known dominant trait and prepared the frequency table in the classroom to illustrate her students their postulate on dominant traits that is not necessary to be common traits in a population.

Teacher Mert employed the drawing to help his students overcome crossing difficulties. Mert's students did not understand parent genotype representing maternal or paternal gametogonium with diploid chromosomes and one-letter represents gametes with haploid chromosomes. Mert employed a big circle for gametogonium, a little circle for ovum and a circle with a tail for sperm cell while teaching crossing.

The participant teachers strategies employed for overcoming students' difficulties were affected by their background. For example, Melis syllabified both terms as homo-zygous and hetero-zygous and focused on homo-hetero syllables while teaching homozygous and heterozygous. She related homo-hetero syllables with chemistry terms of homo-geneous and hetero-geneous and explained with solution examples. This was probably based on her chemistry background.

According to Mert, the scientist lives was attractive for his students, besides students like drama and find it enjoyable. He tried to catch his students' attentions with the help of the drama of Mendel on genetics topic.

All the participants teachers were aware the students' difficulties in representation and visualization of genetics concepts, and the difficulty related to different biological levels such as a gene and an organism level. To get over these difficulties, Beste, Mert, and Seda took advantage of the animations and videos on the Internet and they employed computer activities in their teaching genetics. Teachers also beneficiated from the technology in teaching homozygous, heterozygous, crossing, hereditary disease. The limitation of using computer and Internet was based on they might be required extra knowledge to comprehend the theme of videos because most of computer activities content exceed the limit the curriculum.

To help her students on probability and independent assortment of gametes, Nehir conducted sex probability activity based on tossing two-coins. In this activity a coin represented the father and X letter was written one side of it and Y letter was written another side. Other coin represented the mother and both side of the coin were written with X letter. She conducted this activity with all students. This activity helped students understand that probability in sex crossing and the crossings results did not depend on the previous child sex or genotypes. Nehir and Seda gave importance on teaching hereditary disease due to the fact that their classroom included students having hereditary diseases relatives. To help her students and increase their awareness, Nehir took all students' opinion about cousin marriage by asking questions such as "do you think to marry with a cousin?" Nehir and Seda warned students verbally about the possible effect of cousin marriage. Seda also prepared a text about hereditary disease and some prevention and she made her students to take not this text in the classroom.

All teachers stated that there was a common science knowledge requirements such as cell, cell parts, DNA, genetics code, chromosome, diploid-haploid chromosomes, germ cells, sperms, ovum, gametogonium, cell division, meiosis, and fertilization. Except Melis, all participant teachers felt that they need to explain this science knowledge because meiosis, fertilization and other topics were held after the genetics topic. On the contrary, Melis changed the order of textbook topics while teaching genetics as genetics after the DNA, meiosis, and reproduction topics. Her reason based on "Learning genetics topic needs good understanding of DNA, meiosis and reproduction… changed the topic order to help students..."

Some of the teachers' strategies on students' difficulty were caused failure or lack of success and even they added new difficulties for students in learning genetics. For example, Melis tried to teach sex-linked genetic disease with pedigree, and Seda tried to teach blood type with tables. Firstly, neither sex-linked genetic disease nor blood types were covered by the science curriculum. Secondly, none of the students did not solve the problems. Thirdly, since teachers solved the problems then, most of the students did not understand the solution giving by the teachers. And then teachers had to repeat the solution two or three times, and this confused students mind more. At the end, both teachers discontinued to teach the solution of these problems.

It was seen that, when the participant teachers were confronted with a student's difficulty, they applied a cyclical procedure based on explanations, giving similar examples, more drill-practice applications, and assignments.

Participant teachers mostly employed explanation as a teaching strategy in order to overcome students' difficulties while learning genetics. Except Melis, the four participant teachers employed explanation to compensate students' science knowledge requirements such as cell, cell part, DNA, genetic code, chromosome, diploid-haploid chromosomes, germ cells, sperms, ovum, gametogonium, cell division, meiosis, and fertilization. Teachers felt that they need to explain this science knowledge because meiosis, fertilization and other topics were held after the genetics topic. All of the participants employed this knowledge especially for the explanation of the underlying mechanism and the meaning of crossing tasks and representation. For examples, Beste employed the explanation for the students' confusion about crossing order and sibling order. Similarly, the explanation was employed as a strategy for the difficulty of students on heterozygous by Melis, for the relationship of genetics concepts by Mert, for the meaning of crossing tasks by Nehir, and Seda. Parallel to explanation, teachers also mostly employed notifying and reminding some points in the genetics topic to help their students on their difficulties. For example, Mert's students did not use arrow in crossing and then he just notified his students to use arrows. Seda reminded her student when they wrote as parents genotypes directly as their children genotype.

The second section of cycle teaching was the examples. For the difficulty of students in the concept of heterozygous, Beste first explained heterozygous and then gave examples of heterozygous crossings. Melis's students thought that dominant traits should be common traits in the population; Melis solved several pedigree problems to help her students.

In addition, participant teachers' selection of traits examples was so skillful for helping students to learn genetics in their classroom. Beste selected known traits as an example in her lesson and she explained that her students live in urban areas so they do not know genetic traits of many animals and plants. According to Beste, the use of unknown traits deepens the difficulty of students to learn genetics; therefore, she preferred to use human traits such as eye color. Melis stated that this age students gave importance in their appearance. She employed mainly human traits examples, especially related to appearance of a person like hair color, eye color, and hair type. Mert especially preferred to use pea traits because he thought that each new traits also need to identify dominant, recessive gene and representation and this process increased the difficulty of his students. Nehir employed same textbook examples in her lesson in order to help her students follow and repeat what they learned in the lesson. Seda selected the hereditary diseases example due to the fact that there were students whose parents had cross-cousin marriages in her classroom and she wanted to prevent her students from cross-cousin marriage in the future by means of increasing their awareness about the rise in probability of hereditary disease in cross-cousin marriages.

The employed cycle teaching to overcome students' difficulty was the assignments. Three main type assignments were common among the teachers; crossing problems, pedigree construction, Internet search. In the case of Melis's students faced with difficulty to distinguish genetics relative and marital relatives, in other words they did not understand blood relations and in-laws relations in a family, she gave an assignment about “What similarities and differences do you have in your family?” to her students. The similar assignment was given about genetic traits by Nehir and about hereditary disease by Seda to their students.

According to participant teachers, students had difficulties with the concepts of inherited traits-acquired traits (Nehir), carrier (Seda), heterozygous (Mert). In addition, Nehir’s students had misconception was that dominant traits should be common traits and Mert’s students had difficulty with notation of dominant phenotype due to the fact that his students preferred to write homozygous dominant genotype instead of both homozygous dominant and heterozygous genotypes. To get over these difficulties and misconception, participant teachers beneficiated from the pedigrees and they gave assignment to their students based on constructing a pedigree on observable traits in their family. Then, these pedigrees were tracked the traits genetics transition through generations by teachers and students to clarify the students’ difficulties.

5. CHAPTER

DISCUSSION

This chapter addressed conclusion and discussion of the research findings and followed by implications for the further researches. The research findings were discussed under two main sections based on the research questions. In the first section, the nature of the science teachers' content knowledge about genetics was discussed with references to the previous studies. In the second part, the nature of the science teachers' pedagogical content knowledge was discussed.

5.1 The Science Teachers' Content Knowledge

In this study, the nature of five science teachers' PCK on teaching genetics was investigated. To examine science teachers' content knowledge on genetics topic, the content test was applied and it consisted of two open-ended questions; one is genetics concepts question and the other one is genetics crossing question.

In the concept question part, teachers were asked to define the seven genetics concepts including gene, dominant gene, recessive gene, phenotype, genotype, homozygous, and heterozygous.

The analysis of the results revealed that teachers' knowledge of concepts was found as partial for the most of the teachers. Descending order of the results of the genetics concept analysis was revealed that teachers has sound knowledge on concept of gene (2 teachers), homozygous (2), phenotype (1), genotype (1), recessive gene (1), dominant gene (0), and heterozygous (0). The similar order was also found for the ontological categorization and the definition of teachers was in the process category for phenotype (4 teachers), gene (2), homozygous (2), genotype (1), recessive gene (1), dominant gene (1), and heterozygous (1). Teachers had difficulties in defining genetics concepts in the process category with respect to ontological categorization (Chi et al., 1994) and teachers' definitions generally were in the matter category consistent with this finding. Tsui and Treagust (2004) highlighted that students have similar tendency to think of genetics concepts as matter based rather than process-based. Chi et al. (1994) stated that students prefer to accept most concepts, actually in process category, as in the matter category initially.

The interesting result was found for the concept of phenotype because only one teacher had sound understanding for phenotype but four teachers' definitions of phenotype were in process category. This situation can be explained with the phenotype definition that is "the physical appearance or biochemical trait of an organism as a result of the interaction of its genotype and the environment." All teachers defined phenotype at least as physical appearance by means of genotype. This definition includes process information of phenotype, probably this affected the obtained results for phenotype. Moreover, the weakest concept for all teachers was heterozygous because none of the teachers' knowledge was sound understanding and only one teacher definition was in process category. The remarkable point was that all teachers stated heterozygous as one of the students difficulties during interviews.

In the crossing question part, a monohybrid-crossing question was asked to evaluate teacher knowledge about crossing. It was an open-ended question. Responses of teachers revealed that Beste, Melis, and Nehir correctly symbolized and solved the problem. Mert and Seda partially answered the crossing problem. In the crossing question, science teachers experienced difficulty in understanding of two different (homozygous and heterozygous) genotype probabilities according to given dominant character phenotype. Beste, Melis, and Nehir solved correctly the crossing question, since they represented their knowledge on symbolizing and solved both of the probabilities. These teachers did not have any hesitation in choosing and applying the correct tasks and probabilities. On the other hand, two teachers only made crossing for the dominant genotype. Interestingly, this was stated as the students' difficulty by Nehir and Mert during the pre-PCK interview. However, Mert also had this difficulty along with the participant Seda. In addition, it seemed that all teachers could easily conduct basic crossing tasks. Thus, the results did not support the assumption that participants who can conduct basic crossing tasks have adequate conceptual understanding on genetics (Rollnick et al., 2008). Here, teachers focused on performing the tasks on crossing correctly probably inhibit their reasoning on the meaning of operations. In other words, teachers' mastery in algorithmic knowledge did not allow them to reason the crossings tasks conceptually (Käpylä et al., 2008; Knippels et al.; Rollnick et al., 2008). The results of crossings also supported the findings in the genetics concepts definitions of teachers that teachers did not have adequate conceptual understanding.

Looking at the teachers' knowledge deficiency such as in definition of heterozygous and in crossing questions, it is expected to be very difficult for a content novice to recognize students' deficiency because of teachers own deficiency (Käpylä et al., 2008). Moreover, teachers having inaccurate and inadequate knowledge might transfer their own deficient knowledge to their students and in this way they can increase to students' conceptual difficulties (Hasweh, 1997; Käpylä et al., 2008; Sanders et al., 1993). For this reason, in order to use effective strategies that enhance students learning, firstly teachers should question their own knowledge of concepts (Lederman & Latz, 1993; Sanders et al., 1993). Focusing on performing crossing tasks probably inhibited their further reasoning on crossing such as the relationships among different the organism levels. Moreover, teachers need to know what is involved in an appropriate the definition of a term or a concept and how to represent these concepts (Rollnick et al. 2008). Results of the study recommended the teacher educators on designing the opportunities for improvement of the genetics understanding of teachers at preservice and inservice education.

5.2 The Nature of Science Teachers' Pedagogical Content Knowledge

In this part of the discussion, the result about second research question related to PCK components; knowledge of curriculum, knowledge of students and knowledge of teaching strategies were discussed.

5.2.1 Teachers' Knowledge of Curriculum about Genetics

The first component was about the science teachers' knowledge of curriculum. The results of the study revealed that teachers could not directly address the curriculum objectives during interviews and teachers' knowledge of curriculum was mainly based on the textbooks. Answers based on the textbook were probably sourced from their teaching because their teaching mainly based on the following the topics sequence in the textbook. This kind of teaching was also kept their teaching greatly inside the curriculum border as well. Hasweh (1987) stated that when teachers feel incompetent, teachers inclined to follow the chapter closely in their planning process and the book chapter function as guidance in their instruction organization to include choice of activities, and examples. In the present study, it was also found that teachers did not have sound knowledge of content on genetics topic. In this manner, teachers' deficiency in knowledge of content would be the reason for their instruction based on following the topic sequence in the textbook.

On the other hand, teachers had some common applications that exceeded the curriculum border. These applications can be categorized in to three. One is previous curriculum (2000) application such as using Latin terms heterozigot [melez] [heterozygous]. The following of the previous curriculum (2000) application means that simply adopting new curriculum and textbooks do not guarantee the success of new curriculum. Similar findings highlighted by Lynn, Bryan, Mark, and Haugan (2012), and Cohen and Yarden (2008). This is also a sign that teachers need see what are the changes of new curriculum and textbook.

The other teacher application exceeding the curriculum was the usage of the F_1, F_2, and P symbols in crossing. During pre-PCK interview, one of the teachers, Beste, highlighted that usage of these symbols was from the university biology courses. Beste and Mert were also graduated from biology department in the art and science faculty and Seda was graduated from the department of biology education in the faculty of education. Tobin, Tippins, and Gallard (1994) stated that understanding of teaching was sourced from their previous learning experiences from elementary education to higher education and teachers generally teach how they learnt. Participants taught how they learn in their faculty and they did not take into account science curriculum during their teaching.

The third application exceeding the curriculum was crossing on hereditary disease. Although all participants admitted that students experienced difficulty with crossing on hereditary disease, Seda and Melis solved crossing on hereditary disease including sex-linked diseases. They even had to solve same crossing repeatedly since their students did not understand the solution. Seda stated as a reason that her students came from cross-cousin marriage family for teaching the hereditary diseases. Although science textbook (Ministry of National Education, 2009) includes an example of sickle-cell disease once as an example of inherited disease and it was only shown with AA (healthy person), Aa (carrier), aa (sick person) in the students textbook but does not include sex linked disease or X^RX^r. Textbook consciously did not use X^RX^r and other representations in hereditary diseases because genetics literature highlighted that students in middle schools had difficulty with basic Mendelian genetics (Knippels et al., 2005) and all participant teachers agreed on the students difficulty with the crossing. Besides Nehir stated that genetics is already a difficult topics and adding representations and information make it more difficult than the curriculum offered ones. For this reason, it is recommended that teachers should keep their teaching inside the curriculum and textbook border not to make it more difficult for their students with some application such as hereditary disease crossing. They can use the examples of textbook and heterozygous genotype more competently to teach their students hereditary disease without increasing the difficulty.

For the curriculum violations of teacher, the context of Turkish educational system might explain the some of the reasons. Since 11 different version of science curriculum were developed and circulated from the republic of Turkey established in 1924 to 2005 (Çalık & Ayas, 2008). Çalık and Ayas highlighted that Turkish teacher could not completely applied the old curriculum before the new curriculum one was adopted (2008). It was a signal the need of assessment of curriculum how much it was applied in educational environment before developing the new ones. After the evaluation of curriculum changes, Coll and Taylor (2012) suggested that it is meaningful not to substantially change science curriculum, as it is happen in Turkey context. The frequent change in curriculum resulted in Turkish teachers' ignoring the curriculum changes and they continued teaching as they get employed to (Coll & Taylor, 2012).

Another application of the participants was skipping some of the textbook activities to save time. Although all participants had time concern to cover the curriculum, they did not use the time wisely due to their curriculum knowledge deficiencies as aforementioned. The curriculum knowledge might help the teacher to focus on the better teaching for the genetics topic because they should use their time to teach conceptually as the literature highlighted (Cavallo, 1996; Friedrichsen & Stone, 2004; Lewis & Wood-Robinson, 2000; Law & Lee, 2004; Lewis & Kattmann, 2004; Lewis et al., 2000a; Marbach-Ad, 2001; Wynne, Stewart & Passmore, 2001). Contrarily participant teachers solved more crossing questions, employed hereditary diseases or other applications (e.g. video) or explanations (e.g. Rh factor, apoptosis) not covered by the curriculum, this resulted in wasting time than expected. Teaching inside the curriculum border also helped teachers to use time wisely.

5.2.2 Teachers' Knowledge of Students about Genetics

The understanding of PCK in the literature (Gess-Newsome & Lederman, 1999; Veal et al., 1998) highlighted that PCK is developed with experience while teaching students. The development of PCK with experience while teaching the students was obvious especially for the components of knowledge of students (Bucat, 2004, Cohen & Yarden, 2008; Gess Newsome, 1992, Hasweh, 2005). In the present study, the entire participants had over 14 years of teaching experience and they represented generally sound knowledge of students with respect to both knowledge of requirements and difficulties of students while learning genetics with some limitations. Student knowledge was discussed under two titles; requirements of students and difficulties of students while learning genetics topic.

