EXPLORING EXPERIENCED SCIENCE TEACHERS' TOPIC-SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE IN TEACHING ECOSYSTEMS

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ABSTRACT

EXPLORING EXPERIENCED SCIENCE TEACHERS' TOPIC-SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE IN TEACHING ECOSYSTEMS

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This research aimed to investigate experienced in-service middle school science teachers' substantive content knowledge and topic-specific pedagogical content knowledge (TSPCK) on the concept of ecosystems. Data were gathered from two science teachers who were teaching concept of ecosystem in the seventh grade level in two different public schools in Ankara, Turkey. Semi-structured interview questions and classroom observations were used as a means to collect data. In data analysis inductive and deductive coding were used. Results which were found in the study presented that science teachers had deficit in substantive knowledge regarding ecosystems since they had partially addressed the basic ecology concepts, including energy flow in ecosystems, decomposers and community concepts. Results of the participants' TSPCK revealed that their orientations towards science teaching were based on transmitting objectives prescribed in the science curriculum to the students even though they hardly remember all of the objectives. Additionally, participants could not link the vertical and horizontal relations successfully. Although science teachers addressed some possible learning difficulties of students, in classroom observations it was noted that they did not use any constructivist method to neither identify students' alternative ideas nor eliminate them. Furthermore, although teachers mentioned some student-centered activities like field trip for teaching ecosystems in interviews, they only used teacher-centered instructional strategies such as questioning and direct instruction. Lastly participants had deficit in using alternative assessment techniques regarding knowledge of measurement and assessments.

Keywords: Topic-specific Pedagogical Content Knowledge, Experienced Science Teachers, Science Education, Ecosystems

ÖZ

DENEYİMLİ FEN BİLİMLERİ ÖĞRETMENLERİNİN EKOSİSTEMLERİN ÖĞRETİMİNE İLİŞKİN KONUYA ÖZEL PEDAGOJİK ALAN BİLGİSİNİN İNCELENMESİ

Tıraş, İlknur

Yüksek Lisans, İlköğretim Fen ve Matematik Alanları Eğitimi

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Bu çalışma, deneyimli ortaokul fen bilimleri öğretmenlerinin ekosistem öğretimine ilişkin alan bilgisi ve konuya özel pedagojik alan bilgisinin araştırılması amaçlamaktadır. Veriler Ankara'da iki farklı devlet okulunda çalışan ve yedinci sınıf seviyesinde ekosistem konusunu öğreten iki fen bilimleri öğretmenlerinin katılımıyla yapılandırılmış görüşme soruları ve ders gözlemi yolu ile elde edilmiştir. Verilerin analize tümevarım ve tümdengelim kodlamaları kullanılarak nicel olarak analiz yorumlanmıştır. Araştırma bulguları, fen bilimleri öğretmenlerinin ekosistemlerde enerji akışı, komünite ve ayrıştırıcı gibi temel ekolojik de kavramlarına yönelik bilgi eksiklerinin olduğunu göstermiştir. Katılımcıların konuya özel pedagojik alan bilgisine yönelik bulgular, fen bilimleri öğretmenlerinin öğretim programında yer alan kazanımları hatırlamamalarına rağmen, fene karşı yönelimlerinin bu kazanımları öğrencilere aktarmak üzerine yoğunlaştığını göstermiştir. Ek olarak, fen bilimleri öğretmenleri öğretim programındaki yatay ve dikey ilişkileri kurmakta zorlanmışlardır. Bunun yanı sıra, fen bilimleri öğretmenlerinin öğrencilerin sahip olabileceği muhtemel öğrenme zorluklarını tahmin etmelerine rağmen, ders gözlemlerinde bu zorlukları tespit etmek veya gidermek amacıyla herhangi bir yapılandırmacı yöntem kullanmadıkları saptanmıştır. Ayrıca fen bilimleri öğretmenlerinin görüşmeler sırasında alan gezisi gibi öğrenci merkezli etkinliklerden bahsetmelerine rağmen, derste sadece direkt anlatım ya da soru sorma gibi öğretim tekniklerini kullandıkları gözlemlenmiştir. Son olarak fen bilimleri öğretmenlerinin ekosistemler konusunu öğretimine yönelik alternatif değerlendirme tekniklerini fazla kullanmadıkları görülmüştür.

Anahtar Kelimeler: Konuya Özgü Pedagojik Alan Bilgisi, Deneyimli Fen Bilimleri Öğretmenleri, Fen Bilimleri Eğitimi, Ekosistemler

To My Mother

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LIST OF ABBREVIATIONS

PCK	Pedagogical Content Knowledge
TSPCK	Topic-specific Pedagogical Content Knowledge
TSPK	Topic-specific Pedagogical Knowledge
PCKg	Pedagogical Content Knowing
CK	Content Knowledge
PK	Pedagogical Knowledge
SMK	Subject Matter Knowledge
KoSC	Knowledge of Students’ Conceptions
TPKB	Teachers’ Professional Knowledge Base
WAT	Word Association Test
DET	Draw an Ecosystem Test
CoRe	Content Representations

CHAPTER 1

INTRODUCTION

Development of teacher knowledge has been always significant for researches (Savaş, 2011). Shulman (1986, 1987) was the first scholar who stated his concerns about teacher knowledge and ideas on how teachers become professionals. He claimed that those who do not understand the content cannot be effective in teaching. Researchers on science education continued to study on teachers' knowledge after Shulman (i.e., Barnett & Hodson, 2001; Friedrichsen, van Driel & Abell, 2011; Geddis, 1993; Gess-Newsome, 2015; Gess-Newsome et al., 2017; Şen & Öztekin, 2019). They tried to test the idea by concentrating on content knowledge and pedagogical content knowledge of teachers (i.e., Akerson, 2005; Childs, & McNicholl, 2007, Gess-Newsome, 2015; Gess-Newsome et al., 2017; Şen et al., 2018). Content knowledge was defined as "the laws, facts, concepts and their relationship with each other in a given topic" (Schwab, 1964) and pedagogical content knowledge (PCK) is "special amalgam of content knowledge and pedagogical knowledge in particular topics which is organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction" (Shulman, 1987, p.8).

According to Shulman (1986) what makes a topic understandable for learners is PCK by means of representations, analogies, examples and demonstrations. Furthermore, he claimed that being able to identify students' preconceptions for the reason that teachers should use methods for reorganization of students' knowledge and curricular knowledge in order to develop their PCK. Therefore, Shulman's views (1986, 1987) explain PCK as including knowledge of representations and knowledge of students' subject matter and learner difficulties. In this view knowledge of representations refers to knowledge of instructional strategies whereas knowledge of students' subject matter and learning difficulties refers to knowledge of learner. However, Shulman's views had deficit in theoretical background and empirical evidence. His ideas considered as simplistic (Kind, 2009).

After Shulman an abundant number of science educators (e.g., Gess-Newsome & Lederman, 2002; Cochran et al. 1993; Grossman 1990; Magnusson et al. 1999) revised the notion of PCK. Like Shulman, Grossman (1990) indicated that PCK is developed by the transformation of subject matter knowledge, general pedagogical knowledge and knowledge of context (see Figure 1.1).

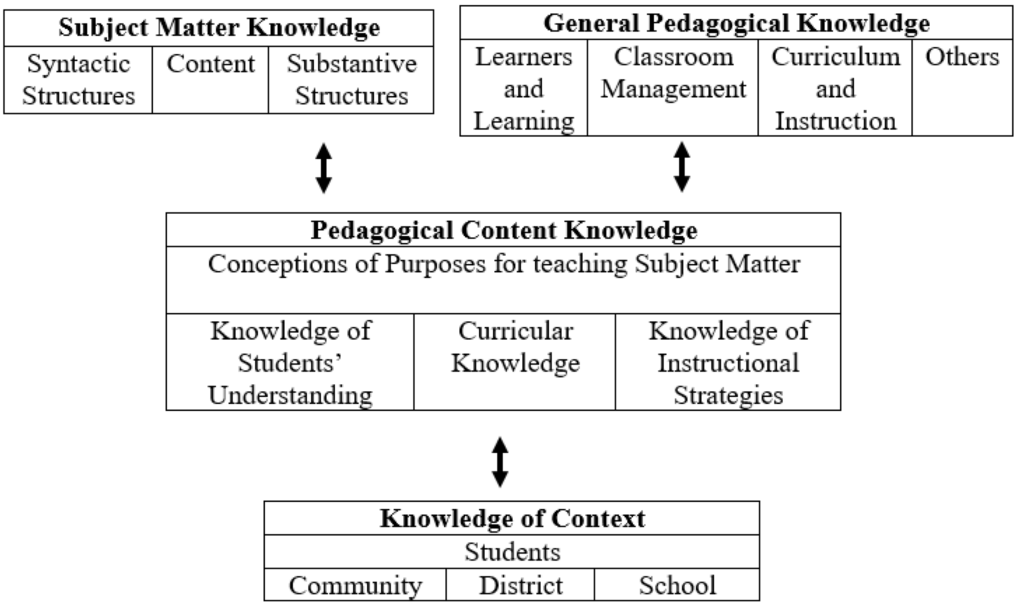

Figure 1. 1. Grossman's PCK Model (1999, p.5)

Within the framework of Grossman's PCK model, it consists of four sub-components that are conceptions of purposes for teaching subject matter that indicated as hierarchically the most important component of PCK, knowledge of students' understanding, curricular knowledge and knowledge of instructional strategies. Nonetheless while explaining her PCK model as a transformation process of knowledge of other domains (1990), Grossman did not mention whether this transformation process is active or passive. Thus, another theory which was based on constructivist views was developed by Cochran, DeRuiter and King (1993). Development of PCK is a dynamic progression (Cochran et al., 1993) which can increase by the time so it was named as pedagogical content knowing (PCKg).

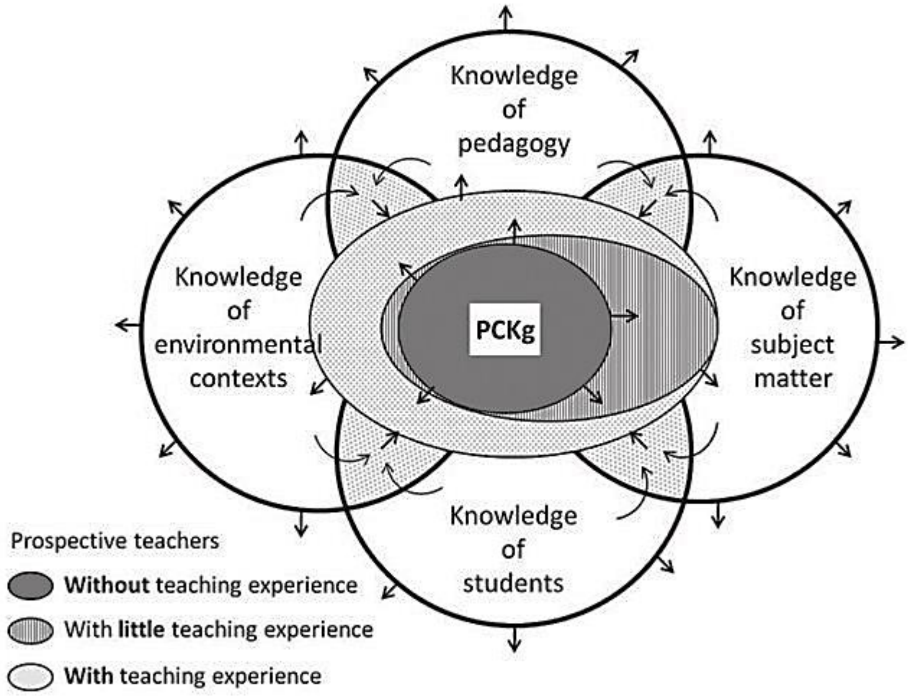

Figure 1. 2. Cochran et al.'s PCKg Model (1993, p.268)

The arrows in Cochran et al.'s PCKg model (see Figure 1.2.) represent the development of PCK over time with experience. According to PCKg model (Cochran et al., 1993), transformation of pedagogical knowledge and subject matter knowledge occur with regards to knowledge of learner and knowledge of context. Unlike Shulman's (1986) definition of PCK, Cochran et al. (1993) defined knowledge of curriculum and educational goals and purposes underneath pedagogical knowledge instead of considering them as separate domains. Besides Cochran et al. (1993) PCKg model had integration and interrelation within its components while forming PCKg.

Another PCK model was formed by Veal and MaKinster (1999) after Shulman (1986, 1987) was criticized by not providing a model for the connection between PK and SMK even though he defined PCK as a bridge between them. Therefore, Veal and

MaKinster (1999) developed a PCK model which included hierarchical relationships between components as represented below.