All of the participant science teachers had sound knowledge of students' requirements for genetics. Participant teachers stated that students require the scientific knowledge prior to learning genetics such as cell, cell parts, DNA, genetic code, chromosome, diploid-haploid chromosomes, germ cells, sperms, ovum, gametogonium, cell division, meiosis, and fertilization. These requirements were parallel with the literature (Banet & Ayuso, 2000; Cavallo, 1996; Friedrichsen & Stone, 2004; Lewis & Wood-Robinson, 2000; Law & Lee, 2004; Lewis & Kattmann, 2004; Lewis et al., 2000a; 2000d; Marbach-Ad, 2001; Pashley, 1994; Wynne et al., 2001). Participants stated that this scientific knowledge was required to understand mechanism of genetics, transfer of genetic information, by the way the meaning of crossing symbols and crossing tasks. As a specific example of students' requirement, Nehir stated that students think that only human can sexually reproduce. Before teaching crossing in plant examples, students should have knowledge about fertilization in plants. This was also a common misconception of students stated in the literature (Tekkaya, 2002).

Teachers were generally aware of science knowledge requirements of students. Moreover, they stated that there was a need to change the topics order in the curriculum and textbook for teaching genetics because genetics code, meiosis, and fertilization were held after genetics topic in textbook. This caused difficulty in learning genetics topic and all participant teachers highlighted that the curriculum topic order should be changed to be able to supply solid knowledge basement for learning genetics. The lack of the pre-requisite knowledge results in problems in learning science (Sirhan, 2007). For the genetics topics; gene, gamete, allele gene, mitosis, meiosis and fertilization concepts were accepted as prerequisite in the literature (Allchin 2000; Bahar, 2002; Bahar et al., 1999; Law & Lee, 2004; Tsui & Treagust, 2003). To compensate scientific knowledge requirements of students for learning genetics topic, four of the participants just tried to give brief information about meiosis, fertilization, and genetics code when they felt necessitate for explanation, especially in crossing. Exceptionally, Melis changed the order of textbook topics before teaching genetics to be able to meet students' science knowledge requirements. In addition, gene, gamete, allele gene, mitosis, meiosis and fertilization concepts already accepted in the literature (Bahar, 2002; Bahar et al., 1999) as difficult topics for learning and as the teachers approach, just brief explanation was not the adequate approach to compensate students' knowledge requirements for conceptual understanding. Allchin (2000) recommended that teachers should teach the complete pathway from gene to trait and this was possible to teaching the DNA, gene, allele gene, mitosis, meiosis and fertilization order. For this reason, curriculum and textbook topic order should be changed as Melis' order in order to meet students' requirements.

Lawson and Thompson (1988) suggested that formal reasoning patterns are essential for sound understanding of genetics concepts due to the having abstract nature. In this manner, teachers explanations related to genetics, particularly the parts were not covered by the curriculum such as apoptosis, in vitro fertilization etc., should be appropriate to the students reasoning abilities.

The participants' knowledge of students' difficulties while learning genetics were parallel with genetics literature. To illustrate, all teachers' students had difficulty with mechanism of crossing, and they could not link between cell division and inheritance as Allchin (2000) and Lewis and Wood-Robinson highlighted

(2000). As stated in Tekkaya (2002) study, Nehir's students thought that plants do not sexually reproduce. Participants stated similarly in Pashley (1994) study their students faced with difficulty in understanding of gene and alleles and this difficulty led to confusion about the other genetics terms such as homozygous, heterozygous, dominance or recessiveness. Beste's students confused hybrid person with heterozygous genotype and similar difficulty was highlighted in Knippels's et al. (2005) study. Mert, Nehir, Seda's students struggled with linking between the major concepts because they were concurrently subjected to various concepts and processes at different levels of organization; micro, macro and organismal levels, which they cannot deal with them. This situation was also underlined in Marbach-Ad and Stavy (2000) and Knippels et al.'s (2005) studies. In a similar vein, Melis and Nehir stated that their students hardly understood some genetic concepts including the difference between things that were inherited and not inherited, and Seda's students underestimated the risk of being carrier, especially in case of cross-cousin marriages. Similar difficulties were stated by Kibuka-Sebitosi's (2007), and they stated in their study that prior to students learn genetics scientifically in school, they gain insight, belief or some knowledge from their parents, community and media, and these are generally naïve understanding or misconception about genetics.

The evident point was that teachers' knowledge of students' difficulties changed from participant to participant. For examples, although Nehir's students thought that plants do not sexually reproduce, remaining participants did not state anything related to this misconception. Mert, Nehir, and Seda's students struggled with linking between the major concepts but Beste and Melis did not state this difficulty. The teachers' knowledge sources for students' difficulties were based on their teaching experiences. Depending solely on their experiences also limit their knowledge on students' difficulties. The teachers' knowledge of assessment is not inside scope of the present study. However, it was seen by the researcher that teacher did not employed any specific assessment methods to detect students' misconception. Limitation in the knowledge of students' difficulties is a hindrance to developing robust PCK (Brown, et al., 2012; Carlsen, 1993; Cohen & Yarden, 2008; Gess

Newsome, 1992; Hasweh, 1987, Käpylä et al., 2008; Sanders et al., 1993; Veal and Kubasko, 2003;Veal et al., 1998) and well-structured teaching cannot be thought without sound knowledge of students. It is recommended that teachers should follow the literature about studies on the genetics topic and other science topics. Moreover, teachers should have the opportunities to share their experiences with their colleagues. Otherwise, each new teacher has to learn everything from the beginning like discovering the wheel again. Bucat (2004) called this fresh starting of each new teacher as professional amnesia; he thought that the PCK studies similar to present studies might help to remediate the professional amnesia. Bucat (2004) suggested both preservice and inservice education to supply the teachers' knowledge of students' difficulties. Furthermore, teachers should be supported on the misconception detection methods to assess their students accurately.

5.2.3 Teachers' Knowledge of Teaching Strategies

Teacher knowledge about teaching strategies about genetics was discussed in this section. The teaching strategies knowledge of the participant teachers were presented with two titles subject specific and topic specific teaching strategies.

5.2.3.1 Teachers' Knowledge of Subject Specific Strategies

Any one of the participant teacher did not use any subject-specific teaching strategies (learning cycle, discovery, inquiry conceptual change etc.) in teaching genetics. Magnusson et al. (1999) stated that teachers have deficient knowledge about the strategies. Similarly, according to Settlage study in 2000, teachers do not know how to implement the subject specific teaching strategies and Flick (1996) stated that teacher do not have enough experience on teaching strategies. In the present study, only Seda took teaching biology course in undergraduate education and other participants did not take any science-specific education. Moreover, similar to most of the other teachers in different studies (DeBoer, 1991, De Jong et al., 1995, Friedrichsen et al., 2007, Ingber, 2009), the participants of the study probably did not have opportunity of observing how the subject specific strategies can be applied in real classroom environment.

According to Freidrichsen and Dana (2005), teachers' goals affected their subject specific teaching strategies. The participant teachers stated their goals as covering curriculum objectives, preparing the high school examination and learners' requirements and interest during interviews. They stated that they had desire to use more students centered teaching strategies while they are teaching. However, they admitted in the interviews that loaded curriculum, preparing students to high school examination, lack of materials and time limitation were the hindrance for the use of students centered teaching. Similar difficulties were also stated by the teachers in the literature (Friedrichsen et al., 2011; Friedrichsen & Dana, 2005; Nargund-Joshi, Park-Rogers, & Akerson, 2011). The other barriers to conducting student centered strategies stated by teachers were curriculum load (Samuelowicz & Bain, 1992), additionally load of teaching works such as checking assignments, preparing and grading exams etc. (Nargund-Joshi et al., 2011) and preparing student centered activities require extra time (Friedrichsen & Dana, 2005).

Moreover, middle school education ends up with high school examination such as SBS (Placement Test) and TEOG (Examination of Transition From Primary Education to Secondary Education) and the result of exam are employed for selection of the high school types such as Science or Anatolian high schools. Students, parents, and teachers believed that the types of high school affect students' academic performance and profession selection (Köse, 1999). The 8th grade student in Turkey are exposed to an atmosphere which covered by examination which required to enter the special high schools. Teachers in every academic domain feel stress on preparing their students to this exam. Similarly, all participant science teachers gave utmost importance to high school examination and exam content take important part in their teaching. Besides, high school examination is completely based on multiple-choice questions. The examination generally included genetics problems based on crossing.

Although all participants were aware of the benefits of student centered teaching activities, they consciously did not allocate much time for student-centered activities and by this way, they preferred to save time for performing more crossing problems. The teachers from different countries such as India (Nargund-Joshi, et al. 2011) and China (Zhang, Krajcik, Sutherland, Wang, Wu, & Qiang, 2003) experience similar exam based educational system and they had to concentrate on multiple choice question teaching so as to their student could solve the exam question.

The above reasons and more for teaching genetics, the participant teachers' PCK is mostly represented with teacher centered teaching and focused on the transfer of the content to students in a didactic fashion.

5.2.3.2 Teachers' Knowledge of Topic Specific Strategies

Teacher knowledge about topic specific teaching strategies were investigated with components of representation, activities, and strategies to overcome students' difficulties employed by teachers while teaching genetics and they were discussed in this part.

The main purpose of the representations employed by the participant was to make the genetics topics more concrete for students. Teachers' most common usage was the textbook illustrations. Moreover, teachers employed Punnet square as alternative to crossing illustrated with arrows. Teachers' utilized tables for genotype and phenotype relationships and frequency table for dominant and recessive traits. Teacher drew the big circle for gametogonium, little ones for gametes as sperm and ovum, chromosomes including different genes. The using sex symbols (♀, ♂), different color for each gene in allele pairs of parents' genotypes are the other usage of illustrations. Teachers' representations were user friendly in all classroom condition because they did not need any material. However, genetics topics included abstract concepts, and these concepts are related to each other with micro level to organism level. Similarly, different levels of representation present in science content were discussed in chemistry by Treagust and Chittleborough (2001) and they stated that teachers' representations enable students to switch between the macro, observable phenomena such as the phenotypic expression of genes, the microscopic entities such as the nucleus and chromosomes, the sub-microscopic phenomena such as DNA and symbolic representations such as notation of genotypes. According to Sander et al. (1993), teachers struggled with finding appropriate representations to facilitate student understanding. For this reason, science teachers should be supported on the representations.

Allchin (2000) suggested that teachers should also use a few well-chosen examples to make genetics topic closer, and more concrete for their students. It was seen that participant teachers adapted the trait examples concerning students' requirements such as their living area, their ages, hereditary diseases traits to prevent students from the possible risk of cross-cousin marriages and some of them employed textbook traits, pea traits to lessen the difficulty. Venville and Treagust (2002) suggested teacher should use elaborated, well-planned analogies and models in a systematic, extended and useful way to enable students develop a more conceptual understanding of genetics. To illustrate, Beste employed shoe analogy for pairing of genes, and Mert employed transparent sheet for recessive genes and colored sheet for dominant genes. Content expert teachers in Gess Newsome (1992) study employed more examples related to students' daily life and developed model and analogies. On the other hand, content novice teachers in Hasweh (1987) study employed the textbook examples and they did not employed analogies. In this manner, the participant teachers were good at the finding examples to increase the effectiveness of their teaching; contrarily they did not use analogies in their teaching. According to Hasweh (1987) and Gess Newsome (1992), teachers should be supported regarding analogies and model for teaching genetics topic.

The central activity employed by teachers was problem solving about crossing. Teachers allocated considerable time for solving genetics problems in order to prepare their students to high school examination. Venville and Treagust (2002) stated that teachers in their study also spent considerable classroom time on problem-solving activities in basic Mendelian genetics. However, to successfully solve these problems, a student does not need to understand the structure and function of genes nor genetics concepts are related with different biological levels. To increase students understanding on genetics, Cavallo (1996), Duncan and Reiser (2007), Venville and Treagust (2002), and Wynne et al. (2001) suggested that teachers should apply conceptual teaching strategies rather than focusing on crossing problems.

On the other hand, spending considerable time on problem solving was discussed in the subject specific teaching but it affects negatively all components of the teachers' genetics teaching and activities as well. Other point was related to selection of problems. For example, Melis and Seda employed hereditary disease problems even as sex-linked genetic diseases on pedigree problems. These problems were not covered by the curriculum and they were not appropriate to this grade level students. These issues were held in the knowledge of curriculum and knowledge of students. Knippels et al. (2005) suggested that focus should not be on solving problems in teaching, but on making connections between conceptual teachings in their studies.

Another activity employed by teachers while teaching genetics was construction of pedigree. Teachers utilized pedigrees to help their students on learning to genetics and acquired traits, dominant and recessive traits, heterozygous concepts. For example, Seda also prepared special pedigree representing hereditary disease in a family and this family had cross-cousin marriages to prevent her students from the potential risk of hereditary disease especially in case of the close cousin marriages.

The computerized activity was employed by the teachers to concrete genetics because student had difficulty to imagine especially the mechanism of genetics and genotype-phenotype relationship. In the literature, specialized programs such as Biologica employed by Tsui and Treagust (2004), iconic model employed by Law and Lee (2004) and these researchers recommended use of computerized program to increase the concreteness and easiness of manipulation. They stated that the increase in the quality and quantity of the similar programs to help students learning genetics. The participant of the study also pointed out limitation of available computerized activities related to the teaching genetics.

Some activities of teachers were powered from the knowledge of students. For example, Melis described her phenotype and then she expected from her students to describe their phenotypes. Melis stated as this age students affected from their appearance. Another activity was use of Mendel’s life drama in Mert teaching and he stated that his students like drama and this activity give them opportunity to dramatize the scientist’s life. Preparing frequency table was directly sourced from a Nehir’s student misconception about commonality and dominancy of a trait. In the aspect power of analogy and representation, Mert’s adoption of helping the Mendel activity was a unique example to explain meiosis, gametogenesis, and fertilization in crossing. In this activity, Mert aimed to help students visualize how gametes are paired randomly in the crossing.

Participants represented small differences in topic specific teaching strategies and these differences could be explained with their content backgrounds. For examples, Mert gave apoptosis example and Seda explained in vitro fertilization to their students. Both of the teachers graduated from biology department in the faculty of art and science and their example and explanation could be sourced from their biology background. In a similar vein, Melis graduated from chemistry department in the faculty art and science and she separated homozygous syllable by syllable as homo-zygous and homo-gene as employed in chemistry. Nehir described the male child expectations of families from different district of Turkey and their unscientific applications to have a male child in their lives. Beste gave an example of a Down syndrome person worked on a store and down café to see Down syndrome people. On the other hand, the differences of teachers in their topic specific strategies were not evident from each other, although participants have different background in different subject area because their graduation fields were different such as department of chemistry and biology in the faculty of art and science and department of biology education and science education in the faculty of education. The reason might be based on the abstract nature of the genetics topic (Banet & Ayuso, 2000; Cavallo, 1996; Friedrichsen & Stone, 2004; Lewis et al., 2000a; 2000d; Marbach-Ad, 2001; Wynne et al., 2001), and difficulty to find appropriate strategies while teaching genetics (Sander et al., 1993, Venville & Treagust, 2002, Tsui & Treagust, 2004; Law & Lee, 2004).

All teachers shared opinion that genetics has abstract nature and there is a great need to concrete, observable, hands on materials and activities. Similarly, the genetics literature highlighted the need of elaborated, well-planned analogies and models (Venville & Treagust, 2002), and computerized activities helped teachers represent the relationship in genetics concepts clearly (Tsui & Treagust, 2004; Law & Lee, 2004). The participant teachers appreciated the difficulty of preparing these kinds of materials and activity. Their excuse was centralized on the time limitations not only employing the activities in classroom but also preparing the material and activities although they gave enormous time for solving the genetics problems in their teaching. Gess Newsome (1992) highlighted the time usage of teachers in classroom and she stated that time usage of teacher influenced the teachers translation of content into teaching practices. Sander et al. (1993) stated that teachers struggled with finding appropriate representations to facilitate student understanding, this was because of teachers knowledge deficiency. Lederman and Latz (1993) reported that well equipped secondary science teachers in their specialty area also struggled with transforming that knowledge into meaningful representations, which is a critical characteristic of PCK facilitating the linkage of learners and their experiences with the material. For this reasons, science teachers should be supported on the representations of genetics concepts and relationships between these concepts by means of models, analogies, and computerized activities.

5.2.3.2.1 Teaching Strategies Employed by Teachers to Overcome Students' Difficulties While Teaching Genetics

When the participant teachers were confronted with a student's difficulty or misconceptions, they generally applied a cyclical procedure based on explanations, giving similar examples, more drill-practice applications, and assignments. Their approach to teaching was valid seemingly not only for the genetics topic but also for the other science topics. This might be explained by the teacher-specific teaching rather than the subject specific or topics specific, because according to Ingber (2009) and De Jong et al. (1995), teachers have a habit to implement the similar sequence and types of activities without thinking which topic was held. According to DeBoer (1991), this teaching cycle was resembled as chronic illness of teacher. It was found similar instructional cycle for teaching of molar topic by Rollnick's et al. study (2008). Friedrichsen et al. (2007) stated that this teaching was probably the only teaching approach that teachers experienced and they are teaching how they learn (Tobin et al., 1994). Similarly, Grossman et al. (2005) focused on the teacher learning experience and stated that as a student in undergraduate education and in the K12 experience are the source of teachers' recognition of teaching and PCK. When teachers did not have wide diversity of experiences on how to teach and they were not supported with subject-specific or topic professional development, they could not represent different teaching approach on genetics.