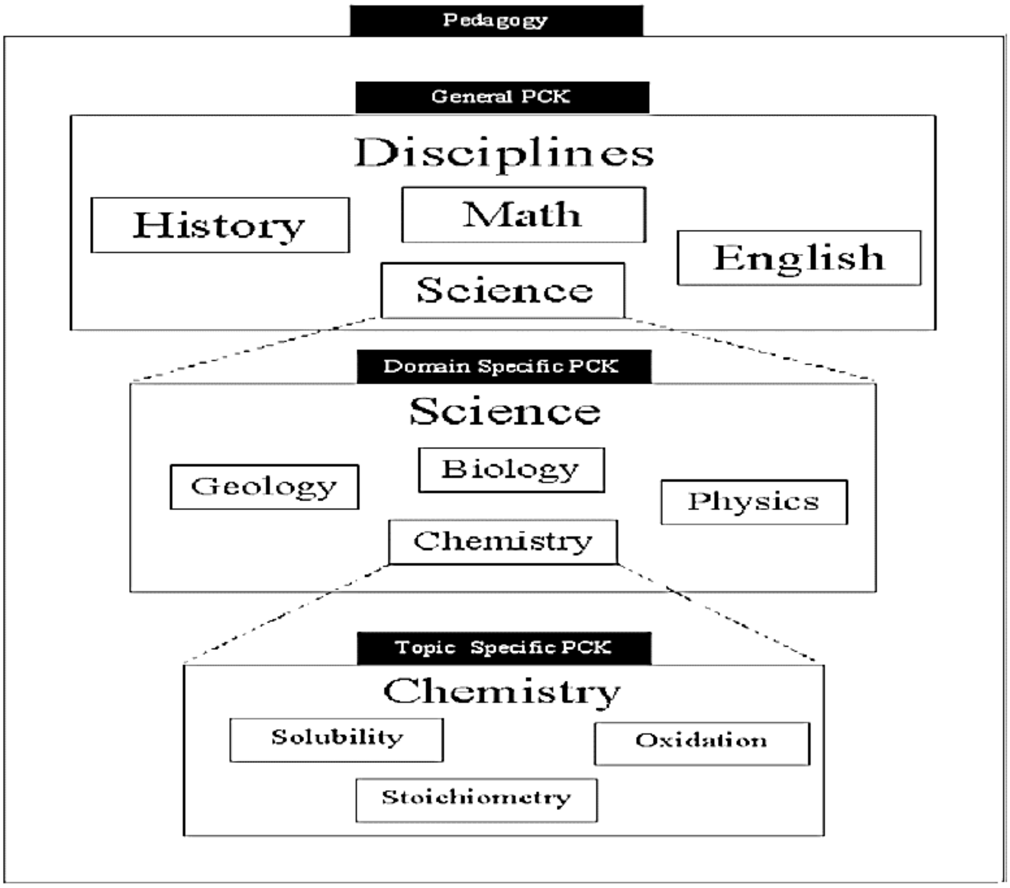

Figure 1. 3. Veal and MaKinster's Hierarchical Taxonomy of PCK (1998, p.7)

In their model of hierarchical taxonomy of PCK, Veal and MaKinster (1998) expressed topic specific PCK as the most specific and general pedagogical skills such as lesson planning, methods for teaching, feedback and evaluating the lesson as covering all categories because teachers should have pedagogy independent from the content. In addition, in order to explain how development of PCK occurs, Veal and MaKinster (1998) developed another PCK model. In this model (see Figures 1.3. and 1.4.), Veal and MaKinster (1998) used content knowledge as a prerequisite for developing knowledge of students, PCK attributes and PCK which is the center of the taxonomy. Yet researchers indicated this development as reciprocal rather than a linear development.

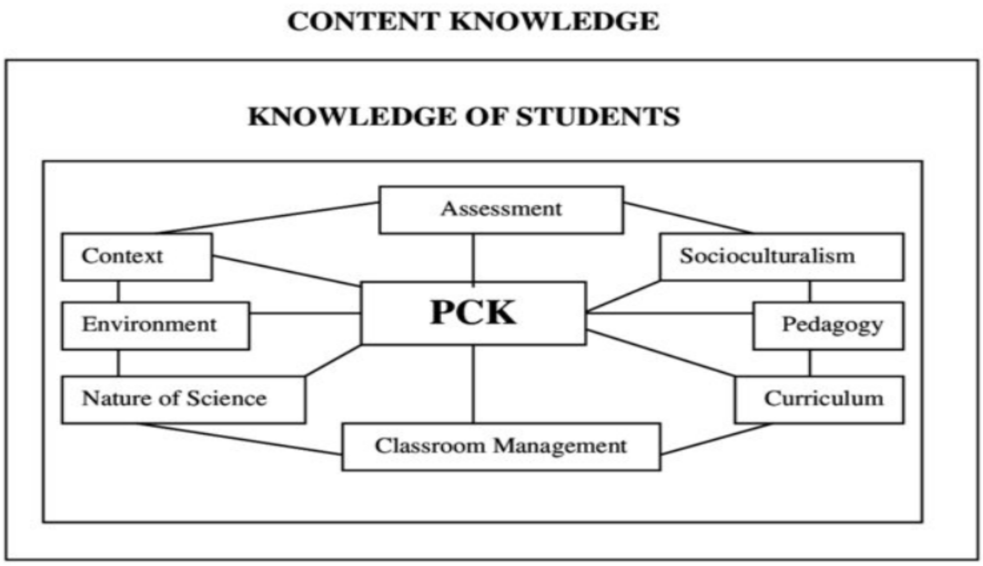

Figure 1. 4. Side View of Veal and MaKinster's Taxonomy of PCK Attributes (1999, p. 11)

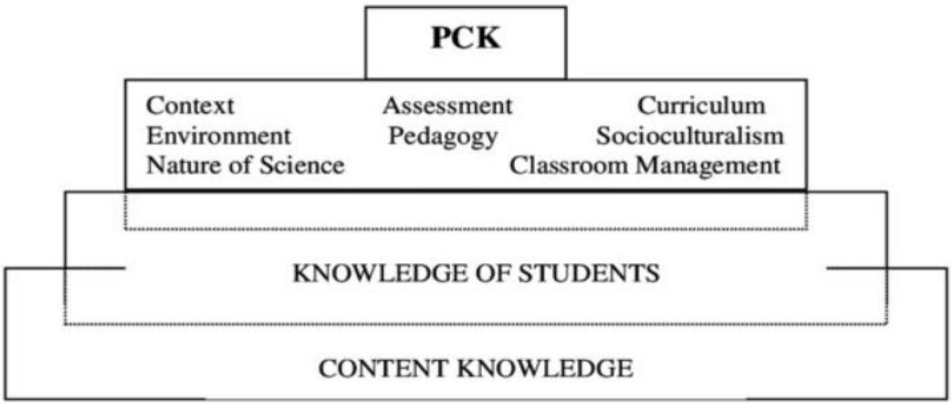

Figure 1. 5. Bird's Eye View of Veal and MaKinster's Taxonomy of PCK Attributes (1999, p11)

Magnusson, Krajcik, & Borko (1999) were other researchers who defined the notion of PCK. They defined PCK with five components as (1) orientations toward science teaching (2) knowledge about science curriculum, (3) knowledge about student understanding of specific science topics, (4) knowledge about assessment in science, and (5) knowledge about instructional strategies for teaching science. As stated in Grossman's (1990) model, there are four fundamental knowledge domains and double-sided arrows represent the mutual impact of domains with each other in Magnusson et al.'s (1999) PCK model (see Figure 1.6.).

In this current study, Magnusson et al. (1999) PCK model was followed and used. Hence each of the five components of Magnusson et al. (1999) PCK model was represented in the definitions of important terms part.

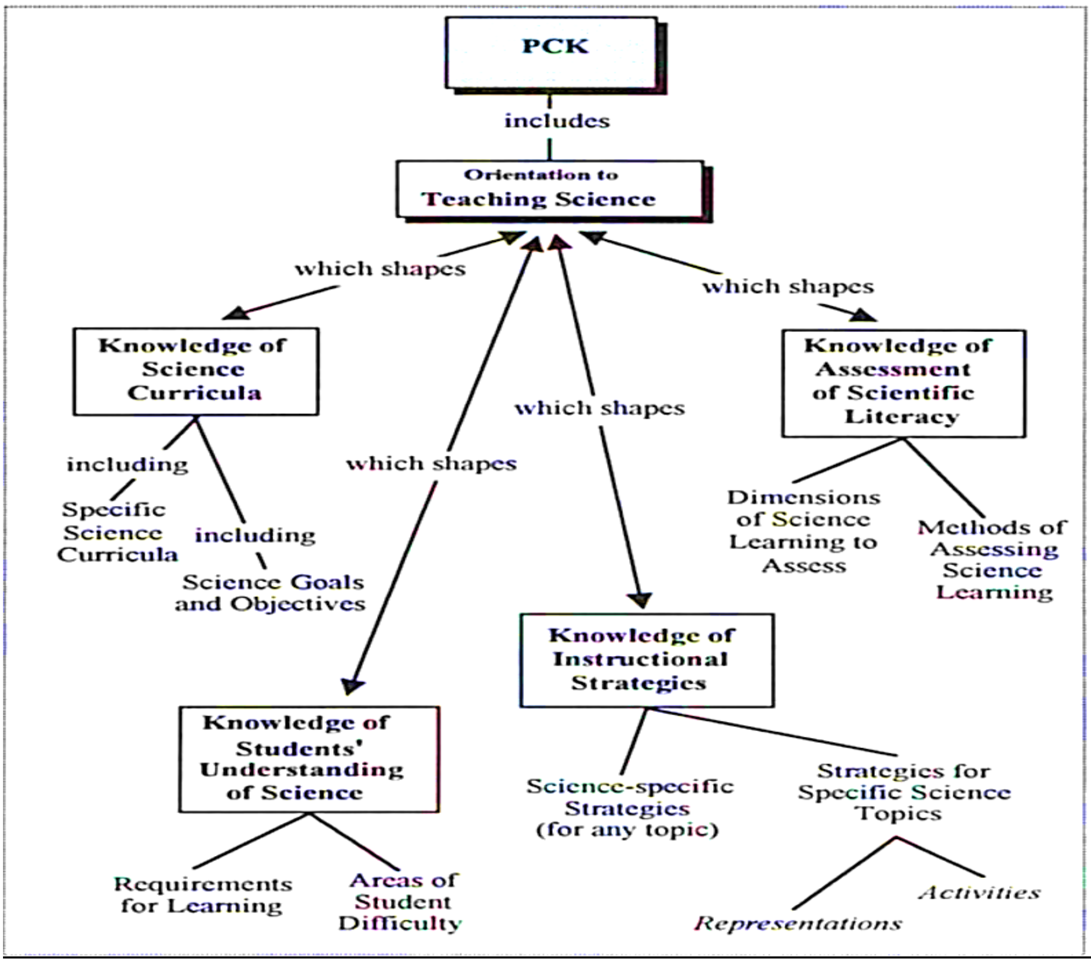

Figure 1. 6. Magnusson et al.'s PCK Model (1999, p.99)

After the models explaining the development of PCK, Gess-Newsome (1999) put PCK models in two categories as integrative and transformative models. In integrative models, Gess-Newsome (1999) considered PCK as a mixture in integrative models where reactants which are SMK, PK and contextual knowledge did not lose their features to form PCK (see Figure 1.7.). Yet integrative models did not consider the integration between SMK, PK and contextual knowledge. Cochran et al.'s (1993) and Val and MaKinster's (1999) PCK models are examples of integrative PCK models. On the other hand, Gess-Newsome (1999) considered PCK as a compound in transformative models where reactants (SMK, PK and contextual knowledge) lost their features in forming PCK (see Figure 1.7.). Examples of these models are Shulman's (1986, 1987), Grossman's (1990) and Magnusson et al.'s (1999) PCK models.

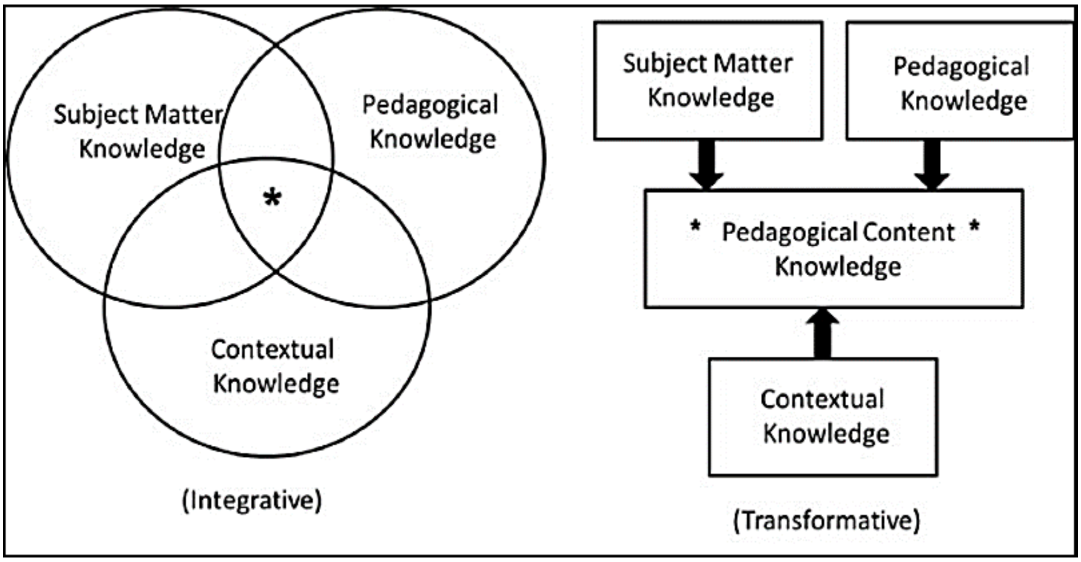

Figure 1. 7. Gess-Newsome's PCK Models (1999, p.12)

*= knowledge needed for classroom teaching

Abell (2008) suggests researchers to understand the significant characteristics of PCK to border their studies. According to Abell there are four essential features of PCK mentioned in the article. The first one is the fact that PCK has some integral parts and these discrete categories shape the research questions and the design of the researches. The second characteristic is that PCK has a dynamic nature since it can be developed by teachers over time with the experience. This feature of PCK shapes the design of the researches. For example, interviews and observations are mostly preferred in PCK researches. The third feature is PCK's dependence on the centrality of content. Researchers should concentrate on inspecting the teacher knowledge of science topic-specific contexts. This characteristic of the PCK influences the questions in the interviews used in data collection in a study. Finally, PCK is not a separate piece of knowledge; however, it is "a special amalgam of content and pedagogy that is uniquely the providence of teachers" (Shulman, 1987, p.8). With the last property of PCK, the researchers also focused on the interactions and transformation of the other types of knowledge.

Moreover, according to Abell, examining the quality of PCK depends on the investigating the interfaces between the components of PCK and the interchange of different sorts of teacher knowledge. As Abell emphasizes there are still some gaps in our understandings of PCK notion that needs further study so that researchers who want to examine PCK ask themselves some outlining questions to consider their research designs. Abell claims that to understand the PCK development, there is a need to decide who the experts are because we need to understand how experience affect PCK development. However, there are two major challenges stated in the article for PCK researchers. The first one is the questions remaining unanswered like "what is the role of teachers' PCK on students' understanding?" In the article it is mentioned that if a researcher does not want to be negligent s/he needs to frame his/her study according to these kinds of questions. The second challenge is to transfer the PCK studies from description to explanation. It is stated in the article that as PCK is a paradigm, moving beyond the description will help researchers and science teacher educators to understand the PCK notion better. All in all, Abell points out the need for further research on PCK and she thinks that for science teacher educators, PCK remains to be a profitable idea. The researchers need to solve the dilemmas of science teaching learning and to comprehend why it is difficult to alter the scenery of science teaching and learning. As Abell mentions in the article the most important issue in the science teaching is how PCK affects the way students learn science though how teachers learn to teach science. Therefore, the researcher kept focusing on the students' understanding more. In fact, the main objective is to teach science and to figure out how students learn science. And to do that, how teachers develop skills to teach science should be investigated.

It is a fact that "teachers need to know the subject matter they teach" (Grossman et al., 2005, p. 205). Therefore, knowledge of the subject matter for teaching seems the most important (Loewenberg, Ball, Thames, & Phelps, 2008) since a complete and coherent understanding of subject matter becomes a prerequisite to the development of PCK (van Driel, Verloop & Vos, 1998). As Jong, van Driel and Verloop (2004) states “understanding of the development of PCK is necessary to design effective teacher education programs”.

In their studies van Djik and Kattmann (2007) also tried to provide an original research model for PCK studies exploring science teachers’ topic-specific PCK to develop teacher education. They prepared a model named “educational reconstruction for teacher education” based on previously established the research model of educational reconstruction. Researchers pointed out that this model emphasized teacher heavily in the design of learning environments and it can increase teachers’ awareness of the conceptual difficulties of their students.

Park and Oliver (2008) conducted a multiple case study. Participants were three high school chemistry teachers to conceptualize PCK based on their descriptive research findings. Data were gathered from various sources such as semi-structured interviews, lesson plans, and teachers’ written reflections, work samples of students and field notes of researcher. Findings presented that the development of PCK involved both knowledge acquisition and knowledge use and it was affected by students’ questions, critical thinking, and answers. Moreover, as a conclusion of this study, researcher pointed out that teachers’ PCK is idiosyncratic since it was developed by each teacher based on their past experiences and knowledge. Additionally, this empirical research resulted in a new affective component of PCK; teacher efficacy which played an important role in connecting understanding and enactment dimensions of PCK. Therefore, researcher modified an evolved model of their heuristic model of PCK claiming that PCK was the heart of teacher professionalism as teachers plan, enact, and reflect on their instructions. Similar to Magnusson et al. (1999), Park and Oliver place orientations toward teaching science on the top and they agreed Magnusson et al. (1999) definition of other PCK components in their hexagonal PCK model (see Figure 1.8.).

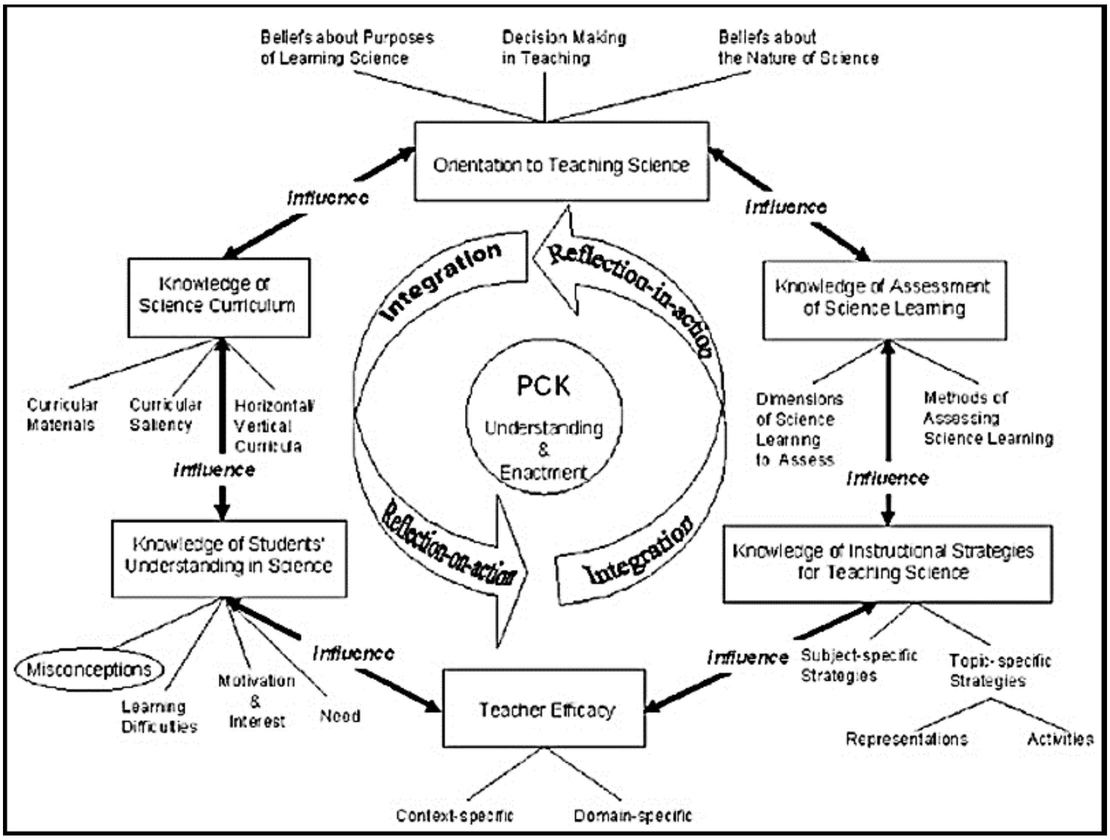

Figure 1. 8. Park and Oliver's Hexagonal Model of PCK (2008, p.279)

Lastly Gess-Newsome (2015) proposed a Consensus Model which takes teachers' professional knowledge base (TPKB) as a starter and develops teachers' topic-specific professional knowledge (TSPK) by findings of research and practice. The difference between TPKB and TSPK is TSPK deals with subject matter, pedagogy and context. Similar to Magnusson et al. (1999), according to the Consensus Model, teachers' beliefs and orientations have an impact on teachers' practice as filters and amplifiers.

TPKB consists of assessment knowledge, pedagogical knowledge, content knowledge, knowledge of students and curricular knowledge (see Figure 1. 9.).

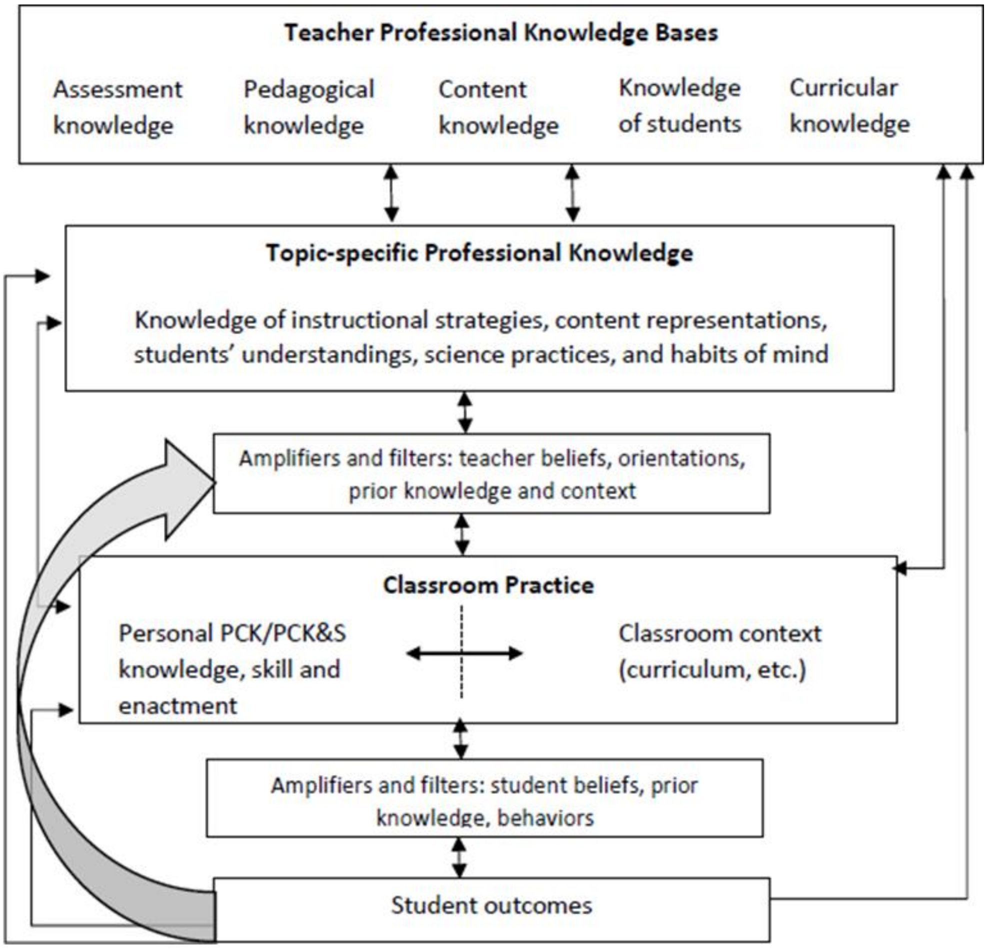

Figure 1. 9. Gess-Newsome Consensus Model for PCK (2015, p.31)

1.1. Significance of the Study

After Shulman defined the PCK (1986), it has been a popular research topic to identify how PCK is developed, what the sources of PCK are and how the components of PCK interact with each other. PCK is specific to the topics (Cochran et al., 1991; Loughran et al., 2004; van Driel et al., 1998; Veal & MaKinster, 1999) and it is hidden in teachers' minds (Abell, 2008). Hence, it is necessary to do a research on how PCK is topic specific and how teachers develop PCK by transforming SMK of different topics

(Abell, 2008; van Driel et al., 1998). Numerous earlier PCK researchers dealt with prospective teachers (Abell, 2008; Aydın, 2012; Kind, 2009) although their PCK deficit in knowledge domains or it does not exist since they do not have any experiences to form a solid PCK (Cochran et al., 1993). Hence, this study examined the teachers who are experienced more than five years in teaching science. Moreover, in the early studies of PCK, some of the components of PCK were ignored. Especially the orientations toward science was the most disregarded component (Şen, 2014) so there is also a need to identify more on science teachers' orientations towards teaching science (Abell, 2008; Friedrichsen & Dana, 2005; Friedrichsen et al., 2010). The current study took all components of PCK into consideration within the framework of Magnusson et al. (1999) model.

Additionally, this study is significant since its data were collected from real classrooms in order to understand how teachers actually use their knowledge in their teaching. Hence the materials, methods and examples developed or used by teachers in this study might be a tool for developing PCK in prospective teachers' training and experienced teachers' developmental programs.

Another significance of the present study relies on the topic selected. Many early studies are conducted in chemistry topics (e.g. De Jong & van Driel, 2004; Mavhunga, 2016) and it is necessary to explore PCK of science teachers regarding biological and environmental topics (Aydın & Boz, 2012; Şen, 2014). This current research focused on science teachers' PCK in the ecology context. Each topic requires a different method of teaching which is why PCK is specific to topic (Veal & MaKinster, 1998). Taking into consideration that PCK is topic-specific, this study focuses on ecosystem concept which is central to ecological topics since it has complex and interrelated concepts (Çokadar & Yılmaz, 2009; Martín-Gámez, Acebal & Prieto, 2018) as a specific topic. Martín-Gámez, (2018, p.1) acknowledge the problem associated with considering the ecosystem as a system' and as a result a difficulty is emerged to connect and comprehend the components, sub-components, processes and relationship involved in ecosystem. Concept of ecology's relation with crosscutting concepts such as energy and matter conservations are significant to study related with the topic since "crosscutting concepts should be learnt by every student to become scientifically literate" (NGSS, 2013). In addition to that, "ecology has connections with science, technology, society, and environment which are parts of scientific literacy" (MNE, 2013, p.29). It is a common conception that the students' scientific literacy in terms of ecology will be affected by their teacher's PCK of this topic. Furthermore, teachers' sufficiency for teaching ecosystem will be an indicator of how well future generations will understand crosscutting concepts such as *energy and matter* and appreciate the importance of saving ecosystems as well as taking action (NGSS, 2013). Therefore, with the topic of ecosystem chosen, the results of the current study will contribute to the PCK literature by providing evidence for science teachers' PCK regarding complex systems like ecosystem. Moreover, findings of this study will be source in understanding the naïve understandings and difficulties of students for the literature regarding ecosystem misconceptions and learning difficulties.

1.2. Statement of the Problem

The current study's goal is to examine experienced science teachers' topic-specific PCK in teaching ecosystems. In addition to syntactic content knowledge of participants, their TSPCK regarding ecosystem was examined in the matter of orientations towards teaching science, curricular knowledge, knowledge of learner, knowledge of instructional strategies and knowledge of assessment techniques. Based on the study goal, the research as well as sub-research questions were raised.

1.2.1. Research Questions Addressed

2. What are the experienced science teachers' content knowledge regarding ecosystem?
3. What are the experienced science teachers' topic-specific pedagogical content knowledge regarding ecosystem?

1.2.2. Sub-research questions

1.1. What are the experienced science teachers' subject specific knowledge (i.e., subject matter knowledge) on ecosystem?

2.1. What are the experienced science teachers' orientation towards science with respect to beliefs about goals of science teaching?

2.2. What are the experienced science teachers' knowledge about science curriculum?

2.3. What are the experienced science teachers' knowledge about students' understanding of ecosystem?

2.4. What are the experienced science teachers' knowledge about assessment of ecosystem concept?

2.5. What are the experienced science teachers' knowledge about instructional strategies for teaching ecosystem?

1.3. Definitions of Important Terms

In this part, the most frequently used terms in the current study were described.

Content Knowledge (CK): Schwab (1964) categorized content knowledge as syntactic content knowledge and substantive content knowledge. And syntactic content knowledge refers to the nature of science knowledge (Khalick & BouJade, 1997) whereas substantive content knowledge includes facts, principles and theories (Abell, 2007). In this study only substantive content knowledge was examined and it refers to the ecosystem content knowledge.