Moreover, participants employed some strategies specific for the difficulties of genetics topic. Teachers appreciated the difficulties of genetics as highlighted in genetics literature (Knippels et al. 2005; Pashley, 1994) and they employed some strategies to lessen or not increase the difficulty of learning genetics such as using only Turkish genetics term rather than Latin ones; not using F_1, F_2, P_1, P_2, x symbols. Participants respected the representation difficulties; they employed Punnet square for crossing, tabulating the relationships, transparent sheet for recessive and colored sheet for dominant, drawing the gametogonium as a big circle and gametes as sperm and ovum. To help probabilistic thinking, teachers employed activities such as tossing a coin for sex crossing, and constructing frequency table for dominant phenotype. Participant employed the pedigree construction for different difficulties such as to teach inherited trait-acquired trait, heterozygous, carrier etc. In addition, participant teachers' selection of trait examples was so skillful for helping their students to learn genetics in their classroom such as known traits for urban students, appearance traits for their age, pea traits to keep similarity, textbook traits to keep simplicity, hereditary disease traits examples to prevent students from hereditary diseases. All teachers employed the technology either documentary videos or computer programs to be able to compensate representational and relationships difficulties in genetics. However, the employed videos or computerized activities were not in abundance and some of them employed by teacher were not covered by the curriculum. Essentially, there was obvious need to more computerized activities appropriate the curriculum due to the nature of genetics topics.

The literature highlighted that PCK did not develop simultaneously and some PCK components developed earlier than the other components (Friedrichsen et al., 2007; Hanuscin, Lee, & Akerson, 2011; Henze, van Driel, & Verloop, 2008). In the present study, participant teachers represented sound knowledge of students' requirements and knowledge of students' difficulties and this knowledge were accepted as a basement for teaching strategies especially overcome the students' difficulties. However, the participant teachers of the study had limited knowledge on teaching strategies. Participants could not develop representation to teach meaningfully the genetics concepts and activities to help their students learn the relationships between genetics concepts. This situation resulted in weak approaches to help on students' requirements and to overcome the students' difficulties. This means that the deficient component of PCK results in unproductive teaching approach for the students' difficulties.

All of the participant teachers approached to students' misconceptions and difficulties in a similar fashion such as telling and explaining. Additionally, they did not conduct any activity or systematic approach to help their students. Ball and Bass

(2000) pointed out that teachers generally prefer to cyclical teaching pattern and Rollnick et al. (2008) stated that teachers did not focused on the conceptual part of the topic and employed a variety of student-centered approaches while teachers with limited PCK just taught algorithms. According to literature (Knippels et al. 2005; Pashley, 1994), using expository teaching method such as explaining the truth did not help for the remediation of students' misconception. Veal et al. (1998) stated that there is a deep requirement of teaching strategies based on student learning styles and their prior content understandings in conjunction with their own personal development on specific the content. In other words, there is need to robust PCK on teaching genetics.

5.3 Implication and Recommendations

In light of the results revealed and the points discussed, the study has several implications and recommendations for inservice teacher education, curriculum developers and textbook writers, and teacher education research.

As literature highlighted, teaching experience is a main source of PCK (Grossman, 1990; van Driel et al., 2002). On the other hand, merely teaching experience does not mean rich PCK (Friedrichsen et al., 2009). This means that teachers should be supported with professional development to enrich teaching strategies with respect to elaborating students' difficulties, how to respond this difficulties by means of enriched teaching strategies. This support should be discipline based and specific to topic teachers taught (Nakiboğlu & Tekin, 2006). All participant teachers in the study complained about the absence of science or topic specific training, and they stated need on especially for the topic of genetics. This study also revealed that teachers should have the opportunity to reflect on the specific topics with regard to how to use knowledge of curriculum, knowledge of students and teaching strategies in order to make their teaching more effective. Another key point for the development of rich PCK was supplying the long-term professional development for teachers (De Jong et al., 2002; Gilbert, De Jong, Justi, Treagust, & van Driel, 2002; Hanuscin et al., 2011; Nakiboğlu & Tekin, 2006; van Driel et al., 1998).

This study revealed useful information for education of preservice teachers as future teachers. For the reason that the literature depicts that similar to inservice teacher, preservice teachers also have weaknesses in genetics topics (Kibuka-Sebitosi, 2007, Knippels et al., 2005). It was recommended that preservice teachers should be supported on the genetics topic. The support should include not only content knowledge about genetics but also other PCK components. To illustrate, elective courses should be designed to help preservice teachers with regard to students' requirements, students' difficulties, teaching strategies, representations, activities specific to genetics topic.

The PCK studies help to each new teacher to prevent starting teaching over again and reinvent the wheel again (Bucat, 2004; van Direl et al., 1998) because teachers can build their PCK on already experienced practice of teaching and these help to increase their adopting well-developed PCK in their teaching. Moreover, Bucat (2004) stated that teaching as a profession has a common disease named as amnesia due to deficiency for sharing the wisdom of teaching experience and PCK studies hope to help teachers to have shared memory for teaching. The results of this study have valuable information on how to teach genetics topic with regard to PCK components; knowledge of students, knowledge of teaching strategies, knowledge of curriculum and knowledge of content on genetics and each components has unique examples of usage in teaching. This information recommended teacher educator to use in professional development for inservice education and preservice education.

The study results also revealed that teachers are in needs of support in genetics knowledge and teaching strategies and curriculum material for the genetics topic. As aforementioned, the difficulties of genetics were briefly based on abstractness of concepts and relationships among different biological levels. Teacher should be supported by curriculum materials to make it concrete and observable the genetics concepts and relationships among different biological level and they should be in curriculum border and suitable to 8th grade students. These materials can be developed for textbook, as a classroom activities, and computerized activities and available by the all science teachers and students. The main characteristics of the activities should be supported conceptual understanding of students because the activities employed by participant teachers focused on problem solving and activities were based on teacher-centered strategies. Especially, teaching genetics should be deviated from problem solving on crossing and drill and practice cycle by means of increasing the variety of activities.

Consisted with previous studies, the results of the study indicated that PCK is specific to teacher, students, and context (classroom, school environments, students' parents etc.) (Abell, 2008; Lankford, 2010; Nargund-Joshi, et al., 2011; Park & Oliver, 2008). From this point, it can be asserted that PCK changes from teacher to teacher, classroom to classroom. It cannot be reached one answer for how to teach a topic from the PCK study results (Park & Oliver, 2008). Instead, the nature of the PCK revealed that there are numerous approaches to teaching based on the teacher, students and context. The value of PCK studies arouses from the abundance of the variety of the teaching strategies. This study aims to investigate the PCK of teachers for the case of teaching genetics. The result of the study is helpful for the understanding of the nature of PCK on genetics topic.

The literature highlighted that PCK is changed with students and this study focused on the genetics topic on 8th grade. The genetics topic is also held in upper grades in biology courses and there is a need to study the PCK of genetics topic in upper grade students. Moreover, there is a need to study with other science topics, and other grade levels. In this study, teachers taught in public school and the studies should be extended the private school context.

This study can be strengthened by connecting teachers' PCK to student achievement. Researches that connect studies of teacher PCK to students' learning and achievement can provide important insight into the nature of effective instructional practices. Although this brings an additional load to the researcher in gaining access to students' test scores, it would be worth the effort. There should be topic specific examples of experienced teachers’ PCK (e.g. genetics) that demonstrate this level of PCK is linked to student achievement.

REFERENCES

Abd-El-Khalick, F. (2006). Preservice and experienced biology teachers' global and specific subject matter structures: Implications for conceptions of pedagogical content knowledge. *Eurasia Journal of Mathematics, Science & Technology Education, 2*(1), 1-29.

Abell, S. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education, 30*, 1405-1416.

Abell, S. K. (2007). Research on teacher knowledge. In S. K. Abell and N. G. Lederman (Eds.), *Handbook of research on science education* (pp. 1105-1150). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Allchin, D. (2000). Mending Mendelism. *The American Biology Teacher, 62*, 633-639.

Avraamidou, L., & Zembal-Saul, C. (2005). Giving priority to evidence in science teaching: A first-year elementary teacher’s specialized practices and knowledge. *Journal of Research in Science Teaching, 42*(9), 965-986.

Bahar, M. (2002). Students’ learning difficulties in biology: Reasons and Solutions. *Kastamonu Educational Journal, 10*, 73-82.

Bahar, M., Johnstone, A. H., & Hansell, M. H. (1999). Revisiting learning difficulties in biology. *Journal of Biological Education, 33*(2), 84-86.

Ball, D. L., & Bass, H. (2000). Interweaving content and pedagogy in teaching and learning to teach: Knowing and using mathematics. In J. Boaler (Ed.) Multiple perspectives on teaching and learning mathematics (pp. 83-104). Westport, CT:Ablex Publishing.

Banet, E., & Ayuso, E. (2000). Teaching genetics at secondary school: a strategy for teaching about the location of inheritance information. *Science Education, 84,* 313-351.

Baxter, J. A., & Lederman, N. G. (1999). Assessment and content measurement of pedagogical content knowledge. *In J. Gess-Newsome & Lederman, N. G. (Eds.), Examining pedagogical content knowledge: The construct and its implications for science education* (pp.147-162). Hingham, MA, USA: Kluwer Academic Publishers.

Bogdan R. C., & Biklen, S. K. (1998). Qualitative research for education: An *introduction to theory and methods* (3rd ed.). Allyn and Bacon, Boston.

Borko, H., & Putnam, R. T. (1996). Learning to teach. In D. C. Berliner & R. C. Calfee (eds.) *Handbook of Educations Psychology.* New York, NY: MacMillan.

Bransford, J., Brown, A. L., & Cocking, R. R. (Eds.). (1999). *How people learn: Brain, mind, experience, and school.* Washington, D. C: National Academy Press.

Brown, P., Friedrichsen, P. & Abell, S. (2012). The development of secondary biology teachers PCK. *Journal of Science Teacher Education, 23*(5).

Bucat, R. (2004). Pedagogical Content knowledge as a way of forward: Applied research in chemistry education. *Chemistry Education: Research and Practice, 5,* 215-228.

Carlsen, W. S. (1993). Teacher knowledge and discourse control: Quantitative evidence from novice biology teachers' classrooms. *Journal of Research in Science Teaching, 30,* 471-481.

Carter, K. (1990). Teachers' knowledge and learning to teach. In W. R. Houston (Ed.), *Handbook of research on teacher education.* New York: Macmillian.

Cavallo, A. M. L. (1996). Meaningful learning, reasoning ability, and students' understanding and problem solving of topics in genetics. *Journal of Research in Science Teaching, 33*(6), 625-656.

Chi, M. T. H., Slotta, J. D., & de Leeuw, N. (1994). From things to processes: a theory of conceptual change for learning science concepts. *Learning and Instruction, 4*, 27-43.

Clark, D. C., & Mathis, P. M. (2000). Modeling mitosis and meiosis: a problem-solving activity. *The American Biology Teacher, 62*(3), 204- 206.

Cochran, K. F., & Jones, 1. L. (1998). The subject matter knowledge of preservice science teachers. In B. Fraser & K. Tobin (Eds.), *International handbook of science education.* Dordrecht, The Netherlands: Kluwer.

Cochran, K. F., DeRuiter, J. A., & King, R. A. (1993). Pedagogical Content Knowing: An integrative model for teacher preparation, *Journal of Teacher Education, 44*, 263-272.

Cochran, K. F., King, R. A., & DeRuiter, J. A. (1991). *Pedagogical Content Knowledge: A Tentative Model for Teacher Preparation*. East Lansing, MI: National Center for Research on Teacher Learning. (ERIC Document Reproduction Service No. ED340683).

Cochran-Smith, M., & Lytle, S. L. (1999). Relationships of knowledge and practice: Teacher learning in communities. In *Review of research in education* (Vol. 24, pp. 249-306). Washington, DC: American Educational Research Association.

Cohen, R., & Yarden, A. (2008). Experienced junior-high-school teachers’ PCK in light of a curriculum change: “The cell is to be studied longitudinally.” *Research in Science Education, 39*, 131-155.

Coll, R. K., & Taylor, N. (2012). An international perspective on science curriculum development and implementation. In B. J. Fraser, K. Tobin & C. J. McRobbie (Ed.) *Second International Handbook of Science Education* (pgs. 771-782) New York: Springer Publishing Co.

Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions.* Thousand Oaks, California: Sage Publications.

Creswell, J. W., & Miller, D. L. (2000). Determining validity in qualitative inquiry. *Theory into Practice, 39*(3), 124-130.

Çalık, M., & Ayas A. (2008). A critical review of the development of the Turkish science curriculum. In R. K. Coll & N. Taylor (Eds.), *Science education in* *context: An international examination of the influence of context on science curricula development and implementation* (pp. 161–174). Rotterdam: Sense Publishers.

De Jong, O., van Driel, J., & Verloop, N. (2005). Preservice teachers' pedagogical content knowledge of using particle models in teaching chemistry. *Journal of Research in Science Teaching, 42,* 947-964.

De Jong, O., Veal, W., & Van Driel, J. H. (2002). Exploring chemistry teachers' knowledge base. In: J. Gilbert, O. de Jong, R. Justi, D. Treagust & J. van Driel (Eds.). *Chemical Education: Towards Research-based Practice* (pp.369-390). Dordrecht: Kluwer Academic Publishers.

DeBoer, G. E. (1991). *A history of ideas in science education: Implications for practice.* New York, NY: Teachers College Press.

Dogru-Atay, P., & Tekkaya, C. (2008). Promoting Students' Learning in Genetics through Learning Cycle. *Journal of Experimental Education, 76,* 259-280.

Donovan, M. S., & Bransford, J. (Eds.). (2005). *How students learn: Science in the classroom.* Washington, DC: National Academies Press.

Duncan, R.G., & Reiser, B.J. (2007). Reasoning across ontologically distinct levels: students' understandings of molecular genetics. Journal of Research in Science Teaching, 44, 938–959.

Fernandez-Balboa, J., & Stiehl, J. (1995). The generic nature of pedagogical content knowledge among college professors. *Teaching and Teacher Education, 11(3),* 293-306.

Flick, L. B. (1996). Understanding a generative learning model of instruction: A case study of elementary teacher planning. *Journal of Science Teacher Education, 7(2),* 95-122.

Friedrichsen, P. M., & Dana, T. M. (2005). Substantive-level theory of highly regarded secondary biology teachers' science teaching orientations. *Journal of Research in Science Teaching, 42,* 218-244.

Friedrichsen, P. M., (2008). A conversation with Sandra Abell: Science teacher learning. *Eurasia Journal of Mathematics, Science and Technology Education, 4(1),* 71-79.

Friedrichsen, P.M., & Stone, B. (2004). Examining students’ conceptions of molecular genetics in an introductory biology course for non-science majors. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Vancouver, BC, Canada.

Friedrichsen, P.M., Lankford, D., Brown, P., Pareja, E., Volkmann, M., & Abell, S. K. (2007). *The PCK of future science teachers in an alternative certification program*, Paper presented at the National Association for Research in Science Teaching Annual Conference, New Orleans, LA, April 15-18, 2007.

Gess-Newsome, J., & Lederman, N. G. (1999). *Examining pedagogical content knowledge: The construct and its implications for science education* (pp.3-17). Boston: Kluwer.

Gess-Newsome, J. (1992). *Biology teachers’ perception of subject matter structure and its relationship to classroom practice.* Unpublished doctoral dissertation, Oregon State University, OR, USA.

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation nature, sources and development of pedagogical content knowledge for science teaching, In J. Gess-Newsome & N. G. Lederman (Eds.). *Examining pedagogical content knowledge: The construct and its implications for science education* (pp.3-17). Boston: Kluwer.

Gilbert, J.K., De Jong, O., Justi, R., Treagust, D.F., & Van Driel, J.H. (2002). Research and development for the future of chemical education. In J.K. Gilbert, O. de Jong, R. Justi, D.F. Treagust, & J.H. Van Driel (Eds.), *Chemical education: Toward research-based practice* (pp. 391-408). Dordrecht, The Netherlands: Kluwer Academic Press.

Glaser, B. G., & Strauss, A. L. (1967). *The discovery of grounded theory.* Aldine, Chicago.

Grossman, P. L., (1990). The making of a teacher: Teacher knowledge and teacher education. New York: The Teachers College Press.

Grossman, P. L., Schoenfeld, A., & Lee, C. (2005). Teaching subject matter. In L. Darling-Hammond & J. Bransford (Eds.), *Preparing teachers for a changing world: What teachers should learn and be able to do.* San Francisco: Jossey-Bass.

Hackling, M. W., & Treagust, D. (1984). Research data necessary for meaningful review of grade ten high school genetics curricula. *Journal of Research in Science Teaching, 21*(2), 197-209.

Hanuscin, D., L., Lee, M. H., & Akerson, V. L. (2011). Elementary teachers' pedagogical content knowledge for teaching the nature of science. *Science Education, 95*(1), 145-167.

Hashweh, M. Z. (1987). Effects of subject-matter knowledge in the teaching of biology and physics. *Teaching and Teacher Education, 3(2),* 109-120.

Hashweh, M.Z. (2005). Teacher pedagogical constructions: A reconfiguration of pedagogical content knowledge. *Teachers and Teaching: theory and practice, 11,* 273-292.

Henze, I., van Driel, J. H., & Verloop, N. (2008). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe'. *International Journal of Science Education, 30(10),*1321-1342.