Ecosystem: Reece and Campbell (2011) defined ecosystem as an interacting system including abiotic and biotics where exchanging matter and energy take place for in the recycling of chemicals.

Pedagogical Content Knowledge (PCK): Shulman (1986, p.9) identifies PCK as "the ways of representing and formulating the subject that make it comprehensible to others." Having a thought about students' prerequisite knowledge, the methods to reorganize pupils' knowledge and the curricula are necessary for teachers' PCK.

Orientation towards Science: Science teaching orientation tries to understand the purpose of science at a particular level. Teachers' general view about teaching science is represented in this component of PCK. As Magnusson implies "different orientations may be incompatible with each other like discovery and didactic orientation towards science" (Magnusson et al., 1999) so teachers do not have to have only one orientation towards teaching science. In the context of this study, orientation towards science is defined as teachers' orientations towards science teaching and ecosystem teaching.

Knowledge of Science Curriculum: Curricular knowledge includes two different domains as prescribed aims and objectives, as well as explicit curricular programs and materials. Teachers' knowledge of assigned goals and objectives include aims about each topic and grade level in the curriculum. And, teachers' knowledge about curricular programs involves different sorts of curricular programs and materials that ensembles well for teaching certain topic like textbooks, articles, internet, lab materials etc. (Magnusson et al., 1999). In the context of this study, knowledge of curriculum is defined as knowledge of curricular objectives, ranking of them in order of importance and materials used in teaching ecosystems.

Knowledge of Students' Knowledge and Understanding: This component shows teachers' knowledge of student understanding of a topic. Teachers should know the prior knowledge of students before teaching a particular topic. Moreover, they need to identify the possible difficulties that students might have. Generally nonconcrete topics and topics which are not easily related to previous knowledge of students are problematic for students learning (Magnusson et al., 1999). In the context of this study, knowledge of students' knowledge and understanding is defined as knowledge of students' prior knowledge, learning difficulties and misconceptions based on ecosystems.

Knowledge of Instructional Strategies: The sub-dimensions of instructional strategies are subject specific and topic specific strategies with the fact that knowledge of subject specific strategies is wider than knowledge of topic specific strategies. Subject specific knowledge is equivalent to orientations to teaching science. Topic specific knowledge requires particular activities and representations which are used to help students understanding. Analogies, diagrams, instances and representations are some of the representations. With their SMK, teachers also need to be aware of the pros and cons of such representations. Although solely SMK does not lead a better PCK, topic specific knowledge and instructional strategies are used to teach the relationships in the concepts in a more meaningful way (Magnusson et al., 1999). In the current study, knowledge of instructional strategies is defined as knowledge of instructional methods that were used in teaching ecosystems.

Knowledge of Measurement and Assessment Techniques: Teachers need to be aware of what to assess and how to assess it for an effective teaching so this component of PCK has two sub-dimensions. For teachers to know what to assess, teachers should be aware of nature of science, scientific component and subject matter knowledge (Magnusson et al., 1999). In contrast, to know how to assess, teachers should consider diverse assessment methods for each specific topic. In the context of this study, knowledge of measurement and assessment is defined as knowledge of what to assess and when to assess ecosystems.

CHAPTER 2

LITERATURE REVIEW

Since Shulman (1986) first defined the idea of pedagogical content knowledge (PCK), the research continued to examine it deeply. The research studies were done with pre-service teachers, novice teachers, experienced teacher as well as faculty members to examine their level of PCK. The emphasis on the research studies changes according to the perspective of the researchers. Therefore, what part of PCK they are going to focus on, how they are going to collect data and interpret the results also differ in each of the particular study. In the first two part of this chapter aims to review literature on how the research evaluates teachers' PCK and what the results are in the science education literature. In the third part, previous studies have done for examining ecosystem knowledge and understanding are demonstrated.

2.1. Studies related to Pre-service Teachers' PCK

Developing PCK is important for teachers. It takes time and needs experience (Loughran et al., 2012). Some studies investigated the PCK of candidate teachers since they are the future stakeholders in the education society. While some of these studies focus on chemistry topics (Aydın et al., 2013; Boz & Boz, 2008; De Jong & van Driel, 2004; De Jong, van Driel & Verloop, 2005; Mavhunga, 2016; Mavhunga, & Rollnick, 2013), others concentrated on biological and environmental topics (Aydın, Şen, & Öztekin, 2017; Richardson, Byrne & Liang, 2018; Käpylä, Heikkinen & Asunta, 2009 Tıraş, Öztekin & Şen, 2017; Kaya, 2009; Şen, Öztekin & Demirdöğen, 2018, still others interested in physical concept (Sperandeo-Mineo, Fazio, & Tarantino, 2006; Sorge, Kröger, Petersen & Neumann, 2017)

In one of the early studies by De Jong and van Driel (2004), student teachers were investigated to prepare them for a difficult issue in chemistry education; three multiple related meanings of topics in chemistry. In that study researchers focused on two parts of PCK; both knowledge of focusing on the components of knowledge of science learners and knowledge of strategies. Participants were asked to determine and teach a chemistry topic focusing on the macro-micro-symbolic meanings of topics. Data were gathered via semi-structured pre and post teaching interviews. In pre-interviews participants were asked to present and explain their lesson plans. In post-interviews they were requested to reflect their teaching with a focus on teaching and learning difficulties. The findings indicated that there were four teaching difficulties listed by participants after lessons. Some teaching difficulties determined by participants were mixing micro and macro meaning confusingly and handling ways of symbolic representations in textbooks. With respect to student-learning difficulties, participants indicated that students had difficulties in understanding micro (molecules, atoms, etc.) and macro (phenomena, substances, etc.) meanings of formulas and reaction equations. Researcher tried to give participants an opportunity for learning from teaching and concluded that having the opportunity to look for possible solutions by linking their experience with the literature.

In another study De Jong, van Driel and Verloop (2005), investigated 12 student chemistry teachers' PCK on the use of particle models in secondary chemistry education in the framework of Magnusson et al. (1999) model in the Netherlands. Data were gathered via written assignments, audiotape recordings of institutional workshop discussions which enabled student teachers to relate their own teaching experience with articles, and reflective lesson reports submitted at the end of the module. Prospective teachers' initial PCK regarding learning difficulties were listed as from personal memories and observations as well as textbooks. In participants' post lesson reports, it was reported that students had difficulties in understanding the relationship between corpuscular entities and phenomena. Researchers revealed that the PCK of candidate teachers was different before and after teaching. They indicated that learning from teaching helped pre-service teachers to develop their PCK because there were dissimilarities between what participants predicted and indicated in their lesson plans and what they experienced in real classrooms. Also, the difficulties that participants mentioned before or after the lesson were different among participants.

In different cultural context, Faikhamta, Call and Roadrangka (2009) investigated 4 Thai pre-service chemistry teachers' PCK on chemistry. Researchers used Magnusson et al. (1999) model for determining chemistry teachers' PCK. Data were collected via classroom observations, semi-structured interviews, chemistry content knowledge surveys, beliefs surveys and documents. Data were analyzed inductively by using cross-case analysis to compare and contrast the PCK of all participants. Results presented that the student chemistry teachers advanced their PCK while taking the method course and broadened their knowledge about nature of science and student-centered instructional strategies. Therefore, it was suggested prospective teachers to have a methods course and field experience for supporting and enhancing their PCK most efficiently.

In a study conducted by Nilsson (2009), 22 primary science student teachers in Sweden were investigated based on Shulman's pedagogical reasoning model (1987) to determine how student teachers develop their PCK when they encountered some critical incidents in teaching either a chemistry or physics topic. Participants were stimulated on teaching young pupils a science lesson. The pedagogical reasoning and action processes were used to identify different critical incidents that participants experienced. To collect data three sets were used; questions to the participants before the lesson - questions to the school pupils and a questionnaire and audio-records of group discussions on participants' reflections to the total data sets. As a result, student teachers indicated that there were critical incidents connected to classroom management and pupil's attitudes and learning. Therefore, this study showed the importance of experiencing a real-life classroom and reflecting on teaching in order student teachers to develop professionally and find ways to solve critical incidents.

Hume and Berry (2011) conducted a case and an action research within the framework of Magnusson et al. (1999) model with nine prospective chemistry teachers in New Zealand. In the study the student teachers were asked about students' prior knowledge or misconceptions for a specific topic in the first stage. In the second stage, participants worked in three groups and brainstormed about what students need to know about the specific topic. In the third stage, a blank CoRe template was given to the prospective teachers and they were asked to think about the concepts and skills for students for a specific topic. In the final stage, the participants searched accessible reserves, possible teaching and assessment techniques of the given topic which was redox reactions. Moreover, they were asked to think about the pedagogical strategies for naïve conceptions of students. In order to collect the useful data for analysis, reflective journals, audiotaped interviews, Content Representations (CoRes) and field notes were used. Students' answers and journals were coded according to the effectiveness of scaffolding strategies used to build knowledge for designing CoRes and participants' awareness of the dynamic nature of PCK constituents for a specific topic. The findings showed that with the given course of scaffolding strategies, pre-service chemistry teachers improved their capacity to find and decide related information for designing CoRe which is seen as a possible base for future PCK development. As the article stated the participants found designing CoRes difficult. Moreover, the fact that the participants were prospective teachers and they lack the classroom experience and experimentation was a major limitation for them. However, in the article it was stated that designing CoRes enabled student teachers to start accumulating knowledge for PCK and boost their confidence and competence. The researchers were positive that the process of designing CoRes might affect development of PCK for novice teachers in helpful ways and for lifelong. Developing CoRes might have a positive effect on teachers' PCK development since when designing CoRes teachers need to think about the components of PCK for every particular topic which is suitable for nature of PCK.

In their study, Nilsson and Loughran (2012) investigated development of Swedish student teachers' (N= 34) PCK regarding a specific science topic participant chose from chemistry or physics to teach by using Magnusson et al. (1999) PCK model. Students participated within a semester which they took a science methods course in which they were introduced the construct of PCK and CoRe. Then it was asked from student teachers to construct a CoRe related to a topic they decided both before they teach the subject in a Science Learning Center and school practicum. The prevalent topic chosen by students was air (with a number of 12 students choosing it) among floating and sinking, sound, volcanoes and water. Therefore, the study particularly was based on the data of those. In the purpose of data collection CoRe pre-test, CoRe post-test, a comparison between these two with written self-reflections for all stages and a final semi-structured focus group interviews were used. In quantitative data analysis, self-assessment scores at singular and group level. Qualitatively, participants' reflections, confidence and reasons for changes were analyzed. Findings showed that the candidate science teachers broadened their PCK with the articulation of their experiences. With developing CoRes prospective teachers were able to think about the components of PCK and develop their teaching skills with practice. Nilsson and Loughran suggested that CoRe methodology should be used by science teacher educator since it prompts student teachers to begin acknowledging PCK in their own understanding.

Mavhunga and Rollnick (2013) tried to improve the PCK quality of pre-service chemistry teachers regarding chemical equilibrium topic in South Africa. Data were gathered via a specifically developed Topic-Specific PCK tool for Chemical Equilibrium and pre and post-intervention quantitative and qualitative tools. Analysis of the data in this study showed that the quality of topic-specific PCK can be improved significantly by means of explicit discussions in such interventions. Moreover, the findings also supported that there is a reciprocal relationship between PCK and pedagogical transformation. Researchers concluded that participants improved thoughts about teaching of chemical equilibrium concepts before actually teaching the topic in a class. Thus, Mavhunga and Rollnick suggested that pre-service teachers should be supported to improve their PCK quality by implementing in teacher education programs.

In another study, Mavhunga (2016) conducted a mixed methods research with 36 student teachers who were in their third year of study in a chemistry method class in South Africa. Her aim was to see transferability of the pedagogical transformation competence and to transform content knowledge in the topic of intervention; thus, developing TSPCK based on Geddis and Wood (1997) PCK model. Data were collected in two sets. One set was based on the topic of intervention which was the particulate nature of matter to improve TSPCK quality. A TSPCK tool was administered before and after intervention as pre-TSPCK and post-TSPCK. The other set was based on transform; chemical equilibrium topic. A similar TSPCK tool on chemical equilibrium was administered before and after intervention and also a vignette was used to determine participants' quality of TSPCK. Data pointed out that prospective teachers can improve their TSPCK in the topic by transforming their content knowledge in the topic of intervention as well as transform successfully.

In another study Mavhunga and Rollnick (2016) examined the relationship between TSPCK which was generated in Gess-Newsome (2015) and science teachers' underlying beliefs via an intervention aiming the development of TSPCK regarding chemical equilibrium. Data were gathered from 16 final year pre-service chemistry teachers in South Africa who were administered a specifically designed TSPCK instrument for chemical equilibrium and another instrument for teachers' beliefs before and after the treatment. Additionally, before and after the intervention an open-ended question was asked to the participants to be able to collect written responses on top of the discussions collected through audio-recording. The study results pointed out that the enhancement of TSPCK regarding chemical equilibrium had a significant positive impact on shifting or underlying teacher science beliefs from teacher centered towards learner centered beliefs. In contrast, the study also presented that traditional and reformed teacher science beliefs were existed in developed TSPCK which considered as a caution point since it contradicts the traditional association of PCK with learner centered beliefs.

Kind (2017) conducted a mixed method study to provide rubric having a grading criterion for PCK based on Gess-Newsome (2015). Two hundred thirty-nine prospective science teachers were participated in the study in the UK and data were collected via a questionnaire including closed questions and three topic-specific vignettes. The data of vignettes were analyzed qualitatively for topic-specific professional knowledge (TSPK) and content knowledge (CK) as well as for the indication of appropriate and accurate CK. The results showed that the rubrics were successfully show how qualified TSPK and CK as well as how these associates. It was also suggested that with these rubrics, pre-service teachers as well as out-of-field teachers can be supported to improve their PCK repertoires.