Ingber, J. (2009). *A comparison of teachers' pedagogical content knowledge while planning in and out of their science expertise*. Unpublished doctoral dissertation, Columbia University, NY, USA.

Kablan, H. (2004). *An analysis of high school students' learning difficulties in biology*. Unpublished master's thesis, Middle East Technical University, Ankara, Turkey.

Kagan, D. M. (1992). Professional growth among preservice and beginning teachers. *Review of Educational Research, 62,* 129-169.

Käpylä, M., Heikkinen, J., & Asunta, T. (2008). Influence of content knowledge on pedagogical content knowledge: The case of teaching photosynthesis and plant growth. *International Journal of Science Education, 31*(10), 1395-1415.

Karagöz, M., & Çakır, M. (2011). Genetikte problem çözme: Kavramsal ve süreçsel zorluklar (Problem solving in genetics: Conceptual and procedural difficulties). *Educational Sciences: Theory & Practice, 3*(11), 1651-1674

Kibuka-Sebitosi, E. (2007). Understanding genetics and inheritance in rural schools. *Journal of Biological Education, 41*(2), 56-61.

Kindfield, A. C. H. (1991). Confusing chromosome number and structure: a common student error. *Journal of Biological Education, 25*(3), 193-200.

Knippels, M. P. J., Waarlo, A. J., & Boersma, K. (2005). Design criteria for learning and teaching genetics. Journal of Biological Education, 39(3), 108-112.

Köse, M. R. (1999). Üniversiteye giriş ve liselerimiz [Entrance to the university and high schools], *Hacettepe University the Journal of Education, 15*, 51-60.

Lankford, D. (2010). *Examining the pedagogical content knowledge and practice of experienced secondary biology teachers for teaching diffusion and osmosis.* Unpublished doctoral dissertation, University of Missouri, MO, USA.

Law, N., & Lee, Y. (2004). Using an iconic modeling tool to support the learning of genetics concepts. *Journal of Biological Education, 38*(3), 118-141.

Lawson, A. E., & Thompson, L. D. (1988). Formal reasoning ability and misconceptions concerning genetics and natural selection. *Journal of Research in Science Teaching, 25*(9), 733-746.

Lederman, N. G., & Latz, M. S. (1993). *Emergence and interactions of knowledge structures in the prospective teacher.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, Atlanta, GA.

Lederman, N. G., Gess-Newsome, J., & Latz, M. S. (1994). The nature and development of pre-service science teachers' conceptions of subject matter and pedagogy. *Journal of Research in Science Teaching, 31*(2), 129-146.

Lee, E., & Luft, J.A. (2008). Experienced secondary science teachers' representation of pedagogical content knowledge. *International Journal of Science Education, 30(10),* 1343-1363.

Lewis, J. & Kattman, U. (2004). Traits, genes, particles and information – Revisiting students' understandings of genetics. *International Journal of Science Education. 26*(2), 195-206.

Lewis, J. & Wood-Robinson, C. (2000). Genes, chromosomes, cell division and inheritance- do students see any relationship? *International Journal of Science Education, 22*(2), 177-195.

Lewis, J., Leach, J., & Wood-Robinson, C. (2000a). All in the genes?-Young people's understanding of the nature of genes. *Journal of Biological Education, 34*(2), 74-79.

Lewis, J., Leach, J., & Wood-Robinson, C. (2000b). What's in a cell?-Young people's understanding of the genetic relationship between cells, within an individual. *Journal of Biological Education, 34*(3), 129-132.

Lewis, J., Leach, J., & Wood-Robinson, C. (2000c). Chromosomes: the missing link-young people's understanding of mitosis, meiosis, and fertilization. *Journal of Biological Education, 34*(4), 189-199.

Lincoln, Y. S., & Guba, E.G. (1986) 'But is It Rigorous? Trustworthiness and Authenticity in Naturalistic Evaluation', In *David D. Williams (ed.) Naturalistic Evaluation,* pp. 73–84. San Francisco: Jossey-Bass.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry.* Thousand Oaks, California: Sage Publications.

Longden, B. (1982): Genetics – Are there inherent learning difficulties? *Journal of Biological Education, 16*(2), 135-140

Loughran, J., Berry, A., & Mulhall, P. (2006). *Understanding and Developing Science Teachers' Pedagogical Content Knowledge.* Rotterdam: Sense Publishers.

Loughran, J., Milroy, P., Berry, A., Gunstone, R., & Mulhall, P. (2001). Documenting science teachers' pedagogical content knowledge through PaP-eRs. *Research in Science Education, 31*(2), 289-307.

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge I science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching. 41,* 370-391.

Loughran, J., Mulhall, P., & Berry, A. (2008). Exploring pedagogical content knowledge in science teacher education. *International Journal of Science Education 30(10),* 1301-1320.

Magnusson, S., Borko, H., & Krajcik, J. (1994). Teaching complex subject matter in science*: Insights from an analysis of pedagogical content knowledge.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, March 26-29, Anaheim, CA.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.)*, Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Boston: Kluwer.

Marbach-Ad, G. (2001). Attempting to break the code in student comprehension of genetic concepts. *Journal of Biological Education, 35*(4), 183-189.

Marbach-Ad, G., & Stavy, R. (2000). Students' cellular and molecular explanations of genetic phenomena. *Journal of Biological Education, 34*(4), 200-205.

Marks, R. (1990) Pedagogical content knowledge: From a mathematical case to a modified conception. *Journal of Teacher Education, 41(3),* 3-11.

Marshall, C., & Rossman, G. B. (2006). *Designing Qualitative Research* (4th ed.). Thousand Oaks, CA: Sage.

Mason, K. A., Losos, J. B., & Singer, S. R. (2011). *Biology*. New York: McGraw-Hill

Merriam, S. B. (1998). *Qualitative research and case study applications in education*. London: Sage.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook* (2nd Ed.). Thousand Oaks: Sage Publications.

Ministry of National Education (2006). *Elementary 6th, 7th, and 8th Grades Science and Technology Curriculum*. Ankara: Ministry of National Education Publications.

Ministry of National Education (2009). *Fen ve Teknoloji Ders Kitabı* [Science and Technology Textbook]. Ankara: Ministry of National Education Publications.

Morine-Dershimer, D., & Kent, T. (1999). The complex nature and sources of teachers' pedagogical knowledge. In J. Gess-Newsome, Lederman, N. G. (Ed.), *Examining pedagogical content knowledge* (pp. 21-50). Norwell, MA: Kluwer Academic Publishers.

Munby, H., Russell, T., & Martin, A. K. (2001). Teachers' knowledge and how it develops. In V. Richardson (Ed.), *Handbook of research on teaching* (4th ed., pp. 877-905). Washington, DC: American Educational Research Association.

Nakiboğlu, C., & Tekin, B. B. (2006). Identifying students’ misconceptions about nuclear chemistry. A study of Turkish high school students. *Journal of Chemical Education, 83*(11), 1712-1718.

Nargund-Joshi, V., Park-Rogers, M. A., & Akerson, V. (2011). Exploring Indian secondary teachers’ orientation and practice for teaching science in an era of reform. *Journal of Research in Science Teaching, 48*(6), 624-647.

Nilsson, P. (2008). Teaching for understanding: The complex nature of pedagogical content knowledge in pre-service education. *International Journal of Science Education, 30,* 1281-1299.

Park, S., & Oliver, J. S. (2008). Revisiting the conceptualization of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38,* 261–284.

Pashley, M. (1994). A-level students: their problems with gene and allele. *Journal of Biological Education, 28*(2), 120-126.

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

Reynolds, A. (1992). What Is Competent Beginning Teaching? A Review of the Literature. *Review of Educational Research, 62(1),* 1-35.

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education, 30 (10),* 1365–1387.

Rotbain, Y., Marbach-Ad, G., & Stavy, R. (2006). Effect of bead and illustrations models on high school students' achievement in molecular genetics. *Journal of Research in Science Education, 43*(5), 500-529.

Saka, A., Cerrah, L., Akdeniz, A. R., & Ayas, A. (2006). A cross-age study of the understanding of three genetic concepts: how do they imagine the gene, DNA and chromosome? *Journal of Science Education and Technology, 15*(2), 192-202.

Samuelowicz, K., & Bain, J. D. (1992). Conceptions of teaching held by academic teachers. *Higher Education, 24(93),* 93-111.

Sanders , L. R., Borko, H., & Lockard, J. D. (1993). Secondary science teachers' knowledge base when teaching science courses in and out of their area of certification. *Journal of Research in Science Teaching, 30(7),* 723-736.

Settlage, J. (2000). Understanding to learning cycle: Influences on abilities to embrace the approach by preservice elementary school teachers. *Science Education, 84,* 43-50.

Shannon, J. C. (2006). *How is PCK embodied in the instructional decisions teachers' make while teaching chemical equilibrium?* Unpublished doctoral dissertation, University of Washington, USA.

Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for Information, 22,* 63-75.

Shulman, L. S. (1987). Knowledge and training: Foundations of the new reform. *Hardward Educational Review, 57,* 1-22.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15,* 4-14.

Sirhan, G. (2007). Learning difficulties in chemistry: An Overview. *Journal of Turkish Science Education, 4(2),* 2-20.

Slack, S. J., & Stewart, J. (1990). High school students' problem-solving performance on realistic genetics problems. *Journal of Research in Science Teaching, 27*(1), 55-67.

Springer, L., Stanne, M. E., & Donovan, S. S. (1999). Effects of small-group learning on undergraduates in science, mathematics, engineering, and technology: A meta-analysis. *Review of Educational Research, 69(1),* 21-51.

Tamir, P. (1988). Subject matter and related pedagogical knowledge in teacher education. *Teaching and Teacher Education, 4(2),* 99-110.

Tatar, N., & Cansüngü-Koray, Ö. (2005). İlköğretim sekizinci sınıf öğrencilerinin 'genetik' ünitesi hakkındaki kavram yanılgılarının belirlenmesi. *Kastamonu Eğitim Dergisi, 13*(2), 415-426.

Tekkaya, C. (2002). Misconceptions as barrier to understanding biology. *Journal of Hacettepe University Education Faculty,* 23, 259-266.

Tekkaya, C., Çapa, Y., & Yılmaz, O. (2000). Biyoloji öğretmen adaylarının genel biyoloji konularındaki kavram yanılgıları. *Journal of Hacettepe University Education Faculty, 18,* 140-147.

Tekkaya, C., Ozkan, O. & Sungur, S. (2001). Biology concepts percieved as difficult by Turkish high school students. *Hacettepe University Journal of Eductation, 21,* 145-150.

Tobin, K. G., & Capie, W. (1982). Relationships between formal reasoning ability, locus of control, academic engagement and integrated process skill achievement. *Journal of Research in Science Education, 19,* 113-121.

Tobin, K., Tippins, D.J., & Gallard, A.J. (1994). Research on instructional strategies for teaching science. In Dorothy L. Gabel (Ed.) *Handbook of research on science teaching and learning* (pgs. 45-93). New York: Macmillan Publishing Co.

Treagust, D. F., & Chittleborough. G (2001). Chemistry A matter of understanding representations (pp. 239-267). In Brophy, J. (Ed.|, *Subject-specific instructional methods and activities.* Oxford: Elsevier Science.

Tsui, C., & Treagust, D. F. (2003). Learning genetics with computer dragons. *Journal of Biological Education, 27*(2), 96-98.

Tsui, C., & Treagust, D. F. (2004). Conceptual change in learning genetics: an ontological perspective. *Research in Science and Technology Education, 22*(2), 185-202.

Tsui, C., & Treagust, D. F. (2007). Understanding genetics: analysis of secondary students' conceptual status. *Journal of Research in Science Teaching, 44,* 205-235.

van Dijk, E. M., & Kattmann, U. (2007). A research model for the study of science teachers' PCK and improving teacher education. *Teaching and Teacher Education 23,* 885–897.

Van Driel, J. H., Beijaard, D., & Verloop, N. (2001). Professional development and reform in science education: The role of teachers' practical knowledge. *Journal of Research in Science Teaching, 38(2),* 137-158.

Van Driel, J. H., de Jong, O., & Verloop, N. (2002). The development of preservice chemistry teachers' pedagogical content knowledge. *Science Education, 86,* 572-590.

Van Driel, J. H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35,* 673-695.

Van Driel, J.H., Veal, W.R., & Janssen, F.J.J.M., (2001). Essay review: Pedagogical content knowledge: An integrative component within the knowledge base for teaching. *Teaching and Teacher Education, 17,* 979-986.

Veal, W. R. (1998). *The evolution of pedagogical content knowledge in prospective secondary chemistry teachers.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Veal, W. R., & Kubasko, D. S. (2003). Domain specific pedagogical content knowledge of evolution held by biology and geology teachers. *Journal of Curriculum and Supervision, 18(4), 3*34-352.

Veal, W. R., & MaKinster, J. G. (1999). Pedagogical content knowledge taxonomies. *Electronic Journal of Science Education*, 3, Retrieved May 12, 2008, from http://unr.edu/homepage/crowther/ejse/vealmak.html

Veal, W. R., Tippins, D. J., & Bell, J. (1998). *The evolution of pedagogical content knowledge in prospective secondary physics teachers.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, San Francisco, CA.

Venville, G., & Donovan, J. (2007). Developing year 2 students' theory of biology with concepts of the gene and DNA. *International Journal of Science Education, 29*(9), 1111-1131.

Venville, G., & Treagust, D. (2002). Teaching about the gene in the genetic information age. Australian Science Teachers' Journal, 48(2), 20 – 24.

Wilson, S., Shulman, L., & Richard, A. (1987). “150 Different ways” of knowing: Representations of knowledge in teaching. In J. Calderhead (Ed.), *Exploring teachers’ thinking.* (pp.104-124). London: Cassell.

Wynne, C.F., Stewart, J., & Passmore, C. (2001). High school students’ use of meiosis when solving genetics problems. *International Journal of Science Education, 23*, 501–515.

Yıldırım, A., & Şimşek, H. (2006). *Sosyal Bilimlerde Nitel Araştırma Yöntemleri,* Seçkin Yayıncılık Ankara.

Yilmaz, Tekkaya, & Sungur (2011). The comparative effects of prediction/discussion-based learning cycle, conceptual change text, and traditional instructions on student understanding of genetics. *International Journal of Science Education, 33(*5), 607-628.

Yin, R. K. (2003). *Case study research: Design and methods* (3rd ed.). Thousand Oaks, California: Sage Publications.

Yin, R. K. (2009). *Case study research: Design and methods* (4th ed.). Thousand Oaks, Washington DC: Sage Publications.

Zembal-Saul, C., Krajcik, J., & Blumenfeld, P. (2002).Elementary student teachers’ science content representations. *Journal of Research in Science Teaching, 39,* 443-463.

Zhang, B., Krajcik, J., Sutherland, L. M., Wang, L., Wu, J., & Qiang, Y. (2003). Opportunities and challenges of China’s inquiry-based education reform in middle and high school: Perspectives of science teachers and teacher educators. *International Journal of Science and Mathematics Education, 1*, 477–503.

APPENDICES

A. KALITIM TESTİ

1. Aşağıdaki terimleri tanımlayınız?
    a. Gen:
    b. Arı döl:
    c. Melez döl:
    d. Genotip:
    e. Fenotip:
    f. Baskın gen:
    g. Çekinik gen:

2. Bezelyeler için sarı renkli tohum karakteri (S) yeşil renkli tohum karakterine (s) baskın olduğu bilindiğine göre;

Sarı x Yeşil renkli tohuma sahip bitkilerin çaprazlamasını yapınız?

B. AN EXAMPLE OF TRANSCRIPTION OF OBSERVATION

t- Genotipi nasıl belirliyoruz; anneden ve babadan gelen genler şeklinde ve harflerle.
t-Eğer diğer bireyin almış olduğu bu karakter heterozigot ise yani annesi yada babasından biri uzun diğeri kısa ise nasıl ifade ediyoruz; heterozigot.
TA-1

Fenotip	**Homozigot/Heterozigot**	**Genotip**
Uzun boy	Homozigot	UU
Uzun boy	***Heterozigot***	
Kısa boy		

t- nasıl gösteriyoruz bunu
ss- büyük U, küçük u
t- büyük U, küçük u. Uzun boyu büyük U kısa boyu küçük u.anlaşıldı mı?
TA-1

Fenotip	**Homozigot/Heterozigot**	**Genotip**
Uzun boy	Homozigot	UU
Uzun boy	Heterozigot	***Uu***
Kısa boy		

t- dolayısıyla burada büyük U daha baskın olduğu için fenotipe nasıl yansımıştır; uzun boy olarak. Baskılamıştır, uzun boy kısa boyu baskılamıştır. Ortaya çıkma olasılığı yüksek olduğu için fenotipte ne olacaktır; uzun boy.
t- Kısa boyu nasıl ifade ederiz.
A3e- Heterozigot mu heterozigot mu?
t- arkadaşınız dedi ki homozigot mu heterozigot mu? Homozigot olursa ne olur, heterozigot olursa ne olur?
t- öğretmen el kaldıran öğrencilerden sb yesöz hakkı verdi.
sb- homozigot olursa hem anneden hem babadan kısa boy almalı yani
t- küçük u küçük u olur. Heterozigot olursa
se-büyük U küçük u olur.
t- peki bu durumda büyük U küçük u olursa şu özellik yani uzun boy kısa boyu baskılamaz mı?
ss- Evet
t- baskıladığı zaman bunun görüntüsü ne olur?
Ss-Uzun boy olur.
t- Uzun boy olur. O zaman kısa boy olur mu? Olmaz. Öyleyse çekinik bir özelliğin fenotipe yansıması için ne olması lazım homozigot olması lazım. Ancak kısa boy nasıl ortaya çıkar, fenotipe nasıl yansır homozigot olursa.
TA-1

Fenotip	**Homozigot/Heterozigot**	**Genotip**
Uzun boy	Homozigot	UU
Uzun boy	Heterozigot	Uu
Kısa boy	Homozigot	***uu***

t-Eğer heterozigot olursa o zaman baskın özellik çekinik özelliği baskılayacağından dolayı fenotipe çekinik özellik yansımaz.