In a recent study, Mavhunga (2018) worked with 15 candidate chemistry teachers in South Africa to analyze participants' TSPCK (Park & Oliver, 2008) regarding dynamic chemical equilibrium in a chemistry methodology course with a period of over 6 weeks. The interventions in the course included lectures and tutorial works introducing the five content-specific components of TSPCK one at a time. Data collected via CoRes developed by participants on the topic of chemical equilibrium. Moreover, participants were asked to develop expanded lesson plans that were semi-structured and open ended to allow pre-service teachers to write their suggestions on conceptual teaching strategies. Both CoRes and expanded lesson plans were gathered at the end of the intervention as an assignment of the method course. Data were then analyzed by the use of a qualitative in-depth analysis method. The findings of the study revealed an interaction between the components of PCK in a linear, interwoven way or a combination of two so it was emphasized that PCK and TSPCK shared similar features which resulted of complex and idiosyncratic interactions of components. The findings also showed that the most complex interactions between components were arose from participants' descriptions of a sequence and a summary of a lesson.

Pre-service teachers' PCK regarding chemistry topics was not only investigated abroad. There are some examples of researches in Turkey, too. For example, Boz and Boz (2008) conducted a qualitative case study with pre-service chemistry teachers to investigate their knowledge of instructional strategies regarding particulate theory. They studied with 22 prospective chemistry teachers who were in their 5th year of university education and collected data via a class vignette entitled "Particulate Structure of Matter', semi-structured interviews to understand reasons and responses given to the vignette and lessons plans and lesson plans planned by 4 participants after vignettes to introduce the particle nature of matter to the students in the situation given in the vignette. This study showed the participants' one dimension of PCK; knowledge of topic-specific instructional strategies. The results revealed the majority of participants would use concrete objects to teach the particulate nature of matter. Researchers suggested that different types of knowledge in the knowledge base like subject matter knowledge and knowledge of students' difficulties could be used to develop PCK. Also, they indicated that student teachers should know the appropriate instructional strategies to teach specific chemistry topics.

The study conducted by Aydın, Boz and Boz (2010), examined the aspects affecting candidate secondary school chemistry teachers' selections of instructional methods for teaching separation of mixtures. Six senior pre-service chemistry teachers who enrolled in the Teaching Experience Course participated in the study. Data was collected by using semi-structured interviews, lesson plans, and participants' reflections on their teaching and classroom observations of participants' teaching. Data were analyzed qualitatively. The findings revealed that there were several factors affecting participants' instructional decisions. These factors were founded as mentors, students, the topic taught, general pedagogical knowledge, own learning styles, subject matter knowledge, concerns about classroom management, and availability of materials.

In their action research study Aydın et al. (2013) aimed to find more about how three prospective chemistry teachers developed their PCK regarding rate of reaction. Participants enrolled in a 14-week CoRe-based mentoring-enriched practicum course. For data collection process CoRes, semi-structured interviews and reflection papers were used. Participants were asked to prepare pre-, mid- and post-CoRes. Participants were interviewed after they prepared their CoRes. Reflection papers were written by the participants after their teaching practices. Findings showed that supporting pre-service teachers with a CoRe-based mentoring-enriched practicum course which enriched with the PCK framework foster the development of pre-service chemistry teachers' PCK.

As a secondary analysis of their study mentioned above Aydın et al. (2015) concentrated on how three prospective chemistry teachers' PCK components improved with a 14-week CoRe-based mentoring-enriched practicum course and the nature of those interactions. In order to analyze data content analysis and the constant comparative method. To understand the result better new method PCK maps were drawn. Results presented that the interactions developed between PCK components were idiosyncratic. In addition, PCK integration developed from fragmented to more integrated and coherent one. In conclusion practicum, reflections and educative mentoring should be used in teacher education in order to monitor how interactions between PCK components developed in time.

In another study related to candidate chemistry teachers Demirdöğen et al. (2016) conducted a case study examining the prospective chemistry teachers' early PCK development based on the nature of science which is complex in nature. 30 pre-service chemistry teachers who enrolled in a Research in Science Education course during two-semester participated in the study. An open-ended instrument, interviews, observations, lesson plans and reflection papers were used in order to collect data for the study. Findings revealed that there was a development of PCK for nature of science from knowledge to application level. Moreover, successful NOS teaching practices were results of higher integration of PCK components.

Although research in PCK generally focused on chemistry topics, there are also studies regarding biology or environmental education. Regarding environmental education, for instance, Kaya (2009) studied the relationships among the components of pre-service science teachers' (PSTs) pedagogical content knowledge (PCK) involving the topic 'ozone layer depletion'. The results of his studies revealed that most PSTs had very superficial knowledge and various naïve conceptions in science topics. Moreover, they did not have adequate pedagogical knowledge of the effective teaching of science (Kaya, 2009). In a most recent study, Richardson, Byrne and Liang (2018) investigated the impact of a general methods course with an explicit course instruction on environmental education (EE) to develop pre-service teacher's PCK and teaching-efficacy beliefs regarding EE. Participants were 26 junior level prospective teachers. Data were gathered through some environmental subscales. Tests were used as pre- and post-assessments in the study. According to the data pre-post means presented a significant increase for both teaching efficacy and outcome expectancy. Thus, in this study, Richardson et al. showed the positive effect of an improved general methods course on the development of pre-service teachers' PCK and EE teaching efficacy beliefs based on the relationship between PCK development and teacher efficacy.

Regarding biological topics, for example, Käpylä, Heikkinen and Asunta (2009) investigated the impact of the amount and quality of content knowledge on pedagogical content knowledge regarding photosynthesis and plant growth. 10 primary and 10 secondary prospective Finnish biology teachers participated in the study. Data were gathered by the use of questionnaires, lesson preparation task and an interview based on Van der Valk & Broekman (1999) method. The findings revealed that a qualified CK has a positive impact on student teachers' PCK and effective teaching. The research also revealed that primary prospective biology teachers had some difficulties in reaction of photosynthesis. Hence, it was suggested that student teacher should be supported by guidance to represent and analyze the CK and

Like the other studies conducted with the pre-service teachers, Özcan and Tekkaya (2011) worked with 6 prospective science teachers to explore their PCK of evolution. In order to collect data semi-structured interviews, concept maps and lesson plans were used. Findings demonstrated that prospective teachers participated in the study had sufficient knowledge about students and instructional strategies. Consequently, it was also found that the student teachers lack of information about the place of the content in the curriculum although they mentioned about some possible concepts, which learners could consider as problematic, indicating some clue for knowledge of curriculum. The participants expressed the reasons for these difficulties as the religion related beliefs of students, the topic of the evolution itself (since it is debatable), and inadequate materials. As for the instruction strategies, they planned to use case studies, field trips and learning cycle. In order to assess the topic of evolution, prospective teachers chose tests and portfolios. Similarly, Tekkaya and Kılıç (2012) investigated senior biology teacher candidates' PK and CK of evolution. Their study indicated that participants had lack of knowledge about the place of evolution topic in the biology curricula and required knowledge regarding evolution and nature of science although they had sufficient information about pupils' difficulties and general ideas about measurement and evaluation techniques and instructional strategies. Tıraş, Öztekin and Şen (2017) studied with pre-service elementary science teachers to find out their PCK on sustainable development. Three female prospective science teachers took part in the study. Data were gathered qualitatively via semi-structured interviews. Results demonstrated participants' lack of adequate information about sustainable development, objective prescribed for sustainable development and the place it occupies in the science curriculum. Additionally, it was also revealed that participants had lack of knowledge of students' understanding of SD due to lack of experience. However, when considered prospective science teachers' knowledge of instructional strategies as well as evaluation and assessment techniques, participants showed a supporting background because all participants mentioned student-centered teaching approaches like argumentation.

In addition to studies related to chemistry and biology, there are a few studies conducted in physics education. One of them belonged to Sperandeo-Mineo, Fazio and Tarantino (2006). In this study 28 Italian pre-service physics teachers' development of PCK within the framework of Magnusson et al.'s (1999) PCK model of regarding modelling thermal physical phenomena was investigated. A multiple case study method was used in the study and data were collected via the admission test, pre and post open answer tests, worksheets and other empirical materials prepared by student teachers and the logbooks of the two tutors and the researcher. After a five phased and 30 hours of workshop, participants were also asked to prepare a homework. In the findings it was reported that preliminary subject matter understanding of participants was not enough for developing the disciplinary capabilities necessary to teach modeling of the natural world. Moreover, it was indicated that the implemented teaching/learning environment was efficient in guiding participants to structure an appropriate PCK. In addition, the study showed that using pedagogical tools helpful for the modelling procedures, was significant for the conceptualization of the role of the physics model. Researcher concluded that in order to prevent possible difficulties which student teachers would have in the future there is a necessity to provide student teachers with tools.

Sorge et al. (2017) examined the content, pedagogical content and pedagogical knowledge of 200 pre-service physics teachers who were enrolled in different years of education at 12 different universities in Germany. They looked at the relations among these three knowledge types, how the three types of knowledge and their relations vary over different years of education and factors affecting the level of each component of professional knowledge. In order to collect data an instrument to elaborate the development of PK, CK and TSPK was developed specifically for this study. The study results indicated that PK, CK and PCK based on Gess-Newsome (2015) model were different constructs. In addition, it was found that in the first year of teacher education, PCK was more related to PK but in later years it was more closely related to CK. Lastly, findings of this study presented that classroom observations had a positive impact on the professional development of pre-service physics teachers no matter what grade they were in or how successful they were. Therefore, it was suggested that pre-service teachers should experience not only formal learning opportunities but also additional different types like observing expert teachers.

It is very crucial for pre-service teachers to develop PCK, and to help them there are some courses at the universities like method courses. Tekin (2006) investigated how special method courses impact pre-service teachers' PCK. The participants were 56 prospective teachers from a large public university located in Turkey. The duty of each candidate teacher was to organize and present a science topic within curriculum. Observation sheets and evaluation forms were used to gather data for the study. For the data analysis descriptive statistics were conducted and the findings revealed that although the candidate teachers obtained enough PCK after the presentations, the activities selected for students' active involvement and the designs were insufficient. Moreover, the researcher stated that the participants had difficulty in connecting scientific concepts with another and asking critical questions about the topic. According to the results of this study, it is suggested that in order to help prospective teachers to develop PCK, there is a need for more practice in the specific courses.

In a recent study, Nilsson and Karlsson (2019) aimed to explore the use of content representations (CoRes) combined with video and related digital tools could be a way of determining Swedish student teachers' PCK regarding four different biology topics in four different vignettes as; protein synthesis, Big Bang theory, memory and fermentation topics. Secondary science student teachers (N=24) participated in the study and they were provided with CoRes and video records of their practicum in order for them to reflect. The annotated video recordings and the written reflections were used as data in analysis of each of the participants. The findings indicated that the CoRes helped student teachers to be prepared beforehand and reasoning in plan-teach-reflect cycle showed the types of knowledge used in teaching practices and also improve student teachers' PCK. Nilsson and Karlsson concluded that using CoRes as a means of planning lessons on specific topics with video records and reflections supported student teachers to examine how they perceive teaching and learning science topics as well as develop their PCK.

In this section previous studies provided a background for the current study in regards of pre-service teachers' PCK were demonstrated. In the next section the studies done with in-service teachers based on their PCK will be revealed.

2.2. Studies related to In-service Teachers' PCK

As there are many studies done with pre-service teachers, there are also other studies which were conducted with teachers; some of them examined experienced teachers' PCK (e.g. Akerson, 2005; Henze, van Driel & Verloop, 2008; Drechsler & Van Driel, 2009; Yarden & Cohen, 2009; Lankford, 2010; Park & Chen, 2011, 2012), while others focused on novice teachers' PCK (e.g. Appleton & Kindt, 1999; Williams, Eames, Hume & Lockley, 2012) regarding biology, physics and chemistry, topics. Additionally, some of the studies involved graduates or university teacher (e.g. Abell, Rogers & Gagnon, 2009; Gess-Newsome, 2018). First studied related to biology were reported. This part followed by physics and chemistry.

1.3.2. Studies related to experienced teachers' SMK AND PCK

Lankford (2010) was one of the researchers who investigated 6 experienced in-service biology teachers' PCK of diffusion and osmosis in the USA. In this study Magnusson et al. (1999) PCK model was used as the theoretical framework. Data were gathered by means of observations, semi-structured interviews, lesson plans and student handouts. After the analysis the results showed that except one teacher the rest of them held a constructivist orientation towards science. Demonstrations and laboratory investigations were used by the teachers as teaching methods and again the teachers holding constructivist perspective used 5E method. Teachers were able to detect students' difficulties and try to get rid of them by describing the terminology before instruction, using demonstrations and computer animations. They also checked students' prior knowledge and used formative assessments. Observations helped teachers to realize if students actually learn the topic or not and had an opportunity see the potential difficulties with the assessments. According to the results of this study, Lankford concluded that the participants in the study had well developed PCK. The researcher also claimed that the orientations of the teachers formed the other components of teachers' PCK since all of them are integrated.

Park, Jang, Chen and Jung' (2011) studies with 7 high school biology teachers in order to investigate the relationship between teachers' PCK score on PCK rubric developed in by Park et al., (2008) and their level of reform-orientation in their instructions. Data were collected via pre- and post- interviews, and classroom observations where teachers were teaching photosynthesis or heredity. In this study whether or not a teacher's class reform-oriented (RTOP) (Sawada et al., 2002) scores were used. The findings of this study demonstrated that the level of a teacher's PCK is significantly related to the degree which his/her instruction was reform-oriented. Moreover, study showed that Lesson Design and Implementation of the RTOP was highly interrelated with knowledge of instructional strategies and representations (KISR). In a similar study, utilizing pentagon model, Park and Chen (2012) examined the nature of integration of PCK components with four high school biology teachers in the context of photosynthesis and heredity instruction in Midwest America. Semi-structured interviews, lesson plans, non-participant classroom observations, instructional materials and students' work samples were used as data sources. The results of the study indicated that the interaction of PCK components had a significant impact on the construction of PCK. The findings of the study indicated that knowledge of student understanding (KSU) and KISR had the most and strongest connections compared to the other components. Moreover, it was pointed out that the quality of a teacher's PCK, which was demonstrated via a PCK Map, was dependent on the consistency between components and the strength of individual components.