TA-1

Fenotip	**Homozigot/Heterozigot**	**Genotip**
Uzun boy	Homozigot	UU
Uzun boy	Heterozigot	Uu
Kısa boy	Homozigot	uu

t-Anlaşıldı mı? Peki bunu da yapalım hemen.

t- Şu özellikleri bu sefer harflerle değil de şekillerle ifade ettim. Düz saçı kare (☐) ile kıvırcık saçı daire (**O**) ile gösterdim.

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐		
☐**O**		
OO		

t- Biri anneden biri babadan geliyor. Yani şuradaki düz saç anneden, (*t-öğretmen bu arada tabloyu dolduruyor*)

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐	☐	
☐**O**		
OO		

t-düz saç babadan geliyor.

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐	☐☐	
☐**O**		
OO		

t-Bunun nasıl ifade edebiliriz genotipte ☐ ve ☐ olur değil mi? Bu bireyin fenotipi ne olur

ss- kare olur.

t- hayır hayır dış görünüşü, yani görünüş olarak düz saçlı mı olur, kıvırcık saçlı mı olur?

ss- düz saç.

t- düz saç.

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐	☐☐	Düz
☐**O**		
OO		

t- Peki düz saç (☐) kıvırcık saç (**O**)genotip olarak nasıldır?

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐	☐☐	Düz
☐**O**		
OO		

ss-☐ ve **O.**

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐	☐☐	Düz
☐**O**	☐**O**	
OO		

t- kare (☐**)** ve daire **(O)**. Fenotipi nedir bunun, dış görünüşe nasıl yansır bu özellik. Şu düz saç (☐) şu kıvırcık saç (**O**); kıvırcık saç düz saçı ne yapar, baskılar. Ne olur o zaman.

Se- kıvırcık.

Sb- kıvırcık saç olur.

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐	☐☐	Düz
☐**O**	☐**O**	Kıvırcık saç
OO		

t-kıvırcık saç olur.

t- diğerinin gen dizilimi nasıl daire (**O**) ve daire (**O**).

TB1-

Düz saç→ ☐

Kıvırcık saç→ **O**

	Genotip	**Fenotip**
☐☐	☐☐	Düz
☐**O**	☐**O**	Kıvırcık saç
OO		

t-Peki bunun genotipi ne olacaktır; anneden kıvırcık saç, babadan kıvırcık saç.

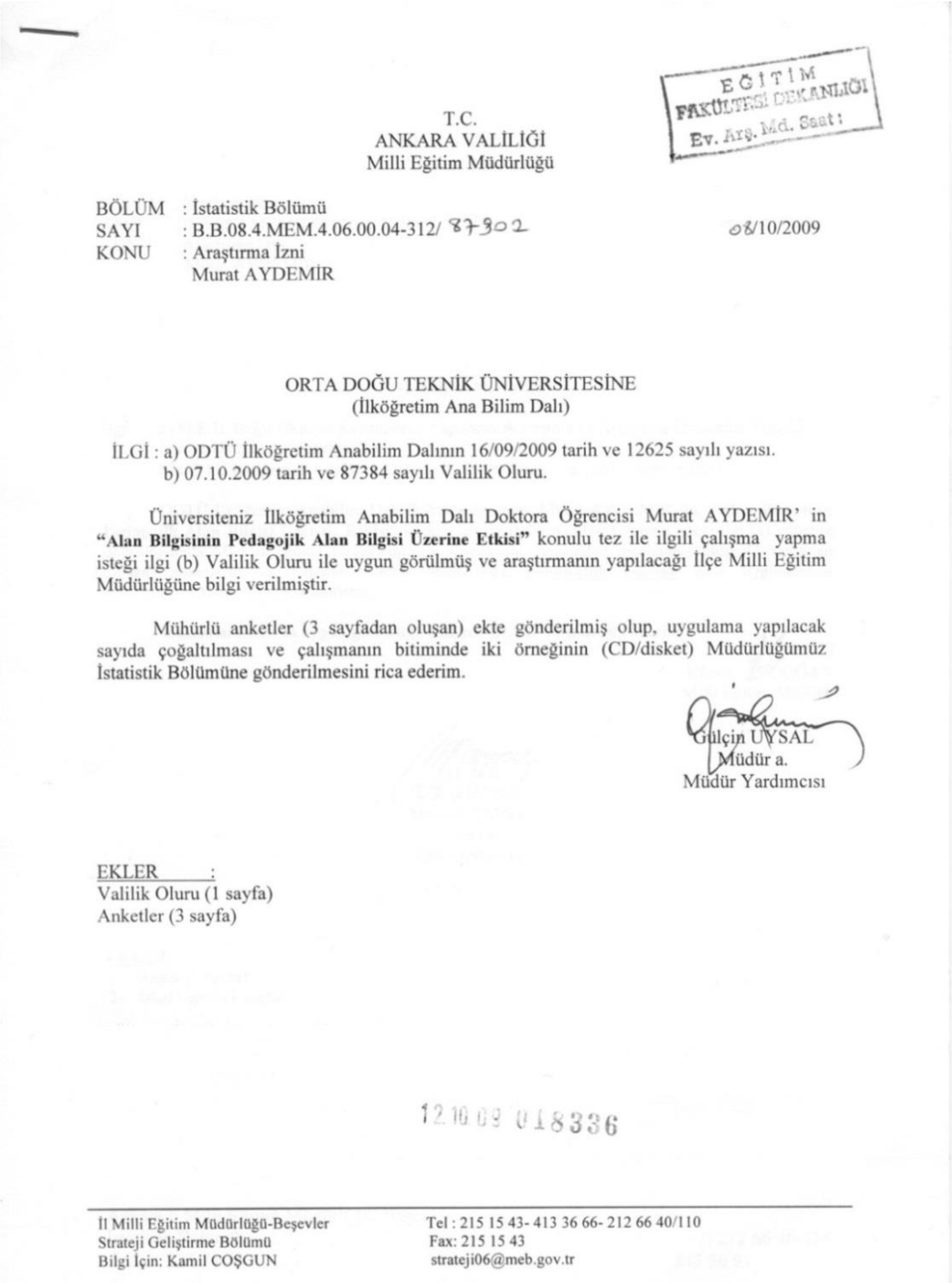
C. Pre-PCK INTERVIEW QUESTIONS (TURKISH)

1. Genetik kavram ve çaprazlama için programdaki kazanımlar nelerdir?
2. Genetik kavram ve çaprazlamasının öğretilmesini etkileyen öğrencilerinize ait bilgiler nelerdir.
    i. Genetik kavram ve çaprazlamasını öğretilmesinde öğrencilerinin sahip olması gereken hazır bulunuşlulukları nelerdir?
    ii. Genetik kavram ve çaprazlanmasının öğretilmesini etkileyen öğrencilerinizin sahip olduğu öğrenme güçlükleri nelerdir?
3. Genetik kavram ve çaprazlanmasının öğretilmesinde ne tür öğretim stratejileri kullanıyorsunuz?
    i. Genetik kavram ve çaprazlanmasının öğretilmesinde ne tür örnekler ve gösterimler kullanıyorsunuz?
    ii. Genetik kavram ve çaprazlanmasının öğretilmesinde ne tür etkinlikler yapıyor veya yaptırıyorsunuz?
    iii. Genetik kavram ve çaprazlanmasının öğretilmesinde karşılaştığınız öğrenim güçlüklerinin giderilmesinde ne tür öğretim stratejileri kullanıyorsunuz?

D. Pre-PCK INTERVIEW QUESTIONS (ENGLISH)

1. What are the objectives related with the concepts of genetics and crossing in the science curriculum?
2. What kinds of factors do affect students' learning of the concept of genetics / crossing?
    - i. What are the requirements needed for the students' learning of the concept of genetics / crossing?
    - ii. What are the difficulties faced by students while learning of the concept of genetics / crossing?
3. What kinds of teaching strategies do you use to teach the concept of genetics / crossing?
    - i. What kinds of representation do you use in order to teach the concept of genetics / crossing?
    - ii. What kinds of activities do you use in order to teach the concept of genetics / crossing?
    - iii. What kinds of teaching strategies do you use in order to overcome students' difficulties of learning the concept of genetics / crossing?

E. THE PERMISSIONS FROM MINISTRY OF NATIONAL EDUCATION



EĞİTİM
FAKÜLTESİ DEKANLIĞI
Ev. Arş. Md. Saat :

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

BÖLÜM : İstatistik Bölümü
SAYI : B.B.08.4.MEM.4.06.00.04-312/ 87302
KONU : Araştırma İzni
Murat AYDEMİR

08/10/2009

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(İlköğretim Ana Bilim Dalı)

İLGİ : a) ODTÜ İlköğretim Anabilim Dalının 16/09/2009 tarih ve 12625 sayılı yazısı.
b) 07.10.2009 tarih ve 87384 sayılı Valilik Oluru.

Üniversiteniz İlköğretim Anabilim Dalı Doktora Öğrencisi Murat AYDEMİR' in **"Alan Bilgisinin Pedagojik Alan Bilgisi Üzerine Etkisi"** konulu tez ile ilgili çalışma yapma isteği ilgi (b) Valilik Oluru ile uygun görülmüş ve araştırmanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Mühürlü anketler (3 sayfadan oluşan) ekte gönderilmiş olup, uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde iki örneğinin (CD/disket) Müdürlüğümüz İstatistik Bölümüne gönderilmesini rica ederim.

Gülçin UYSAL
Müdür a.
Müdür Yardımcısı

EKLER :
Valilik Oluru (1 sayfa)
Anketler (3 sayfa)

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F. EXTENDED TURKISH SUMMARY

(Genişletilmiş Türkçe Özet)

ÖĞRETMENLERİN PEDAGOJİK ALAN BİLGİLERİNİN ARAŞTIRILMASI: GENETİK ÖĞRETİMİ DURUMU

GİRİŞ

Öğretmenler hakkında insanların algısı zaman içerisinde değişmektedir. Yaklaşık 100 yıl önce bir konuyu biliyor olmak konuyu etkin bir şekilde öğretmek için yeterli görülüyordu (Shulman, 1986). Pedagoji bilgisi, ikincil olarak alan bilgisinin gerisinde düşünülüyordu. 20. yüzyılın ikinci yarısından itibaren öğretmenlik yetenekleri üzerine olan algı değişmeye başladı ve sınıf yönetimi, öğretim metotları ve değerlendirme yöntemleri gibi pedagojik bilgilere yönelim başladı. Shulman (1986) George Bernard Shaw'ın "Bir şeyi yapmayı bilen yapar, yapmayı bilmeyen ama öğretmeyi bilen öğretebilir" (p. 4) sözü ile bu dönemi açıklamaktadır.

Shulman (1986) "Eksik olan paradigma nedir?" sorusunun alan bilgisi ve pedagoji bilgisinin birleşimi olan pedagojik alan bilgisi (PAB) ile cevaplandırılabileceğini belirtti. PAB, öğrencilere konunun daha anlamlı hale getirmek için öğretmenin kullandığı analojiler, gösterimler ve örnekler olarak tanımlanmıştır (Shulman, 1986).

1986 yılından itibaren araştırmacılar PAB'ın nasıl geliştirilebileceğini ve PAB bileşenlerinin birbirleri ile nasıl etkileşim içinde olduklarını araştırmışlardır. Yapılan bu çalışmalar PAB'ın yapısının konuya özgü olduğunu göstermiştir

(Cochran, King ve DeRuiter, 1991; Loughran, Mulhall ve Berry, 2004; van Driel ve ark., 1998; Veal ve MaKinster, 1999). Bununla birlikte, PAB'ın nasıl konuya özgü olduğu ve öğretmenlerin farklı konuların öğretiminde PAB'ı nasıl kullandıklarına yönelik yeterli çalışma bulunmamaktadır (Abell, 2008; van Driel ve ark., 1998). Bu nedenle, öğretmenlerin bir konuyu anlatırken öğrencilerin anlamalarını kolaylaştıracak, pedagojik olarak güçlü gösterimleri sınıf ortamında nasıl kullandıklarını açıklamayı amaçlayan PAB çalışmalarına ihtiyaç duyulmaktadır (Abell, 2008; Avraamidou ve Zembal-Saul, 2005; Bucat, 2004; De Jong, van Driel ve Verloop, 2005 Loughran ve ark., 2004; Morine-Dershimer ve Kent, 1999; Shannon, 2006; van Driel ve ark., 1998).

Bu çalışma da öğretmenlerin sınıf ortamında genetik konusunun öğretiminde PAB'larını nasıl kullandıkları incelenmiştir.Bu çalışma sonucunda gerçek sınıf ortamında elde edilecek olan PAB'a yönelik bu bilgiler alanyazına bilgi sağlamanın yanı sıra diğer fen öğretmenleri içinde değerli bir bilgi kaynağını oluşturacaktır. Çünkü deneyimli öğretmenlerin kullandığı çeşitli öğretim yöntem ve stratejileri diğer öğretmenler için yardımcı olacaktır. Bu yönüyle konuya özgü PAB çalışması hem öğretmenlere hem de PAB teorisine katkıda bulunacaktır (Loughran ve ark., 2004).

Diğer mesleklerin aksine deneyimli öğretmenlerin deneyimlerini aktardıkları bir sistem olmadığı için, Bucat (2004) öğretmenlik mesleğinin yeni öğretmenlerinin uygulamada öğrenilmesini "tekerleğin tekrar icadı" olarak betimlemektedir ve bu durumu "mesleki bellek yitimi" olarak adlandırmaktadır. Bucat (2004) ve van Driel ve ark., (1998)' e göre PAB çalışmalarının önemli bir amacı her şeyin baştan icad edilmesi gereken sistemin önüne geçip, öğretime yönelik bilgi birikimini sağlamaktır. Deneyimli öğretmenlerin öğretime yönelik zengin bir bilgisi oldukları bilinmekte ancak bu bilginin öğretmen adayları ve yeni öğretmenlere aktarılması oldukça önemlidir. Bu noktadan hareketle, bu çalışmada olduğu gibi deneyimli öğretmenlerle yürütülen PAB çalışmalarına ihtiyaç duyulmaktadır (Loughran ve ark., 2004; Nilsson, 2008; Shannon, 2006; van Driel, de Jong ve Verloop, 2002; Zembal-Saul, Krajcik ve Bluemenfeld, 2002).

Bu çalışmanın amacı, deneyimli fen öğretmenlerinin genetik konusunun öğretiminde PAB'larını nasıl kullandıklarının incelenmesidir. Bu amaç doğrultusunda, sınıf ortamında deneyimli öğretmenler tarafından genetik konusunun nasıl öğretildiği ve ne tür öğretim stratejileri kullandıkları araştırılmıştır. Bu çalışma sonucunda elde edilen somut örneklerin genetik konusunun öğretimine, öğretmen adayları, yeni öğretmenlerin ve hizmet içi eğitim programlarının hazırlanmasına yönelik katkı sağlaması beklenmektedir (van Driel ve ark., 2001).

Bu çalışmada öğretmenlerin konuya özgü olarak incelendiği PAB'ları genetik konusu ele alınarak incelenmiştir. Alanyazında öğrencilerin genetik konusunda zorlandıkları ve kavram yanılgılarına sahip oldukları belirtilmektedir (Bahar ve ark., 1999; Banet ve Ayuso, 2000; Venville ve Donovan, 2007). Bu çalışma ile genetik konusuna yönelik deneyimli öğretmenlerin PAB'larına ait bulguların diğer öğretmenlerinde etkin öğretimine katkıda bulunabileceği ve bu sayede öğrencilerin genetik konusunu öğrenmelerinde kullanılabileceği düşünülmüştür.