Jüttner et al. (2013) investigated and described developing and using reliable, objective and valid instruments to measure biology teachers' CK and PCK separately in the German states of Bavaria and North Rhine-Westphalia. The topics that were assessed in the CK test were neurobiology, vertebrates, plants and cytology. Whereas the topics took place in PCK test were neurobiology, vertebrates and plants (angiospermae). In order to develop a test instrument to measure biology teachers' CK and PCK, Jüttner et al. (2013) have conducted this study. In order to do that they have developed a paper-pencil test and 158 experienced biology teachers answered the test. At the end Jüttner et al. claimed that the instruments they developed measures teachers' PCK objectively in a valid and reliable way. Moreover, they suggested to use new instruments with classroom observation to examine teaching quality as well as student learning relations to PCK. Researchers constructed two paper-and-pencil tests to measure CK and PCK of teachers in the framework of the integrative PCK model by using Rasch model in analysis and administered it to 158 in-service biology teachers. Findings of the study pointed out that CK has three levels as a lower level of sophistication (declarative CK), higher (procedural) and even higher level (conditional CK). Moreover, a statistically low but significant correlation was detected when CK measures were compared to PCK measures of all participants unlike the other empirical researches that presented high correlation between CK and PCK. Therefore, the findings of the study indicated that CK and PCK were interrelated but very different.

Mthethwa-Kunene, Onwu and de Villiers (2015) investigated four biology teachers' PCK in the Swaziland and its development regarding genetics. In this study PCK was considered as the blending of TSCK, PK and knowledge of students' preconceptions and learning difficulties. Concept maps constructed by teachers, pre- and post-lesson interviews, video-records of the lessons, post-lesson questionnaire and reflective journals of teachers as well as work samples of students were used as data sources. The findings revealed that teachers had declarative and procedural content knowledge and they used context-based teaching, illustrations, peer-teaching and analogies as topic-specific instructional strategies. However, they did not use physical models and experimental activities and had lack of knowledge of students' preconceptions on genetics. Consequently, post-lesson reflections helped teachers to refine and develop their PCK. Thus, it was suggested that teacher reflective thinking skills should be supported and implemented in teacher education.

One another study regarding teaching evolution was conducted by Lucero, Petrosino and Delgado (2016) in order to find more about how subject matter knowledge (SMK) and knowledge of students' conceptions (KOSC) of four high school biology teaches in the USA on evolution by natural selection based on Magnusson et al. (1999) PCK model are connected. Data sources were interviews made with teachers on SMK, teacher predictions on students' common misconceptions through the Conceptual Inventory of Natural Selection (CINS) and students' responses to CINS with classroom observations. Results of the study revealed that SMK and KOSC were relatively interdependent. Moreover, it was also noted that teachers in this study had

SMK ranged from 65% to 80% on the CINS and there was a minimum threshold of SMK to diagnose students' alternative conceptions.

In their study Borg et al. (2014) investigated Swedish upper secondary school teachers' (N=3229) conceptual understanding of sustainable development (SD) based on their CK and experience. Data collected through an online questionnaire including both Likert scale and multiple-choice questions based on the concept of SD and analyzed quantitatively by using principal component analysis (PCA). The results of the study showed that there were differences regarding subjects. Subjects of this study generally did not have a holistic understanding of SD because they did not consider three dimensions of SD which are ecological, social and economic. As oppose to the subject based results, the findings of this study revealed that there were no significant differences regarding teachers' experience levels.

In her study, Rollnick (2017) studied with seven high school science teachers in South Africa and identify how their CK on semi-conductors affected their PCK based on Gess-Newsome (2015) model. For data analysis concept maps of teachers, video-records taken in the lessons and journals were used. The findings showed that teachers developed their PCK by improving their ability to design instructional strategies, use representations and assessment techniques. Moreover, it was also indicated in the study that the development of CK was closely bounded up with teachers' ideas on teaching it.

Stender, Brückmann and Neumann (2017) have done a research on examining the relationship between the topic-specific professional knowledge (TSPK) regarding the model developed by Gess-Newsome (2015) and teaching scripts, which were two different types of PCK. In this study it was also aimed to investigate the impact of TSPK on beliefs, motivation and self-regulation as well as teaching scripts. 49 German physics teachers participated in the study where they were administered an online questionnaire regarding teaching the force concept and Newton's law for the grade level 9. Findings of the study revealed that as the Transformation Model of Lesson Planning implied, CK and TSPK affected the quality of teaching scripts which was moderated by motivation and self-regulation. Therefore, it was concluded that teachers' TSPK, motivation and self-regulatory skills had to be strengthened equally to improve their PCK.

In order to understand how students' achievement and interest was affected by teachers' PCK regarding Gess-Newsome (2013) model and motivation Keller, Neumann and Fischer (2017) studied with 77 physics teachers and 1614 students in total in Germany. The study included a pre-post design for teaching electricity specifically electric energy and power in between. Data were collected via videos taken in the classes and tests administered before the instruction began and after the instruction was completed. Tests were composed of measures of students' both achievement and interest. Results showed that teachers had moderate level of PCK whereas they were motivated and eager to a moderate and high level. Moreover, it was also pointed out that teachers' PCK mainly affected students' learning while teachers' motivation had an impact on students' interest. Thus, researchers concluded that a teacher should be both knowledgeable and motivated to help students learn and be enthusiastic.

In their research, Mazibe, Coetzee and Gaigher (2018) conducted a case study including 4 physical science teachers in South Africa. The aim of the study was to investigate and compare teachers' reported PCK of graphs of motion with their enacted PCK in the framework of the TSPCK model suggested by Mavhunga and Rollnick (2013). The CoRe tool, interviews and lesson observations were used as data in the study. In order to analyze the data gathered two TSPCK rubrics were developed as one being for reported and the other for enacted. The findings presented the fact that all of the teachers' reported PCK levels were higher than their enacted ones and all participants had at least one component that was one level below in enacted PCK compared to their reported PCK. For example, one of the teachers in this study, revealed awareness of learners' difficulties and the strategies to uncover and address those difficulties in his reported PCK. However, during the lesson it was seen that although the teacher revealed students' misconceptions and difficulties by asking them questions, he was unable to explain time as a vector. Therefore, even though teacher got a score as developing for his reported PCK regarding conceptual teaching strategies, he was scored as basic according to his enacted PCK. The possible reason for those discrepancies between teachers' enacted and reported PCK was explained as the fact that teachers had difficulties in formulating their PCK in writing but when they were in real classroom context, they managed to utilize their dynamic forms of PCK (Alonzo & Kim, 2016).

A group of researchers focused on developing teachers' PCK applying different programs. For instance, a series of study was conducted by Van Driel and his colleagues (1998) in order to examine 12 chemistry teachers' PCK with a teaching experience more than 5 years in the Netherlands on chemical equilibrium topic by conducting both workshops which aimed to develop chemistry teachers' PCK of chemical equilibrium and an experimental course in classroom practice. Workshops were organized before, during and after the experimental course application. All workshops were audio-recorded and participants were asked to collect and correct some written assignments from their students. Additional data were gathered via participants' written responses to some assignments applied during the courses and to evaluative questionnaire after the course. The recordings and the both students' and teachers' written responses were used as data for this study. The findings of the study showed that teachers developed their knowledge of students' reasoning and learning difficulties on chemical equilibrium topic after participating in workshops and an experimental course. Moreover, it was also reported that some of the participants gained knowledge of successful instructional strategies and representations related to the topic.

Drechsler and Van Driel (2007) investigated nine experienced Swedish teachers' PCK of acid-base chemistry after two years of a teacher training course which deals with possible difficulties the students could have and how models were used during instruction. The researchers aimed to examine this topic since the content was found complicated and the models used in the lessons were not interpreted teachers consistently. The participants were mostly male and they were interviewed by researchers in order to collect data. The interview was a semi-structured design including three stages; briefing and warm-up, main and the debriefing phase. Briefing and debriefing phases were not audio recorded in the study since in those phases the researchers were trying to refresh participants' memories about the course and asking for participant comments at the end. In the main phase teachers were asked about students' thoughts as well as their comments on the textbooks they used and developments of their teaching with different types of models. To complement the data, teachers were also asked to draw a story-line to express their level of satisfaction with their teaching performance. For the data analysis in the findings, Drechsler and Van Driel transcribed the data, summarized the answers of the teachers and categorized them to see resemblances and alterations between teachers' PCK. In the findings the study showed that all the teachers recognized some students had difficulties in understanding the different models. And they stated that it was a good idea to point out the difference between the phenomenological (Boyle and Arrhenius models) and particle level (Brønsted model) explicitly. However, the teachers showed variations based on how they reflect to their own teaching. Although some of the participants reflected on students' difficulties, there a few teachers who stressed the significance of different models (Boyle, Arrhenius and Brønsted models) of acids and basis. The others were worried about their own performance. According to the story-lines drawn, the teachers thought that level of satisfaction with teaching acid-bases would be not more different than other topics in chemistry.

Adopting Gess-Newsome's (1999) model Rollnick et al. (2008) conducted two case studies in Africa in order to investigate the impact of subject matter knowledge on PCK. The first case included teaching the mole concept in a high school and the second case examined teaching the chemical equilibrium in an Access program at a tertiary institution. Data were collected via pre- and post- lesson interviews, classroom observations, PaPers and CoRes. Findings of the data in this study showed that PCK of these two teachers were limited to their understanding of the content which was SMK. Moreover this study showed that CoRes helped in developing an image of teachers' PCK by making the use of representations and topic-specific strategies visible. Thus Rollnick et al. suggested that teachers should be supported to improve their SMK but in order this change to be helpful the assessment regime should be changed and also classroom conditions should be improved.

Another study was conducted in the field of Earth science by Verloop and his colleagues (Henze, van Driel & Verloop, 2008). They perform study with nine experienced science teachers' PCK development over the years in their natural settings based on Grossman (1990) and Magnusson et al. (1999) PCK model regarding Models of the Solar System and the Universe in the Netherlands. They have used semi-structured interviews which were audio taped and took place in three subsequent academic years shortly after teachers finished the lessons about solar system and universe. After analyzing data, Henze et al. developed two types of PCK models for participants. Type A was used to describe teachers who focused on model content whereas Type B was used to describe teachers who focused on model content, model production, and thinking about the nature of models. The results of the study showed that teachers can be identified either having characteristics of Type A or Type B. It was observed that teacher possessing Type A PCK have developed instructional strategies further but they were still mainly concentrated on model content. With regards to development of PCK Type B, researchers concluded that knowledge of instructional strategies, students' understandings and assessment were changed for the better. Researchers concluded that teachers' initial pedagogical perspectives, epistemological views and SMK regarding models of the solar system and universe might have affected their development of PCK over the years.

In a more recent study Clausen (2018) explored the PCK of four Danish geography teachers regarding the topic of weather formation and climate change by following Gess-Newsome (2015) PCK consensus model. Semi-structured interviews and classroom observations were data sources and analyzed in four different cases. The findings revealed that four participants' orientations and beliefs were in alignment with their enacted PCK so they had different ways to teach the topic according to their orientations and beliefs. However, it was stated that teachers partially emphasized the dual perspective which are both transmitting the knowledge and skills and develop actions as active and competent citizens that curriculum requires. For instance, they mentioned the knowledge dimension and future visions and commitments of students. Whereas they did not touch upon students' actions.

Another line of research interested in developing experienced teachers of PCK. For instance, Nilsson (2014) studied with three experienced secondary science teachers in a learning study where science teachers worked with a researcher to understand the chemical concept of ion and how ions formed for 10 weeks. Data were collected via video recordings in lesson and stimulated recall sessions where teachers and researcher reflected on the lessons to examine their PCK development, their students' learning and the effect of that knowledge on their teaching. Data analysis of this study revealed that teachers being involved in a learning study and listening to students helped them to improve their PCK since they were challenged to question their aims, objectives and taken-for-granted assumptions. Conducted another learning study, Nilsson and Vikström (2015) examined whether or not 6 secondary science teachers alter their PCK when they inquired their own teaching. Data were gathered via interviews and video-recorded lessons both before after the project. Teachers were grouped in two and took three learning study cycles per teacher during three semesters. Team 1 took forces and motion, atoms and ion and work and effect lesson whist Team 2 took matter, solution chemistry and photosynthesis. Before and after these lessons teachers were interviewed and video-recorded by the researcher. Results showed that four of the teachers changed their instruction while one of them performed almost the same. However, as one teacher did not teach the same subject as before the lesson cycles, the data gathered from that teacher was excluded. The examples of the alterations teachers made in their second video-recorded lessons were some changes in the definition of the object of learning, how they picked and altered examples for students and how the lessons were structured.

Yarden and Cohen (2009) explored 6 experienced Israeli in-service high school teachers' PCK of cell topic by using the five components of Magnusson et al. (1999) PCK model. Participants joined in three focus groups and one workshop which took place in the summer of 2005 based on a teachers' course named "Teaching the Cell Longitudinally". In order to collect data various ways were used like visual illustrations, teachers' reactions to students' clarifications of biological phenomena, semi-structured interviews, teachers' tests, workshop discussions, questionnaire which was applied to teachers for probing their expectations of the workshop and unfamiliar test questions to assess knowledge of cell in curriculum. According to the results teachers had contrast in their orientations since they both think that the topic was very important but they reduced the time for instructing the cell topic because they were concerned about students' difficulties. Moreover, teachers had little knowledge of curriculum about the cell topic. Cohen and Yarden also state that the teachers had lack of knowledge on integrating biological phenomena at the macro (organismal) level.

Bravo and Cofré (2016) explored how two biology teachers' PCK regarding evolution changed when they enrolled in a professional development program (PDP) including content updates, lesson plans developed collaboratively and practice of planned lesson. An interview before the training process to understand teachers' CoRes for evolution and a group interview after the practiced lessons as well as an individual interview based on reflecting their practices and video recordings of the 6 lessons per teacher were used as data and analyzed qualitatively in this study. The findings of the study pointed out that teachers altered their beliefs and knowledge of instructional strategies and methods for teaching evolution thinking that the NOS aspect should be taught explicitly as well as their knowledge of students' learning difficulties and misconceptions regarding evolution such as religious beliefs or emotional obstacles. The study also indicated that reflecting their own practices helped teachers to develop their transformation.

Chan and Yung (2017) studied with two experienced high school biology teachers in Hong Kong by following Magnusson et al. (1999) model to examine how they develop their PCK from the pre-lesson planning to the post-lesson reflection regarding the polymerase chain reaction which is a newly added topic in the New Senior Secondary (NSS) curriculum in Hong Kong. Semi-structured interviews, classroom observations, classroom artifact and field notes were used as data sources in this study. The findings of this study showed that previous experiences of teachers gave some information about how teachers plan to teach new topic. To illustrate one of the teachers used his previous SMK to state some potential learning difficulties so that he can form some instructional strategies to overcome these misconceptions. In addition, the findings indicated that SMK can be a two-edged sword for both contributing and drawing a line at PCK development depending on the teacher. This is because when they have familiarity with the subject, they can both identify the prerequisite knowledge and be unaware of possible difficulties in understanding the teaching materials or textbooks.

A most recent study, working with 35 physics teachers and their 907 students, Liepertz and Borowski (2019) investigated the relationships between teachers' professional knowledge, in-class actions and students' outcomes by using the Consensus Model (Gess-Newsome, 2005) showing a model of professional knowledge and skill including PCK. Data collected by two different paper-and-pencil tests for teachers and students which administered before and after teachers taught the lesson on the force concept. Also, one of the lessons of each teachers was videotaped and analyzed to see the interconnectedness of the lesson content structure. The results showed that teachers' CK and PK pointed out an impact on teachers' topic specific PCK. With regards to the Consensus Model, it was concluded that the relationship between the teacher professional knowledge base (TPKB) and the topic-specific professional knowledge (TSPK) has to be specified more. In addition, the results revealed that teachers' PK had a minor significant influence on classroom practice including strong classroom management. However, findings also indicated that higher interconnectedness among physics contents provide students with a better learning outcome. Therefore, researcher suggested to verify interconnectedness of content structure as an indicator of quality of teachers' instruction.

Thus, in the following section studies related to novice teachers' PCK reported. There are many studies interested in exploring novice teachers' PCK (e.g., Friedrichsen et al., 2009; Hanuscin et al., 2010; Pitjang-Mosabala & Rollnick, 2018; Williams et al., 2012).

2.2.2. Studies related to novice teachers' PCK

In their study Friedrichsen et al. (2009) investigated prior knowledge for teaching among two beginning biology teachers and two biology teacher interns those who entered Alternative Certificate Programs (ACP), comparing them in accordance with their teaching experience. Two of the beginning biology teachers had 2 years of prior biology teaching whereas two interns had lack of experience. Lesson Preparation Method used as a tool in which participants were asked to prepare a lesson plans to teach heritable variation concept. In addition to lesson plans follow-up interviews were used as data sources. Findings showed few alterations between teachers with two years of teaching experience and interns in the development of PCK. All participants had didactic teaching orientations and all of them had lack of knowledge for teaching in all components of PCK when they started to ACP. However, it was noted that two participants having teaching experience were beginning to integrate components of their PK into their teaching. Therefore, it was concluded that teaching experience with reflections can help future teachers to develop a framework and tools for a sophisticated knowledge in science teaching.

Williams, Eames, Hume and Lockley (2012) examined 4 science teachers who were at the beginning of their career in New Zealand. They investigated teachers' PCK of organic chemistry and technology units, how developing CoRes affect their lesson planning and practice. Novice teachers were supported by the experts of pedagogy and subject matter. The study was designed with qualitative research methods followed by case study approach. For the purpose of data collection several methods were used like field notes, observations and interviews. In the results, Williams et al. found out that the collaboration of experts and novice teachers were helpful to both sides. Novice teachers stated that it was helpful especially in developing their knowledge of curriculum and instructional strategies. With using CoRes teachers also claimed that they used time efficiently in the classroom, realized the need to use more daily life examples and felt more confident to teach the topic of organic chemistry. Moreover, their orientations toward science altered after organizing CoRes with practiced teachers. This study showed us that using CoRes can be helpful not only for pre-service teachers but also for novice teachers to develop their PCK when expert teacher helps them in constructing process.

Pitjeng-Mosabala and Rollnick (2018) examined how 14 novice uncertified graduate science teachers develop topic specific pedagogical content knowledge (TSPCK) regarding particle nature of matter. Participants involved in a professional development intervention (PDI). In order to collect data pre- and post- TSPCK and CK tests, CoRes constructed by teachers, for only four selected participants' videos and field taken in lessons as well as pre- and post-lesson interviews conducted with teachers were used. The results of both whole group and selected group of teacher showed a development of TSPCK in their teaching. However, four teachers who selected and post-interviewed presented higher improvement compared to the others.

Therefore it was concluded that classroom practice is crucial for developing novice teachers' PCK with an appropriate reflection.

As in science education it is crucial that having a well-developed PCK, teachers also need to know about nature of science to teach science properly. That means they need to have PCK not only for scientific topics but also for the nature of science which is categorized as syntactic knowledge of subject matter. So as to understand how teachers use their knowledge of NOS in their lessons for K-6 learners and how teachers' practices constitutive of their PCK for NOS, Hanuscin, Lee and Akerson (2010) studied with three teachers over a 3-year period. In the study researchers predicated on Magnusson et al.'s (1999) transformative model of PCK. Researchers tried to examine the interaction between PCK components as teachers taught NOS. They developed a professional development program for teachers including workshops where NOS was introduced to the teachers. Moreover teachers investigated their curricula to see if NOS was integrated and concentrated on the strategies for teaching NOS. There were 6 teachers who participated to the workshops for over 3 years in the study but only 3 of them included in the research study. The researchers collected data from a variety of sources like questionnaire and interviews that conducted both at the beginning and end of the program, field notes and transcripts, videos, lesson plans and teachers' written contributions to professional publications. While analyzing data the researchers used modified analytic induction for developing their coding schema and detecting outstanding themes. Researchers used matrices to triangulate the data and negative cases to modify their declarations. They especially focused on how teachers translate their understanding of NOS to students and how successful they are when helping students to understand NOS. In the findings of the study Hanuscin et al. stated three separate but connected ways teachers transformed their understanding of NOS to accessible forms for their students. These ways comprise of translation of language into a way which students can understand (kid-friendly terms), defining NOS operationally based on inquiry-based experiences and creating analogies to NOS from children's literature. The study revealed that as teachers get their students define NOS operationally in the context of inquiry, they tried to help students to understand what scientists do. In five aspects the researchers expressed how teachers alter their knowledge into systems that can be understood by students (PCK). The first one is orientations toward teaching science and it is found that teachers developed an inquiry orientation as they developed professionally. Hanuscin et al. pointed out that in consistent with Abell's statement, orientations can change over time and be context specific. The data suggested that since participants in the study learned both NOS and inquiry at the same time, the harmony between their orientations and teaching of NOS increased. The second one is knowledge of curriculum. The participants had lack of time and materials needed to support NOS instruction in the curriculum in the study. After the professional development, the researchers figured out that the teachers were capable of concentrating on NOS within their curriculum. The third one is knowledge of instructional strategies. The researchers indicated that teachers were not only implementing the subject-specific strategies shown like inquiry but also creating their own strategies for embedding NOS. The fourth one is knowledge of assessment. Hanuscin et al. pointed out that the teachers had deficient knowledge of assessment precise to NOS. the fifth one is that knowledge of learners. This category as stated in the article in Magnusson et al.'s model for PCK consist of two categories which were requirements for learning and areas of students difficulty. The researchers suggested that workshops, more practice and providing assessment strategies for NOS can help teachers to develop their PCK.

2.2.3. Studies Related to Comparison of experts and novices' PCK AND SMK

Other studies interested in comparing experts and novices' PCK AND SMK (e.g. Appleton & Kind, 1999; Veal & Kubasko, 2003; Akerson, 2005; Kınık, Rakunt & Öztekin, 2018). For example, Appleton and Kindt (1999) conducted a two-staged study. In the first study they investigated PCK of Australian beginning teachers by using Grossmann's (1990) model based on how they cope with their limited PCK and in the second study they studied with in-service teachers to examine how teachers understand and use the activities that work in teaching science. Participants of the study were 9 pre-service and 20 in-service teachers in this study. For the means of collecting data, classroom observations and interviews were used. Interview results of prospective teachers revealed that some teacher candidates did not teach the whole scientific content and they were likely to avoid teaching science because they feel insecure about teaching a scientific topic due to their lack of SMK. The findings also showed the activities used in the class were not for the students but for prospective teachers to hide their inadequate PCK because some activities were irrelevant to the specific concept that they were teaching. According to the observation of the researchers, the in-service teachers integrated using hands-on activities to their development of PCK after they got used to them. Therefore researchers pointed out the importance of such activities related to the curriculum and the time needed for pre-service teachers to develop PCK. Appleton and Kindt also suggested a connection between instructional strategies and knowledge of curriculum so there is a need for a more integrated curriculum which can lead students to inquiry.

In one of the studies conducted by Veal and Kubasko (2003) 12 secondary American pre and in-service biology and geology teachers were investigated in order to determine how and why biology and geology teachers approach teaching evolution. In order to collect data classroom observations, field notes, semi-structured interviews which were audiotaped and unstructured conversations with in-service teachers as well as documents collected pertaining to the secondary science methods course were used. Data were analyzed qualitatively. Findings showed that many of the participants used traditional approaches whereas some of them used hands-on activities with an inquiry approach. Moreover, candidate teachers were deficit in knowledge of students as well as topic-specific activities, labs and analogies so they mostly relied on direct instruction. Comparing geology and biology teachers, it was seen that geology teachers were more knowledgeable about biology topics than biology teachers knew about geology topics. In addition it was indicated that the geology teachers used students' prior biology knowledge except genetics. The differences between geology and biology as well as their approaches to evolution teaching were mainly preconfigured because of the differences in the communities of inquiry.

Krepf et al. (2018) conducted an empirical study with 9 expert and 9 novice teachers in order to examine which knowledge teachers activated to assess a videotaped lesson and its effectiveness in learning. For data sources and analysis, a lesson video on optics where the law of refraction (Snell's law) was being studied were shown to the participants and with a subsequent interview, teachers were asked to analyze the lesson. Findings of the analysis showed that expert teachers intensively activated their CK and PCK which differed them from novice teachers. Thus results also added that experts activated their CK and PCK in a combination rather than separate.

Akerson (2005) examined how experienced in-service teachers and one primary school teacher candidate compensate for their lack of knowledge on the topic of astronomy were compared. Observations and videotapes were used to gather data in this study. Akerson stated that there were some prompting aspects like students' questions and comments that help experienced teachers to compensate their deficiency in content knowledge. Thanks to their experience, these teachers try to differ what was not working and find a better way for teaching the topic which was affecting the instructional methodology selection of teachers. It found that experienced teachers changed their lesson plans and tried to provoke alternative conceptions of students by using scientifically appropriate clarifications. On the other hand, it was found that the issue for compensating her lack of content knowledge for the pre-service teacher was the personal concerns rather than what students need. Therefore when pre-service teacher selected an activity, she was not successful applying it because of the lack of learner knowledge. Akerson suggested that with the increase in the content knowledge, teachers can change the instructional strategies as well as know more about the students.

2.2.4. Studies related to graduate and university teachers

Although it seems like that PCK is a notion related to the teachers in the elementary, middle and high school, it is vital for next generation science teachers' educators to develop PCK at the universities. In the study Abell, Rogers & Gagnon et al. (2009) investigated doctoral students' PCK developments in order to suggest a model for the development of knowledge for teaching science teachers. They argued their own experiences as doctoral students and faculty members from three universities. They provided five different vignettes to represent how they developed PCK over time with different ways. In the first vignette, with the help of observation, reading and teaching experiences Gagnon developed PCK of instructional strategies. In the second vignette, by involving in an independent reading course and its duties such as reading chapters before meetings, commenting on them and summative assessments, and observing his instructor plan a 16-week methods course, Rogers developed PCK of curriculum. In the third vignette, being an apprentice with his professor in a methods course and having the responsibility of observing, taking notes and teaching his own section, also having conversation about the assessment techniques helped Lee to develop PCK for assessment. Moreover he stated that he started to see the assessment as a cycle and as a summative assessment he asked his students to prepare a portfolio. In the fourth vignette, Hanuscin was responsible for developing and teaching his own section of an elementary science methods course. He planned assessments and class activities to stimulate students' ideas about science and science teaching so he developed PCK of learners. In the last vignette, Abell stated how she developed PCK of orientations. She pointed out that she was teaching an elementary science method for a while when she got the grant for making video cases of elementary teachers using best practices in their teaching. After observing, teaching and mentoring students she was able to develop PCK of orientations. For the final model they developed a continuum starting with observer and continuing with apprentice, partner, independent instructor and mentor as time passes through the doctoral program. They suggested that there is need for a vision for doctoral preparation and new standards for science teacher education.

In order to examine PCK of university professors regarding quantum chemistry, Padilla and van Driel (2011) interviewed with 6 university professors teaching quantum chemistry at Bachelor's level. In this study identifying and analyzing relationships between specific PCK components were also aimed. According to the findings of this study, there were relationships between teachers' knowledge of students learning and curriculum. Moreover it was indicated that assessment was less cared than students' understanding, curriculum and instructional strategies. In addition study revealed that most of the teachers had a didactic orientation towards teaching and focused on problem solving instruction method.