Araştırma soruları:

Bu çalışmanın amacı fen öğretmenlerinin genetik konusunda alan bilgileri ve pedagojik alan bilgilerinin (PAB) araştırılmasıdır. Bu amaca yönelik çalışmanın araştırma soruları aşağıda verilmiştir:

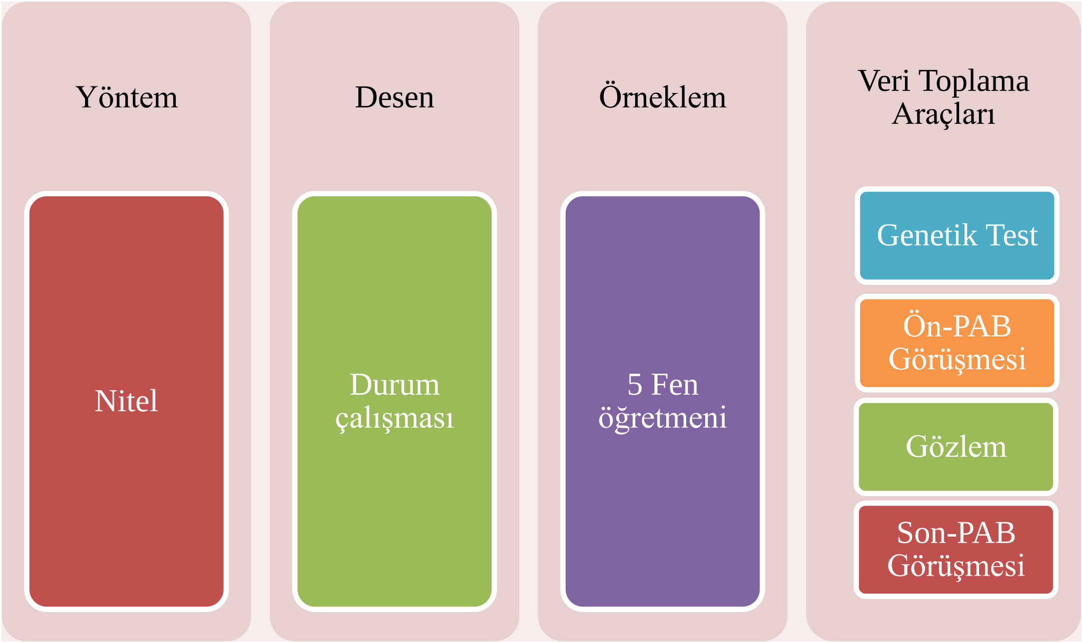
1. Fen öğretmenlerinin genetik konusunda alan bilgilerinin durumu nedir?
2. Fen öğretmenlerinin genetik konusuna yönelik pedagojik alan bilgilerinin durumu nedir?
    a. Fen öğretmenlerinin genetik konusuna yönelik öğretim programı bilgilerinin durumu nedir?
    b. Fen öğretmenlerinin genetik konusuna yönelik öğrenci bilgilerinin durumu nedir?

        i. Fen öğretmenlerinin genetik konusunun öğrenilmesi için gereken öğrenci ihtiyaçlarına yönelik bilgilerinin durumu nedir?
        ii. Fen öğretmenlerinin genetik konusunun öğrenilmesinde karşılaşılan öğrenci zorluklarına yönelik bilgilerinin durumu nedir?
    c. Fen öğretmenlerinin genetik konusuna yönelik uyguladıkları öğretim stratejileri nelerdir?
        i. Fen öğretmenleri genetik öğretiminde ne tür gösterimler kullanmaktadırlar?
        ii. Fen öğretmenleri genetik öğretiminde ne tür etkinlikler yapmaktadırlar?
        iii. Fen öğretmenleri genetik konusunun öğrenilmesinde karşılaşılan öğrenci zorluklarının giderilmesine yönelik ne tür öğretim stratejileri kullanmaktadırlar?

YÖNTEM

Çalışma Deseni

Bu çalışmada deneyimli fen öğretmenlerinin PAB'ları nitel araştırma yöntemlerinden biri olan durum çalışması araştırma deseni kullanılmıştır. Nitel çalışma yöntemi kişiler ve olaylar için kapsamlı bir bilgi sağladığı için tercih edilmiştir. Durum çalışması deseni ise öğretmenlerden (durum-örnek) detaylı bir bilgi elde edilebilmesi için seçilmiştir (Merriam, 1998). Çalışmanın yöntemi Şekil 1' de gösterilmiştir.



Şekil 1. Çalışmanın Yöntemi

Katılımcılar

Bu çalışmada, nitel örneklem seçilim yöntemlerinden amaçlı örneklem seçilimi uygulanmıştır. Örneklemde PAB açısından en zengin ve değerli olduğu düşünülen fen öğretmenleri ile çalışılma yapılması amaçlanmıştır. Ankara'da beş devlet ortaokulundan 8. sınıflara genetik konusunu anlatan deneyimli beş fen öğretmeni (biri erkek, dördü bayan) katılmıştır. Katılımcı olan öğretmenlere (Beste, Melis, Mert, Nehir ve Seda isimleri çalışmada rumuz olarak kullanılmıştır) ait kısa bilgi Tablo 1 de verilmiştir. Katılımcı fen öğretmenlerinin hepsi öğretime yönelik farklı özelliklere ve deneyimlere sahip olmaları çalışmaya zengin bir veri sağlayacağı varsayılmıştır.

Tablo 1. Katılımcı Öğretmenlerin Özellikleri

Katılımcı	Cinsiyet	Bölüm	Fakülte	Öğretmenlik deneyimi (yıl)	Öğretim deneyimleri
Beste	Bayan	Biyoloji	Fen Edebiyat fakültesi	22	İki ders kitabı yazımı Ders kitabı editörlüğü Dershane için fen sorusu hazırlama Dershane deneyimi Fakültede genetik dersine katılım
Melis	Bayan	Kimya	Fen Edebiyat fakültesi	14	Fen laboratuvarı hizmet içi eğitimine katılım
Mert	Erkek	Biyoloji	Fen Edebiyat fakültesi	17	Dershane deneyimi Dershane için fen sorusu hazırlama Fakültede genetik dersine katılım
Nehir	Bayan	Fen öğretmenliği	Eğitim enstitüsü	30	Ülkenin tüm bölgelerinde (Doğu, Batı, Kuzey) fen öğretmenliği deneyimi
Seda	Bayan	Biyoloji öğretmenliği	Eğitim fakültesi	15	6 yıllık biyolog olarak laboratuvar deneyimi öğretmenlik deneyiminin tamamı fen öğretmenliği üzerine MEB soru bankası için fen sorusu hazırlama Fakültede genetik dersine katılım

Veri Toplama Araçları

Alan bilgisi ve PAB bileşenlerine ait bilgi toplanılmasında veri toplama aracı olarak genetik test, ön-PAB görüşmesi, gözlem ve son-PAB görüşmesi yapılmıştır. Veri toplama araçları ile PAB'a ait bileşenlere yönelik veri toplanması amaçlanmıştır ve Tablo 2 veri toplama araçlarını ve PAB bileşenlerini göstermektedir.

Tablo 2. Veri Toplama Araçları

Veri Toplama Araçları	Hedeflenen PAB bileşenleri
Genetik Test	Alan bilgisi
Ön-PAB görüşmesi	Öğretim programı bilgisi Öğrenci bilgisi Öğretim stratejileri bilgisi
Gözlem	Öğretim programı bilgisi Öğrenci bilgisi Öğretim stratejileri bilgisi
Son-PAB görüşmesi	Öğretim programı bilgisi Öğrenci bilgisi Öğretim stratejileri bilgisi

Çalışmada Kullanılan PAB Modeli

Alanyazında farklı şekillerde PAB modelleri olduğu için bu çalışmada Magnusson ve ark.'a (1999) ait olan model çalışmanın amacı ve yapısına uygun olarak uyarlanarak kullanılmıştır. Magnusson ve ark.'ın (1999) PAB modeli bilgi ve inanç boyutlarını içermekte olup, beş bileşenden oluşmaktadır. Bu beş bileşen fen öğretimine yönelik bilgi, fen öğretim programı bilgisi, öğrenciler ile ilgili bilgi, öğretim stratejileri bilgisi ve değerlendirmedir. Bu çalışmada Magnusson ve ark.'ın (1999) PAB modelinde yer alan fen öğretim programı bilgisi, öğrenciler ile ilgili bilgi ve öğretim stratejileri bilgisi olmak üzere üç bileşen çalışılmış olup, ayrıca inanç boyutu da çalışılmamıştır.

Sonuçlar ve Tartışma

Çalışmanın sonuçları çalışma problemlerine uygun olarak aşağıda sunulmaktadır.

Fen Öğretmenlerinin Alan Bilgisi

Bu çalışmada öğretmenlerin alan bilgisi genetik kavram sorusu ve genetik çaprazlama sorusu olmak üzere açık uçlu toplam iki sorudan oluşan genetik test ile değerlendirilmiştir.

Genetik kavram sorusunda öğretmenlere gen, dominant gen, çekinik gen, fenotip, genotip, arı döl ve melez döl olmak üzere yedi kavramın tanımlanması sorulmuştur. Sonuçların analizinde öğretmenlerin çoğunun genetik kavram bilgileri konusunda kısmi bilgiye sahip oldukları bulunmuştur. Bununla birlikte, analiz sonuçları öğretmenlerin gen (2 öğretmen), arı döl (2), fenotip (1), genotip (1), çekinik gen (1), baskın gen (0) ve melez (0) kavramları için tam bilgiye sahip olduklarını göstermiştir. Benzer şekilde ontolojik kategorilendirme sonuçları incelendiğinde öğretmenlerin fenotip (4 öğretmen), gen (2), arı döl (2), genotip, (1), çekinik gen (1), baskın (1) ve melez (1) kavram tanımları işlem kategorisinde yer aldığı görülmektedir. Ontolojik kategorilendirme açısından öğretmenlerin genetik kavramlarını işlem kategorisi içerisinde tanımlamakta zorlandıkları bulunmuştur (Chi ve ark., 1994). Ayrıca, öğretmenlerin genetik kavram tanımlamalarının genellikle madde kategorisi içerisinde yer aldığı tespit edilmiştir. Tsui ve Treagust (2004), öğrencilerin de benzer eğilim içerisinde olduğunu ve genetik kavramlarını işlem kategorisinden daha çok madde kategorisinde düşündüklerini belirtmiştir. Benzer olarak, Chi ve ark. (1994)'da işlem kategorisinde yer alan pek çok kavramı öğrencilerin başlangıçta madde kategorisinde düşünmeyi tercih ettiklerini belirtmiştir.

Genetik çaprazlama sorusunda öğretmenlere bir tane açık uçlu monohibrit çaprazlama sorusu sorulmuştur. Analiz sonuçlarında Beste, Melis ve Nehir'in doğru bir şekilde sembolize ettiği ve çözdükleri bulunmuştur. Mert ve Seda öğretmenlerin çaprazlama sorusunu kısmi olarak cevaplandırdıkları bulunmuştur. Çaprazlama sorusunda öğretmenler dominant karakter fenotipine ait iki farklı genotip (arı döl ve melez döl) olasılığının olduğu bilgisinde zorluk yaşamışlardır. Beste, Melis ve Nehir iki farklı olasılık bilgisini kullanarak çaprazlama sorusunu doğru olarak cevaplandırmışlardır. Bu öğretmenler doğru cevaba ait işlemlerde ve olasılıklarda zorluk yaşamamışlardır. Diğer iki öğretmen ise sadece baskın genotipe göre çaprazlama yapmıştır. Bununla birlikte, ön-PAB görüşmesinde Nehir ve Mert öğretmenin bu durumu öğrenci zorluğu olarak belirtmeleri dikkat çekicidir. Ayrıca, öğretmenlerin hepsi bazı genetik kavramlarda yeterli kavram bilgisine sahip olmasa da çaprazlamayı kolay bir şekilde yapmışlardır. Öğretmenlerin çaprazlamayı doğru olarak yapmaya odaklanmaları muhtemelen çaprazlama işlemlerinin anlamını düşünmelerini engellemektedir. Diğer bir taraftan, çaprazlama işleminde uzmanlaşmalar, hız ve sonuca odaklanmaları, çaprazlama işlemlerini kavramsal olarak düşünmelerini engellemektedir (Käpylä ve ark., 2008; Knippels, Waarlo ve Boersma, 2005; Rollnick ve ark., 2008).

Genetik kavramları ve çaprazlama sonuçlarına bakıldığında katılımcıların kendi eksiklerinden dolayı öğrencilerin eksikliklerini tespit etmelerini beklemek çok zordur (Käpylä ve ark., 2008). Yanlış ve eksik bilgiye sahip olan bir öğretmenin kendi eksik bilgisini öğrencilerine aktarma ihtimali yüksek olup bu durum öğrencilerin kavramsal zorluklarını arttıracaktır (Hasweh, 1997; Käpylä ve ark., 2008; Sanders ve ark., 1993). Bundan dolayı öğrencilerin anlamlı öğrenmelerini sağlayacak etkin stratejileri kullanabilmeleri için öğretmenlerin öncelikle kendi kavramsal bilgilerini sorgulamaları gerekmektedir (Lederman ve Latz, 1993; Sanders ve ark., 1993). Çaprazlama işlemine odaklanmaları öğretmenlerin çaprazlamanın bir organizmanın farklı biyolojik düzeylerde ilişkileri içerdiği gibi çaprazlama üzerine düşünmelerini de engellemektedir. Öğretmenlerin bir kavramın doğru olarak neler içerdiğini ve bu kavramları nasıl görselleştirebileceğini bilmesi gerekmektedir (Rollnick ve ark. 2008). Bu çalışmanın sonuçları öğretmen adayları ve öğretmenler için genetik konusunda öğretmenlerin kavramsal anlamalarını destekleyecek öğretmen eğitiminin düzenlenmesini önermektedir.

Fen Öğretmenlerinin Pedagojik Alan Bilgilerinin Durumu

Bu kısımda çalışmanın PAB üzerine olan ikinci araştırma sorusu öğretim programı bilgisi, öğrenci bilgisi ve öğretim stratejisi bilgisine ait sonuçlar tartışılacaktır.

Genetik Konusunda Öğretmenlerin Öğretim Programı Bilgisi

Çalışmanın sonuçlarında öğretmenlerin öğretim programı kazanımlarını tam olarak belirtemedikleri ve öğretmenlerin programa yönelik cevaplarının genellikle ders kitabı ile sınırlı olduğu bulunmuştur. Yapılan sınıf içi gözlemler öğretmenlerin öğretimlerinde ders kitabında verilen konu sıralamasını izlediklerini göstermiştir. Diğer bir yandan bu durum öğretmenleri büyük ölçüde öğretim programı sınırları içerisinde tutmaktadır. Öğretmenler kendilerini yetersiz hissettikleri durumda ders kitabını sıkı sıkıya takibe dayanan ders planlamasını ve etkinlik ve örnek seçimi gibi öğretimlerinin organizasyonunda ünite içeriğini ve sıralamasını bir rehber olarak kullanmaya eğilimli olduğunu Hasweh (1987) belirtmiştir. Bu çalışmada da öğretmenlerin sağlam bir alan bilgisine sahip olmadıkları bulunmuştur. Bu bağlamda öğretmenlerin alan bilgisindeki eksiklikleri onların ders kitabı sıralamasını takibe dayanan eğitimlerinin sebebi olabileceği düşünülmektedir.

Diğer bir yandan öğretmenlerin öğretim programı sınırlarını aşan bazı uygulamalar yaptıkları gözlenmiştir. Bu uygulamalar üç kısımda gruplandırılabilir. Bunlardan ilki 2000 yılı öğretim programına ait olan [melez yerine] heterozigot kavramının kullanılması gibi Latince kavramların kullanılmasıdır. Bir önceki (2000 yılına ait olan) öğretim programına ait uygulamaların devam etmesi yeni öğretim programının uygulanmasında bazı sorunlar olduğunu göstermektedir. Lynn, Bryan, Mark ve Haugan (2012) ve Cohen ve Yarden'de (2008) çalışmalarında benzer bulguları belirtmiştir. Bu durum, öğretmenlerin yeni öğretim programına ve ders kitaplarına ait değişikliklerin neler olduğu konusunda desteklenmesi gerektiğini de göstermektedir.

Öğretim programını aşan diğer bir öğretmen uygulaması ise çaprazlamalarda kullandıkları F_1, F_2 ve P sembolleridir. Örneğin, Beste öğretmen ön-PAB görüşmesinde bu sembolleri üniversitedeki biyoloji derslerinde kullandıklarını belirtmişlerdir. Beste ve Mert fen edebiyat fakültesi, biyoloji bölümü mezunu olup, Seda öğretmen ise biyoloji öğretmenliği mezunudur. Tobin, Tippins ve Gallard (1994) öğretmenlerin öğretmenlik anlayışı ilkokul eğitiminden üniversite eğitimine kadar almış oldukları eğitimden beslenmekte olduğu ve öğretmenlerin öğrencilikleri sırasında nasıl öğrendilerse öyle öğrettiklerini belirtmişlerdir. Çalışmanın katılımcıları da öğretim programına rağmen fakülte eğitimlerinde nasıl öğrendiler ise öyle öğretmeyi tercih ettikleri gözlemlenmiştir.

Öğretim programını aşan üçüncü bir öğretmen uygulaması da kalıtımsal hastalık çaprazlamasıdır. Bütün katılımcı öğretmenler öğrencilerinin kalıtımsal hastalık çaprazlamasında zorlandıklarını belirtmelerine rağmen Seda ve Melis öğretmen kalıtımsal hastalık çaprazlamasını ve hatta cinsiyete bağlı kalıtımsal hastalık çaprazlama örneklerini sınıflarında çözmüşlerdir. Öğretmenler, bu kalıtımsal hastalık çaprazlamasına ait soru çözümlerini öğrencileri anlamadıklarını ifade ettikleri zaman birkaç defa tekrarlamak zorunda kalmışlardır. Ayrıca, Seda öğretmen bazı öğrencilerinin akraba evliliği olan ailelerin çocukları olduğu için kalıtımsal hastalık çaprazlaması sorusunu çözdüğünü belirtmiştir. Fen ders kitabı (MEB, 2009) incelendiğinde orak hücreli anemiyi AA (sağlıklı birey), Aa (taşıyıcı birey), aa (hasta birey) şeklinde bir kalıtımsal hastalık çaprazlaması örneğini içerdiği fakat cinsiyete bağlı kalıtımsal hastalık çaprazlaması veya X^RX^r şeklinde bir gösterim içermediği görülmektedir. Ayrıca, katılımcıların hepsi öğrencilerin çaprazlamada zorlandıkları konusunda aynı fikirdedirler. Bunun yanında, Nehir öğretmen genetik konusunun öğrenciler için zor bir konu olduğunu ve programda olandan farklı olarak eklenecek herhangi bir gösterimin ve bilginin konuya ek bir zorluk katabileceğini belirtmiştir. Bundan dolayı, öğretmenlerin kalıtımsal hastalık çaprazlaması gibi öğrencilerin konuyu öğrenmelerini zorlaştıracak olan öğretim programı dışı uygulamalardan kaçınmaları ve mümkün olduğunca programın sınırlarına öğrencilerin durumlarını göz önüne alarak uymaları önerilmektedir. Öğretmenler ders kitabında belirtilen örneği ve melez genotip örneklerini etkili bir şekilde kullanarak kalıtımsal hastalıkları öğrencilerine zorluğu arttırmadan öğretmeleri önerilmektedir.

Öğretmenlerin öğretim programı dışına çıkmalarına sebepleri arasında Türk eğitim sisteminin yapısı da gösterilebilir. Türkiye Cumhuriyeti kurulduğu 1920'li yıllardan 2005 yılına kadar 11 farklı öğretim programı hazırlanmıştır (Çalık ve Ayas, 2008). Çalık ve Ayas (2008) öğretmenlerin eski öğretim programını tamamen uygulamayı başaramadan yeni programın uygulanmaya geçildiğini belirtmişlerdir. Bu durum yeni bir programın geliştirilmesinde bir önceki programın ne kadar uygulandığının belirlenmesine olan ihtiyacı da göstermektedir. Öğretim programı değişimi üzerine değerlendirmeleri sonucunda Coll ve Taylor (2012) Türkiye'de devamlı program değişimi yapılmamasının anlamlı olacağını belirtmişlerdir. Sürekli olan öğretim programı değişiminin Türk öğretmenlerinin bu değişimleri göz ardı ederek alıştıkları gibi öğretmeye devam etmeleri sonucunu doğurmuştur (Coll ve Taylor, 2012).

Yapılan sınıf içi gözlemler, katılımcıların ders kitabında yer alan bazı etkinlikleri atlayarak zaman kazanmaya çalıştıklarını göstermiştir. Bütün öğretmenlerin öğretim programında belirtilen konuları tamamlama konusunda zaman kaygıları olmasına rağmen bahsi geçen öğretim programı bilgisi eksiklerinden dolayı zamanlarını iyi kullanamadıkları gözlemlenmiştir. Öğretim programı bilgisi, öğretmenlerin zamanlarını alanyazında (Cavallo, 1996; Friedrichsen ve Stone, 2004; Lewis ve Wood-Robinson, 2000; Law ve Lee, 2004; Lewis ve Kattmann, 2004; Lewis ve ark., 2000a; Marbach-Ad, 2001; Wynne, Stewart ve Passmore, 2001) belirtildiği üzere kavramsal bir öğretim yapmaları gibi daha iyi bir genetik öğretimine odaklamalarına da yardımcı olacağı düşünülmektedir. Öğretmenlerin öğretim programı dışı olan daha fazla çaprazlama sorusu çözmeye odaklanmaları, kalıtımsal hastalık ve çaprazlamaları, diğer uygulama ve açıklamaları (Rh faktörü, programlanmış hücre ölümü gibi) öğretim zamanın beklenilenin üzerinde boşa geçmesine neden olmaktadır. Öğetim programı sınırlarına uyulması öğretmenlerin öğretim zamanını daha etkin kullanmalarında yardımcı olacaktır.

Genetik Konusunda Öğretmenlerin Öğrenci Bilgisi

PAB'ın öğrencilere öğretirken gerçekleşen deneyimlerle geliştiği alanyazında belirtilmiştir (Gess-Newsome ve Lederman, 1999; Veal ve ark., 1998). Öğrencilere öğretirken PAB gelişimi özellikle öğrenci bilgisi bileşeninde belirgindir (Bucat, 2004, Cohen ve Yarden, 2008; Gess Newsome, 1992, Hasweh, 2005). Çalışmaya katılan öğretmenlerin hepsi 14 yıl üzerinde bir deneyime sahip olup genetik konusuna yönelik öğrenci ihtiyaçları ve öğrenci zorlukları açılarından genellikle yeterli öğrenci bilgisine sahip oldukları bulunmuştur. Öğrenci bilgisi genetik konusunu öğrenirken karşılaşılan öğrenci ihtiyaçları ve öğrenci zorlukları olarak iki kısımda incelenecektir.

Genetik konusuna yönelik olarak katılımcıların hepsi yeterli öğrenci ihtiyaç bilgisine sahiptirler. Öğretmenler, öğrencilerin genetik konusunu öğrenmeden önce hücre, hücrenin kısımları, DNA, genetik kod, kromozom, üreme hücresi, üreme ana hücresi, hücre bölünmeleri ve üreme konuları gibi ön bilgileri bilmelerine ihtiyaç duyduklarını belirtmişlerdir. Öğrencilerin genetik komsunun öğrenilmesine temel oluşturacak olan bu bilgi ihtiyacı alanyazında da (Banet ve Ayuso, 2000; Cavallo, 1996; Friedrichsen ve Stone, 2004; Lewis ve Wood-Robinson, 2000; Law ve Lee, 2004; Lewis ve Kattmann, 2004; Lewis ve ark., 2000a; 2000d; Marbach-Ad, 2001; Pashley, 1994; Wynne ve ark., 2001) belirtilmektedir. Katılımcılar bu ön bilgilerin öğrencilerin kalıtımın mekanizması, genetik bilginin nasıl aktarıldığı ve çaprazlamada yer alan işlemler ve sembollerin anlaşılmasında gerekli olduğunu belirtmişlerdir. Bu duruma özel bir örnek olarak Nehir öğrencilerinden bazılarının sadece insanların eşeyli ürediği şeklinde düşünceye sahip olduğunu belirtmiştir. Bitkilere ait genetik çaprazlamasını öğretilmesinden önce öğrencilerin bitkilerin nasıl üredikleri konusunda bilgi sahibi olmaları gerekmektedir..

Çalışma sonuçları, öğretmenlerin öğrencilerin konu bilgisine yönelik ihtiyaçları konusunda genellikle yeterli bilgiye sahip olduğunu göstermiştir. Öğretim programında genetik kod, mayoz ve üreme konuları genetik konusundan sonra öğretilmesine rağmen öğretmenler bu kavramların öğrenciler tarafından öğrenebilmesi için bu konu sıralamasının değiştirilmesi gerekliliğini vurgulamışlardır. Öğretmenlere göre ders kitabında yer alan bu sıralama öğrencilerin genetik konusunu öğrenmesini zorlaştırmaktadır ve bu nedenle sıralamanın genetik konusundan önceye alınarak öğrencilerin genetik konusu için gerekli olan bilgileri sağlam bir şekilde öğrenmeleri sağlanmalıdır.

Ön bilgi eksikliği fen öğreniminde çeşitli problemlere neden olmaktadır (Sirhan, 2007). Örneğin, gen, gamet, alel gen, mayoz ve üreme gibi kavramların genetik konusu için ön bilgi olarak öğrenilmesi gerektiği alanyazında belirtilmektedir (Allchin 2000; Bahar, 2002; Bahar ve ark., 1999; Law ve Lee, 2004; Tsui ve Treagust, 2003). Çalışmaya katılan dört öğretmen özellikle çaprazlamalarda olmak üzere genetik konusunu anlatırken mayoz, genetik kod ve üreme gibi konulara ait sadece kısa bir bilgi vererek öğrencilerin genetik konusunu öğrenmeleri için gerekli olan ön bilgi ihtiyaçlarını sağlamaya çalışmışlardır. Öğretmenlerden sadece Melis öğrencilerin ön bilgi ihtiyacını karşılanması için kitaptaki anlatım sırasını değiştirmiştir. Gen, gamet, alel gen, mitoz, mayoz ve üreme kavramları alanyazında (Bahar, 2002; Bahar ve ark., 1999) öğrencilerin öğrenmede zorlukla karşılaştıkları kavramlar olarak belirtilmiş olup sadece kısa bir bilgi verilmesi öğrencilerin anlamlı bir şekilde bu kavramları öğrenmeleri için doğru bir yaklaşım olarak kabul edilmemektedir. Allchin (2000) öğretmenlerin genden karaktare kadar olan işlem sürecinin öğretilebilmesi için DNA, gen, alel gen, mitoz, mayoz ve üreme kavramlarının öncelikle öğretilmesi gerektiğini belirtmiştir. Bu bağlamda öğrenci ihtiyaçlarının karşılanabilmesi için Melis'in ders anlatımında tercih ettiği gibi öğretim programı ve ders kitabı sıralamasının değiştirilmesi gerekmektedir.

Lawson ve Thompson (1988) genetik kavramlarının soyut olan yapısından dolayı öğrencilerin anlamlı öğrenebilmeleri için soyut işlemler döneminde olmaları gerektiğini belirtmiştir. Bu bağlamda öğretmenlerin özellikle öğretim programı dışı olan programlanmış hücre ölümü, rahim içi döllenme gibi genetik konusuna yönelik açıklamalarında öğrencilerin gelişimsel dönemlerini göz önüne almaları gerekmektedir.

Katılımcıların öğrencilerin genetik konusunu öğrenirken karşılaştıkları zorluklara ait bilgileri önceki çalışmalarla örtüşmektedir. Örneğin, Allchin (2000) ve Lewis ve Wood-Robinson (2000) yürüttükleri çalışmalarda öğrencilerin çaprazlamanın mekanizması anlamakta zorlandığını ve hücre bölünmesi ile kalıtım arasında ilişkiyi kuramadıklarını tespit etmişlerdir. Benzer olarak Nehiröğretmenin öğrencileri Tekkaya'nın (2002) çalışmasında belirtildiği gibi bitkilerin eşeyli üremediklerini düşünmektedirler. Pashley (19994) çalışmasına benzer olarak katılımcı öğretmenler öğrencilerinin gen ve aleller konusunda zorlandıkları ve bu zorluğun da saf döl, melez döl, baskın ve çekinik gibi diğer genetik kavramların anlaşılmasını zorlaştırdığını belirtmişleridir. Beste öğretmende öğrencilerinin Knippels ve ark. (2005) çalışmalarında belirtikleri gibi melez birey ile melez genotip kavramlarını karıştırdıklarını belirtmiştir. Ayrıca, Mert, Nehir ve Seda ise öğrencilerin aynı yapıda birden fazla kavramı öğrenmeleri gerektiği ve genetiğe ait süreçlerin bir canlının organizma seviyesi makro ve mikro seviyelerinde gerçekleşiyor olması öğrencilerinin genetik kavramlarının birbirleri ile ilişkilendirmekte zorlandıklarını belirtmişlerdir. Benzer zorluk Marbach-Ad ve Stavy (2000) ve Knippels ve ark.'ın (2005) çalışmalarında belirtilmiştir. Melis ve Nehir öğrencilerinin katılımsal olan ve kalıtımsal olmayan özellikleri birbirleri ile karıştırdıklarını belirtmişlerdir. Seda ise öğrencilerinin akraba evliliği sonucu kalıtımsal hastalıklar için taşıyıcı birey olmanın oluşturabileceği riskleri tam kavrayamadıklarını ve küçümsediklerini belirtmişlerdir. Kibuka-Sebitosi (2007) öğrencilerin okulda genetik konusunu bilimsel bir şekilde öğrenmeden önce genetik konusunda ailelerinden, toplumdan, medyadan kaynaklı bazı bilgi ve inançlara dayalı bir genetik anlayışına sahip olduklarını ve bu anlayışın genellikle yüzeysel olup kavram yanılgıları içerdiğini belirtmiştir.

Katılımcıların öğrencilerinin genetik konusunu öğrenirken karşılaştıkları zorluklara ait bilgi konusunda açıkça görülebilen nokta bu bilginin öğretmenden öğretmene değiştiğidir. Örnek olarak Nehir öğrencilerin bitkilerin eşeyli üremediği düşüncesine sahip olduğunu belirtirken, diğer katılımcıların hiçbirisi öğrencilerin bu kavram yanılgısını belirtmemişlerdir. Mert, Nehir ve Seda öğrencilerin genetik kavramlarını ilişkilendirmede zorluk yaşadığını belirtmiş olmasına rağmen Beste ve Melis bu zorluktan bahsetmemişlerdir. Öğretmenlerin öğrencilerin öğrenme zorluklarına ait bilgilerinin kaynağı olarak sadece öğretim deneyimleri gözükmektedir. Sadece öğretim deneyimlerinin kaynak oluşturması öğretmenlerin öğrenci bilgilerini sınırlandırmaktadır. Öğrenci bilgisinin sınırlı olması sağlam bir PAB gelişiminde engel oluşturmaktadır (Brown ve ark., 2012; Carlsen, 1993; Cohen ve Yarden, 2008; Gess Newsome, 1992; Hasweh, 1987, Käpylä ve ark., 2008; Sanders ve ark., 1993; Veal ve Kubasko, 2003;Veal ve ark., 1998) ve iyi yapılandırılmış bir eğitim sağlam bir öğrenci bilgisi olmadan düşünülemez. Genetik konusu için ve diğer fen konuları için öğretmenlerin öğrenciler üzerine yapılan bilimsel çalışmaları takip etmeleri önerilmektedir. Öğretmenlere sahip oldukları öğretim deneyimine ait bilgileri meslektaşları ile paylaşabilecekleri fırsatlar sunulmalıdır. Aksi takdirde, her bir yeni öğretmen tekerleği baştan icat edilmesi gibi öğretime dair pek çok şeyi baştan deneyimleyerek öğrenmek zorunda kalacaktır. Bucat (2004) yeni öğretmenlerin en baştan başlamaya benzeyen bu tür başlangıç döngüsünü mesleki unutkanlık olarak adlandırmaktadır ve bu çalışmada olduğu gibi PAB çalışmaları bu unutkanlığa çare olabileceğini belirtmiştir. Bucat (2004) ayrıca öğretmen adayları ve öğretmenler için öğrenci bilgisi üzerine eğitimlerin verilmesi gerekliliğini belirtmiştir.

Öğretmenlerin Öğretim Bilgisi

Öğretmenlerin genetik konusuna yönelik uyguladıkları öğretim stratejileri, gösterim, etkinlikler ve genetik konusunun öğrenilmesinde karşılaşılan öğrenci zorluklarının giderilmesine yönelik ne tür öğretim stratejileri kullandıkları alt başlıkları bu kısımda verilecektir.

Öğretmenler kullandıkları gösterimler ile genetik konusunun öğrencileri için daha somut hale getirmeyi amaçladıkları gözlemlenmiştir. Öğretmenlerin gösterimlerde çoğunlukla ders kitabı görsellerinden faydalandığı tespit edilmiştir. Ayrıca, öğretmenler Punnet karesini çaprazlama alternatifi olarak öğretmektedirler. Öğretmenler genotip fenotip ilişkisini görselleştirmesinde, baskın ve çekinik karakterlerin toplumda bulunmasına ait sıklık durumu gibi durumlarda tablolardan da yararlanmışlardır. Öğretmenler üreme ana hücreleri için büyük daireleri, gamet olarak yumurta için küçük çemberi, sperm için de kuyruğu bulunan küçük bir daire çizerek gösterimlerini kullanmışlardır. Cinsiyet sembolleri (♀, ♂), ebeveynlerin genotiplerinin her biri için farklı renkler kullanılması da diğer öğretmenlerin görsel kullanımları arasında yer almaktadır. Öğretmenlerin kullandıkları gösterimler materyal gerektirmediği için her sınıf ortamı için kullanışlıdır. Ancak genetik kavramlar soyut kavramlar olup bu kavramlar hücreden organizma düzeyine kadar her şey ile ilişkilidir. Fen konularındaki farklı düzeylerdeki görselleri kimya konusunda Treagust ve Chittleborough (2001) tarafından incelemiş ve öğretmen görsellerinin makro olarak gözlenebilir genotipin fenotipe yansıması gibi bir durumu, hücre çekirdeği ve kromozom gibi mikroskobik parçaları ve mikro düzeyinde altı olan DNA'nın incelenmesi ve genotipin harflerle ifadelendirilmesi gibi sembolleştirmeleri öğrencilerin kavramalarını kolaylaştıracak bir yapıda olmaları gerektiği vurgulanmıştır. Sanders ve ark.'larına (1993) göre öğretmenler öğrencilerin anlamalarını kolaylaştıracak olan gösterimlerin geliştirilmesinde zorlanmaktadırlar. Bundan dolayı öğretmenlerin genetik konusu için gösterimler konusunda desteklenmesi önerilmektedir.

Allchin (2000) genetik konusunu öğrencilerine daha somutlaştırabilmek için öğretmenlerin iyi seçilmiş örnekleri kullanmalarını önermektedir. Çalışmasında öğretmenlerin özellikle genetik karakter örneklerinin seçiminde öğrencilerin yaşadıkları yer, yaşları, kalıtımsal hastalıklardan öğrencilerini korumak, öğrencilere konuyu kolaylaştırma amacıyla ders kitabı örneklerinin seçilmesi, bezelye örneklerinin seçilmesi gibi öğrenci ihtiyaçlarını gözettikleri bulunmuştur. Venville ve Treagust (2002) öğretmenlerin öğrencilerin kavramsal anlamalarını kolaylaştıracak iyi planlanmış analoji ve sistematik modellerin kullanılmasını önermektedir. Benzer olarak, bu çalışmada da Beste ayakkabı çifti analojisini gen çifti için ve Mert şeffaf kâğıtları çekinik gen için renkli kâğıtları da baskın gen için kullanmıştır. Alanında uzman olan öğretmenlerin daha çok öğrencilerin yaşamlarına uygun örnek kullandıklarını ve daha çok model ve analoji geliştirdiklerini Gess Newsome (1992) yılına ait çalışmasında da belirtilmiştir. Bunun aksine alanında zayıf olan öğretmenlerin ise ders kitabı örneklerini kullanmayı tercih ettikleri ve analojiler kullanmadıkları tespit edilmiştir (Hasweh, 1987). Bu bağlamda çalışmaya katılan öğretmenler öğretimlerinin etkinliğini arttıracak örnekler bulabildikleri ancak analojilere öğretimlerinde yeterince yer vermedikleri bulunmuştur. Bu nedenle, öğretmenlerin analojiler konusunda desteklenmesi gerekmektedir.

Öğretmenlerin genetik konusunda öğretim etkinliklerinin temelini çaprazlama konusunda problem çözme oluşturmaktadır. Öğretmenler öğrencilerini liseye geçiş sınavlarına hazırlayabilmek için genetik problemi çözümüne öğretimlerinde hatırı sayılır bir zaman ayırmaktadır. Venville ve Treagust (2002) çalışmalarında da benzer olarak öğretmenlerin problem çözümüne Mendel genetiği konusunda oldukça fazla zaman ayırdıklarını bulmuşlardır. Genetik problemini çözebilmek için öğrencilerin ne genlerin yapısını ve görevlerini anlamalarına ne de genetik kavramlarını farklı biyolojik düzeylerle ilişkisini kavramalarına gerek yoktur. Öğrencilerin genetik konusunun kavramsal anlamalarını arttırabilmek için Cavallo (1996), Duncan ve Reiser (2007) venville ve Treagust (2002) ve Wynne ve ark. (2001) çalışmalarında öğretmenlerin problem çözmeye odaklı genetik öğretimine olan odaklanmalarını kavramsal öğretime kaydırmaları gerektiğini belirtmişlerdir. Ayrıca, öğretmenlerin genetik konusunda problem çözmeye odaklı eğitime ayrılan zaman öğretmenlerin sadece etkinliklerini değil diğer tüm öğretim stratejilerini de olumsuz etkilemektedir. Ayrıca, öğretmenlerin problem seçimleri incelendiğinde Melis ve Seda öğretmeninin kalıtımsal hastalık çaprazlaması içeren hatta cinsiyete bağlı kalıtımsal hastalıkları soyağacı üzerinde yer alan problemler çözdüğü görülmektedir. Bu problemler öğretim programında yer almadığı gibi öğrencilerin seviyelerine de uygun değildir. Bu problemlerin durumu öğretmenlerin öğretim programı bilgisi ve öğrenci bilgisi kısmında incelenmiştir. Knippels ve ark. (2005) çalışmasında öğretmenlerin genetik öğretiminde problem çözmeye odaklanmaktan daha çok kavramlar arasında ilişkileri anlaşılmasını sağlayacak olan kavramsal öğretime ağırlık verilmesini önermektedir.

Öğretmenlerin genetik öğretiminde kullanmış oldukları diğer bir etkinlik de soyağacı oluşturulmasıdır. Öğretmenler soyağacını öğrencilerine kalıtımsal ve kazanılan özelliklerin fark edilmesinde, baskın, çekinik karakter ve melez kavramlarının öğretiminde kullanılmışlardır. Örnek olarak Seda kalıtımsal hastalıklar üzerine özel bir soyağacı hazırlayarak öğrencilerini akraba evliliği yapmaları durumunda olası risklere karşı bilinçlendirmeyi amaçlamıştır.

Öğrencilerin genetik mekanizması ve genotip-fenotip ilişkisi gibi konuları zihinlerinden canlandırmaları zor olduğu için öğretmenler genetik konusunu somutlaştırmak amacı ile bilgisayar ortamında olan etkinlikleri de kullanmışlardır. Tsui ve Treagust (2004) tarafından kullanılan “Bioloigca” ve Law ve Lee (2004) kullanılan “Iconic model” gibi bilgisayar programlarını genetik öğretimi için kullanmışlardır ve öğretimde kavramların somutlaştırmasını ve denetimini arttırdığı için bu tür programların kullanılmasını önermişlerdir. Ayrıca araştırmacılar öğrencilerin genetik konusunu öğrenmelerinde yardımcı olacak benzer bilgisayar programlarının nitelik ve nicelik olarak artması gerektiğini belirtmişlerdir. Ancak çalışmaya katılan öğretmenler bu tür bilgisayar ortamındaki program ve etkinliklerin çok sınırlı olduğu belirtmişlerdir.

Öğretmenlerin uygulamış olduğu bazı etkinliklerin öğrenci bilgisinden kaynaklandığı görülmektedir. Örneğin, Melis kendi fenotipini betimledikten sonra öğrencilerinden de kendi fenotiplerini betimlemelerini istemiştir. Melis böyle bir uygulamayı seçmesine sebep olarak bu yaşta olan öğrencilerin dış görünüşlerine önem verdiklerini belirtmiştir. Mert ise Mendel’in hayatı dramasını öğrencilerine yaptırmış ve öğrencilerin drama yapmayı sevdiklerini ve bu etkinlik ile bir bilim insanının hayatını canlandırma fırsatını bulduklarını belirtmiştir. Nehir’in öğrencilerine frekans tablosu hazırlatmasında öğrencilerin bir karakterin yaygınlığı ve baskınlığı konusundaki kavram yanılgıları yönlendirici olmuştur. Analoji ve gösterim etkililiği açılarından Mert’in uyarladığı “Mendel’e yarım edelim” etkinliği mayoz, gamet oluşumu ve üremeyi açıklama konusunda özel bir örneği oluşturmaktadır. Mert bu etkinliğini özellikle gametlerin çaprazlamadan bağımsız olarak eşleştiğini öğrencilerine açıklamak için kullanmıştır.

Çalışmaya katılan öğretmenler öğretim stratejileri yönünden küçük farklılıklar göstermişlerdir. Bu farklılıkları da alan bilgisi ile açıklanabilir. Örneğin, Mert programlı hücre ölümü örneğini ve Seda da rahim içi döllenme örneğini öğrencilerine vermiştir. Her iki öğretmeninde fen edebiyat fakültesi, biyoloji bölümünden mezun olmaları bu örneklerin kaynağını oluşturduğu düşünülmektedir. Benzer şekilde, Melis fen edebiyat fakültesi, kimya bölümü mezunudur ve dersinde homozigot [arı döl] kavramını homo-zigot hecelerine ayırıp kimya da yer alan homo-jen kavramı ile benzerliği üzerinden açıklamıştır. Nehir öğretmen ise dersinde Türkiye'nin farklı bölgelerine ait ailelerin erkek çocuk beklentilerini ve erkek çocuk sahibi olabilmek için yapmış oldukları bilimsel olmayan uygulamalara değinmiştir. Beste Down sendromlu olan bir market çalışanını ve Down cafede çalışanları, Down sendromu konusunu örneklendirmede kullanmıştır. Diğer bir yandan öğretmenlerin farklı fakültelerden mezun olmaları gibi farklı eğitim deneyimleri olmasına rağmen genetik konusundaki öğretim stratejilerindeki farklılıkları belirgin değildir. Öğretim stratejilerindeki yakınlığın sebebi genetik konusunun soyut olması (Banet ve Ayuso, 2000; Cavallo, 1996; Friedrichsen ve Stone, 2004; Lewis ve ark., 2000a; 2000d; Marbach-Ad, 2001; Wynne ve ark., 2001) ve genetik öğretimine yönelik ideal öğretim stratejileri geliştirmenin zorluğu (Sander ve ark., 1993 venville ve Treagust, 2002, Tsui ve Treagust, 2004; Law ve Lee, 2004) kaynak olarak gösterilebilir.

Genetik konusunun soyut olması ve somut, gözlenebilir ve deneyimlenebilir etkinlik ve materyallere ihtiyaç duyulduğu çalışmaya katılan öğretmenlerin hepsinin ortak olarak belirttikleri bir durumdur. Benzer olarak, yapılan çalışmalar, genetik kavramları arasındaki ilişkinin görselleştirilmesi için denenmiş, iyi planlanmış analoji ve modellere (Venville ve Treagust, 2002) ve bilgisayar ortamında olan etkinliklere (Tsui ve Treagust, 2004; Law ve Lee, 2004) ihtiyaç olduğunu göstermektedir. Öğretmenler bu tür ders materyalleri ve etkinlik hazırlamanın güçlüğünü kabul etmektedir. Öğretmenler genetik problemlerine ciddi bir zaman ayırmalarına rağmen bu tür ders materyali ve etkinlikleri hazırlama ve uygulamalarında derslerin zaman sınırlamasını en büyük engel olarak göstermektedir. Gess Newsome (1992) öğretmenlerin sınıf içi zaman kullanımlarının konuyu aktarımlarının kalitesini etkilediğini belirtmiştir. Sanders ve ark (1993) öğretmenlerin alan bilgisi eksikliğinin öğrencilerin anlamalarını kolaylaştıracak olan uygun gösterim bulmalarını etkilediğini belirtmiştir. Ayrıca, Lederman ve Latz (1993) iyi donanımlı lise fen öğretmenlerinin kendi alanlarına ait bilgileri anlamlı gösterimini hazırlarken zorlandıklarını belirtmişlerdir. Bu nedenle, fen öğretmenlerinin genetik kavramları ve bu kavramlar arasındaki ilişkinin görselleştirilmesinde kullanılacak model, analoji gibi gösterimler konusunda desteklenmesi gerekmektedir.

Fen Öğretmenleri Genetik Konusunun Öğrenilmesinde Karşılaşılan Öğrenci Zorluklarının Giderilmesine Yönelik Kullandıkları Öğretim Stratejileri

Çalışmaya katılan öğretmenler öğrencilerin anlama zorluğu ya da kavram yanılgısı ile karşılaştıklarında genellikle açıklama, benzer örnek verme, daha çok soru çözme ve ödev vermeye dayanan bir döngüyü anımsatan süreci benimsemektedir. Bu yaklaşımları sadece genetik konusu için olmayıp genel bir uygulama görünümü vermektedir. Bu durum Ingber (2009) ve De Jong ve ark. (1995) öğretmelerin konudan bağımsız bir şekilde benzer bir sıralamada ve uygulamaları içeren öğretim alışkanlıkları olduğu için öğretmenlerin konuya özgü bir öğretimden daha çok öğretmene özgü bir eğitiminin sonucu olabileceğini belirtmişlerdir. DeBoer'e (1991) göre bu öğretim döngüsü öğretmenlerin kronik bir hastalığı durumundadır. Rollnick ve ark. (2007) yaptığı çalışmada benzer bir öğretim döngüsünü bulmuştur. Friedrichsen ve ark.'a (2007) göre bu öğretim şekli öğretmenlerin gördükleri tek öğretim yaklaşımıdır. Tobin ve ark.'na göre ise öğretmenler nasıl öğrendiler ise öyle öğretmektedirler. Benzer bir şekilde, Grossman ve ark. (2005) ise öğretmenlerin üniversitede ve üniversiteye kadar aldıkları eğitim onların öğretmenlik ve PAB algılarını oluşturduğunu belirtmişlerdir. Öğretmenler çeşitli öğretim yöntemlerini göremedikleri ve konuya özgü öğretim için mesleki destekleri almadıkları bir durumda genetik öğretimi için farklı bir öğretim yöntemini göstermeleri mümkün gözükmemektedir.

Diğer bir açıdan katılımcılar genetik konusuna özgü bazı uygulamalarda da bulunduğu gözlenmiştir. Öğretmenler genetik konusunun alanyazında belirtilen (Knippels ve ark. 2005; Pashley, 1994) zorluğunu kabul ederek, öğrencilerin yaşadığı zorlukları azaltmayı amaçlayan sadece kitapta geçen Türkçe terimlerin kullanılması ve F_1, F_2, P_1, P_2 gibi sembollerin eklenilmemesi gibi bazı uygulamaları da olmuştur.

Alanyazında PAB'ın eş zamanlı gelişmediğini ve bazı PAB bileşenlerinin diğerlerinden daha önce geliştiği belirtilmiştir (Friedrichsen ve ark., 2007; Hanuscin ve ark., 2011; Henze ve ark., 2008). Bu çalışmada katılımcılar öğrenci ihtiyaçları ve zorlukları konusunda sağlam bir bilgi göstermiş olup, bu bilgi özellikle öğrenci zorluklarının giderilmesi için geliştirilecek öğretim stratejileri için temel kabul edilmiştir. Ancak, öğretmenlerin öğretim stratejileri bilgisi yetersiz bulunmuştur. Katılımcılar genetik kavramlarını anlamlı öğretiminde ve kavramlar arası ilişkiyi öğrenmede öğrencilere yardımcı olabilecek olan gösterimleri ve etkinlikleri geliştirememişlerdir. Bu nedenle, öğrencilerin öğrenme ihtiyaçlarının ve zorluklarının giderilmesinde öğretmenler zayıf yaklaşımlar göstermişlerdir. Bu durum PAB bileşenlerindeki eksikliğin öğrenci zorluklarına öğretmenlerin verimsiz uygulamaları ile sonuçlanması anlamına gelmektedir.

Öneriler

Alanyazında belirtildiği üzere öğretim deneyimi PAB'ın ana kaynağını oluşturmaktadır (Grossman, 1990; van Driel ve ark., 2002). Ancak sadece deneyimli olmak zengin bir PAB'a sahip olunacağını göstermez (Friedrichsen ve ark., 2009). Öğretmenlerin öğrenme ihtiyaçları ve karşılaştıkları öğrenme zorlukları için öğrencilerine yardımcı olabilecek zengin öğretim stratejilerini sağlayan hizmet içi eğitimlerle destek olunması gerektirmektedir. Bu desteğin kesinlikle alan bazlı olup, konuya özgü öğretime odaklanması önerilmektedir (Nakiboğlu ve Tekin, 2006). Katılımcıların hepsi özellikle genetik konusu gibi konuları içeren fene özgü hizmet içi eğitim yoksunluğundan şikayetçi olmuşlardır. Bu çalışmanın sonuçları aynı zamanda öğretmenlerin öğretim programı bilgilerini, öğrenci bilgilerini ve öğretim stratejisi bilgilerini yansıtabilecekleri bir imkanın sağlanması gerekliliğini ortaya çıkarmıştır. Zengin bir PAB gelişimini sağlayacak diğer bir desteğinde uzun süreli mesleki eğitimin öğretmenlere sağlanmasıdır (De Jong ve ark., 2002; Gilbert, De Jong, Justi, Treagust ve van Driel, 2002; Hanuscin ve ark., 2011; Nakiboğlu ve Tekin, 2006; van Driel ve ark., 1998).

Alanyazında PAB'ın öğrenme ortamındaki değişikliklerden etkilendiği belirtilmektedir ve bu çalışma genetik konusunun öğretildiği 8. sınıf öğrencileri ile yapılmıştır. Genetik konusu ayrıca biyoloji dersi içerisinde üst sınıflarda işlenmekte olup genetik konusunun üst sınıflarda çalışılması önerilmektedir. Ayrıca, genetik konusu dışındaki diğer fen konularının da benzer bir şekilde çalışılması önerilmektedir. Çalışma devlet okulunda yürütülmüş olup özel okullardaki öğrenme ortamı için çalışmanın genişletilmesi önerilmektedir.

Bu çalışmayı daha güçlü yapabilecek durumlardan birisi de öğrenci başarısı ile öğretmenlerin PAB'larının ilişkilendirilmesidir. Öğretmen PAB'ları ile öğrenci başarısının ilişkilendirilmesi öğretim uygulamalarının başarısının değerlendirilmesine yönelik önemli bir bakış açısı sağlayacaktır. Öğrencilerin sınav sonuçlarının değerlendirilmesi PAB çalışmasına ayrı bir yük getirmesi ihtimaline rağmen sağlayacağı bilgilerin değerinden dolayı önerilebilir. Bu bağlamda deneyimli öğretmenlerin (genetik konusuna ait) PAB'larının öğrenci başarısı ile birlikte değerlendirilmesi yapılmalıdır.

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YAZARIN

Soyadı : AYDEMİR
Adı : Murat
Bölümü : İlkoğretim

TEZİN ADI (İngilizce) : THE INVESTIGATION OF PEDAGOGICAL CONTENT KNOWLEDGE OF TEACHERS: THE CASE OF TEACHING GENETICS

TEZİN TÜRÜ : Yüksek Lisans ☐ Doktora ■

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