In another study the researchers defined high-quality teaching as the focused and cautious planning of instruction providing students a comprehensible learning experience (Gess-Newsome et al., 2017). They only focused on three aspects of knowledge for teaching; academic content knowledge (ACK; which is equivalent to

Shulman's subject matter knowledge), general pedagogical knowledge (GenPK) and PCK. Similar to what Abell (2008) said about the design of the PCK studies, Gess-Newsome et al. also used interviews, observation protocol using a PCK rubric and written reflections in their research design to measure PCK. They developed three components in theoretical path of influence. Component 1 is impact of intervention which impacts teacher knowledge bases as a result of the use of educative instructional materials. Component 2 is about the relationships among teacher variables which investigates the effects of improved knowledge bases on teacher practice. Component 3 is related to the relationship of teacher variables to student achievement including the knowledge bases and teacher practice. In the study researchers studied on a professional development program in which they developed a curriculum as intervention. The participants agreed on teaching at least one section of biology using one of the two curricula selected after the project PRIME for two years. Moreover teachers were asked to attend additional days in summer during two school years. Mixed-method is used in the study for the aim of data triangulation and meaning improvement. A field test in biology developed by the Educational Testing Service was used to assess ACK, and to assess GenPK and teacher practice, an observation protocol was used. The researchers designed Project PRIME PCK Reflection Instrument and the Project PRIME PCK Rubric to assess PCK, which they considered as having three components; PCK-CK, PCK-PK and PCK-CxK. In the article they defined PCK-CK as the networks between topics, the nature of science and illustrations or illustrations of a topic. Whereas PCK-PK was described as the teaching strategies for students learning and for prior understanding. Lastly PCK-CxK was expressed as understanding how students' differences affect instruction. Student achievement was measured by a test including comprehensive items from BSCS. Interviews were conducted two times; one after the program ended and the other at the end of one year or two years. In the findings, the analysis showed that PCK-CK and PCK-CxK are not totally separate. Then the three-construct model of PCK changed to two separate concepts as PCK-CK and PCK-PK. It is found that intervention (component 1) helped teachers to increase their knowledge base. In the component 2, the statistics showed that Gen-PK is highly related with PCK-CK and teacher practice. Within the component 3, researchers found out that solely ACK had an effect on student achievement. Surprisingly teacher practice and student achievement correlation were frail considering the fact that teachers develop PCK through experience. The interviews showed that the PK of the teachers have developed, too. With this study, it is obvious that there are multiple components of PCK to study on and that both focusing on content and pedagogy help teachers to improve their knowledge bases.

In this section studies related to in-service teachers' PCK were revealed. The current study takes ecosystem as the specific topic to focus on as the topic specific nature of PCK acquired. Therefore in the next section studies regarding ecosystem topic, as well as understandings will be revealed.

2.2.5. Review of research conducted on CK and PCK in Turkey

Similar to international study, research on CK and PCK has received great attention by Turkish researchers. Studying with expert science teachers, Şen (2014) conducted a qualitative study based on Magnusson et al. (1999) PCK model with four Turkish experienced science teachers regarding cell topic. He used classroom observations, field notes and pre- and post-interviews to collect data. Data were analyzed inductively and deductively. The results revealed that science teachers violated curriculum despite of their awareness of the curricular cell division objectives and ability to link vertical and horizontal relations. Furthermore, he found that science teachers were able to determine students' alternative understandings about cell division, but they were deficit in terms of knowledge for eliminating them. Furthermore, alternative assessment technics regarding knowledge of cell division were a deficiency science teachers had (Şen, 2014). In a most recent study, Şen and Öztekin (2019) investigated middle school science teachers' contextual knowledge, PCK and the impact of contextual knowledge on PCK on density topic from a sociocultural perspective. They showed that science teachers' knowledge of both curriculum and assessment strategies were limited with their knowledge of subject. Magnusson et al. (1999) transformative PCK model was used in the research due to the convenient distinctions between five components in the model. Semi-structured interviews for both contextual factors and PCK and classroom observation were used in gathering data which were analyzed qualitatively with the help of inductive and deductive coding. Results revealed that teachers' contextual knowledge help them in altering their PCK and support their PCK in some components such as knowledge of curriculum, knowledge of learner and knowledge of instructional strategies. However, it was also stated that when negative effects like lack of technological equipment for showing visuals in the contextual factors cannot be eliminated, it is likely to limit teachers' PCK. Moreover an interception between student component of contextual knowledge and knowledge of learner component of PCK was revealed in this study.

Aydın, Şen and Öztekin (2017) investigated two middle school science teachers' PCK and pedagogical content concerns (PCC) regarding sustainable development (SD). In order to collect data, semi-structured interviews were used and analyzed qualitatively by using inductive and deductive coding. Results of the study presented that students' lack of interest, awareness of SD, and lack of support from schools, teachers' lack of subject matter knowledge as well as high school entrance exam were main concerns of teachers. Moreover study showed that teachers' orientation was towards increasing students' awareness on social issues. Regarding knowledge of curriculum, it was presented that teachers had lack of knowledge on place of SD in the curriculum. For instructional methods to teach SD teachers mentioned student-centered activities like field trip and for assessment techniques they named alternative assessment strategies like project based assessment.

In a recent study Şen, Öztekin and Demirdöğen (2018) examined how teachers' CK had an impact on their PCK regarding cell division topic. Participants were 3 science teachers who interviewed both before and after lessons. In addition to interview, classroom observations and documents that teachers used such as tests and exams were data sources for the study. Findings of the study presented that CK supported two PCK components; knowledge of students' understanding and knowledge of instructional strategies. However, when it comes to knowledge of assessment it was noted that there was no such relation between CK and knowledge of assessment. On the other hand, results of the study also pointed out that CK could cause curriculum violation although CK rich teachers knew more about the curriculum. According to the results, teachers showed schooling goal of teaching to prepare students to real life in pre-interviews whereas they focused on transmitting the curricular objectives to students. Therefore it was concluded that CK may not have an impact on teachers' orientations towards science.

Karışan, Şenay and Ubuz (2013) conducted an investigation with an elementary science and technology teacher. In contrast they examined teacher's PCK regarding the topic of fluid pressure in physics. They used a pre-interview, classroom observations and a post-interview protocol to assess the teacher's PCK. Karışan et al. concluded that the teacher was well-informed about the science curriculum and students' existing knowledge as well as future topics they will learn regarding the liquid pressure topic.

As an addition to PCK investigations on cell division, Köse (2014) also studied on developing a scale for evaluating science teachers' PCK of cell divisions. He developed a scale of 20 questions and applied it onto 182 science teachers. As a result, he found out that teachers who have experience between 5 and 9 and those who have graduated from education faculty had higher levels of PCK compared to others.

Some studies compared teachers or teacher candidates' TSPCK. For example, Aydın (2012) conducted a study for her doctoral dissertation to investigate topic-specific nature of PCK of electrochemistry and radioactivity. Participants of the study were two experienced chemistry teachers. Card-sorting activity, CoRes, semi-structured interviews, lesson observations and field notes were used as data in the study. Teachers' PCK were examined for electrochemistry and radioactivity. It was presented that their PCK of electrochemistry involved content-based and teacher-centered instruction and were linked to other chemistry as well as physics topics. Moreover PCK of electrochemistry included different assessment techniques which were used in the beginning, during and at the end of the lesson. On the contrary, PCK B was found to be less teacher-centered and its connection with other topics were limited. The assessment used in PCK of radioactivity was fragmented and teachers had lack of knowledge in students' learning difficulties and misconceptions regarding radioactivity compared to electrochemistry. Therefore the results revealed topic-specific nature of PCK and it was suggested that teacher education should support topic-specific training. Aydın and Boz (2013) carried out a qualitative case study in

Turkey with two experienced chemistry teachers in order to see the nature of integration among PCK components. They have used card-sorting activity, content representation (CoRe) tool, observation and interviews to collect data. Aydın and Boz observed teachers while teaching redox reactions and electrochemical cells. After analyzing data in three steps within the theoretical framework of Park and Chen (2012), the results demonstrated that knowledge of students and instructional strategy took place in the central of the integrations. In contrast, researchers revealed that assessment knowledge and curriculum were not that effective on teachers' teaching. In this study PCK maps were developed for each teachers and it gave researchers an opportunity to correlate the scores of students' achievement with teachers' PCK maps.

In a similar line, Çaylak (2017) investigated the topic-specific pedagogical content knowledge of a science teacher who was working with gifted students in a single case study. He also aimed to examine the interaction of the science teacher's PCK components. The data were gathered in a long term regarding three physics topics; work and energy, simple machines and friction force via content representation (CoRe), card-sorting activities, classroom observations, field notes and semi-structured interviews. The findings of the study showed that the teacher had more than one orientation toward science teaching and learning. She also had solid knowledge of curriculum, learner and assessment techniques as she designed lessons with activities and used both informal and formal assessment strategies. Lastly with regards to interaction of teachers' PCK components, a different between planning and practicing was found because of the characteristics of gifted students and enrichment curriculum.

In the other studies conducted by Kınık, Rakunt and Öztekin (2018) investigated novice and expert geography teachers' CK and PCK about sustainable development within the framework of Magnusson et al. (1999) PCK model. Data were collected from one expert teacher who had 25 years of experience and one novice with one year of teaching experience via interviews and analyzed inductively. The study findings represented that teachers had partial CK as well as PCK regarding SD. Moreover teachers showed differences when they were asked about objectives in geography curriculum and what SD was about. For example expert teacher defined SD depending on only environmental dimension while novice teacher included all three dimensions of SD which are; environmental, economic and social. In addition teachers indicated they would use mainly the textbook as a source while teaching SD and they stated brainstorming, six thinking hats method, documentaries and presentation were the techniques they use in their instructions. According to the assessment strategies, teachers pointed out that they assess students' knowledge regarding SD based on the curriculum and regulations.

2.3. Studies related to Ecosystem Knowledge and Understanding

This part included previous studies that conducted to examine students' and teachers' knowledge and understanding as well as misconceptions and difficulties regarding ecological concepts, such as food chain, food web, population etc. (e.g. Adeniyi, 1985; Eliam, 2002; Grotzer & Baska, 2003; Griffiths, & Grant, 1985; Gallegos, Jerezano, & Flores, 1994; Hogan, 2000; Jin et al., 2019; Martín-Gámez, Acebal & Prieto, 2018; Munson, 1994; Webb & Bolt, 1990; Çetin, Ertepınar & Geban, 2015; Çokadar & Yılmaz, 2009; Özkan, Tekkaya & Geban, 2004).Some of these studies determined individuals' misconceptions and others tried to eliminate those misconceptions by using different teaching strategies.

Adeniyi (1985) studied with junior secondary school Nigerian students to examine their misconceptions and the sources of these misconceptions on ecological concepts. For data gathering purposes classroom observations, essay test answers and clinical interviews were used. The findings showed that students held some misconceptions on ecological concepts like; for example, they believed that the highest energy would be at the top of a food chain for the reason that the energy was compiled up the chain, that traits develop since they are parts of a predetermined plan and that traits passed on by the bigger and stronger organisms replacing the smaller and weaker ones.

In their study, based on identification of learning hierarchy and related misconceptions, Griffiths and Grant (1985) investigated high school students' understanding of food webs. Data gathered from 200 10^{th} graders. They found out that students held some misconceptions on food web. For example they believed that a change in one population will only affect another population if these are related as prey and predator, that a population placed higher on a food chain within a food web is predator of all populations, that a change in size of a prey population has no effect on its predator population, that if the size of one population in a food web is altered, all other populations in the web will be altered in the same way and that organisms in a population are important only to those other organisms on which it preys for food sources.

Webb and Boltt (1990) investigated the ability of high school and university students to answer questions related to relationships inside the food webs. In total of 162 students age of 15 (N=54), senior high school students aged 17 (N=54) and junior zoology class university students (N=54) participated in the study who were given worksheets and questionnaires which also had free-response format. Results of the study showed no statistically significant difference in the number of correct answers between the three age groups. It was also represented that if questions were simple enough to be answered based on food chain concept, students could predict the possible results of a change in one population. On the other hand almost all of the pupils and first year university students gave incomplete answers when asked about the effect of a change in numbers of one population on another. For example participants selected one of the alternative pathways until they reached the population which the question was based on. Thus study suggested that clear conceptual understanding of food webs should be provided at school level in order to prevent the misconceptions. Misconceptions occurred in this study were about the proximity of populations in the food web.

In one another early study by Barman and Mayer (1994) investigated the high school students' concepts related to food chains and food webs. They have studied with 32 students and used an interview protocol. At the end of the analysis of the interview data, Barman and Mayer revealed that students provided a basic and unexperienced description of the food chain and food web concepts. Moreover they have demonstrated that students also held some alternative conceptions about these topics. In the study 11 high-school biology text book were investigated by the researchers and they have revealed that the text-book authors assumed that students knew the specific connections of terms and generalizations about food relationships. Therefore Barman and Mayer suggested that the text-books should provide students with more details related to the possible interactions in a food web.

In his study where Munson (1994) identified and summarized the key ecological concepts and related misconceptions, implication of misconceptions were listed. In the study Munson constructed tables for the 20 most important concepts in ecology, scientific conceptions and misconceptions on food web, ecological adaptation, carrying capacity, the ecosystem and niche based on previous research studies. He concluded that having misconceptions on ecosystem arises serious problems for environmental educators and they need to provide their students with experiences which encourage them to avoid their misconceptions.

Gallegos, Jerezano and Flores (1994) studied with 506 students as 249 fourth grade, 141 fifth grade and 116 sixth grade students to investigate the prey-predator relations and the preconceptions held by them on the food chain construction. A questionnaire which included three parts was developed and used only once. The first task examined the concept of classifying herbivorous and carnivorous animals as taught in the third grade. The second task included the problems related to different prey and predator relations. The third task assessed the ability of students' drawing three food chains in different ecological contexts. The findings of the study presented the preconceptions of children were dependent on their perceptions of animals' size and ferocity. To illustrate students thought that "animals are carnivorous if they are big and ferocious" (p.268) and that "animals are herbivorous if they are passive or frequently smaller than the carnivorous animals" (p.268) as their preconceptions. Moreover it was indicated that these preconceptions affected students' selection of level of predators while constructing a food chain. The study suggested that the food chains must be taught as an interactive population involved in an ecological context instead of teaching it as a simple set of distinct organisms.

Leach et al. (1995, 1996a, 1996b) examined 200 children's, whose ages between 5 and 16, ecological understandings in the north of England. Five diagnostic probes called "Apple", "Video", "Community", "Scene" and "Eat" were designed and administered by interviews and paper-and-pencil tasks to investigate children's thinking about key ecological ideas. In the Apple probe, students were shown a picture of one colored apple in an apple tree and asked about the germ theory of decay. In the Video probe, students were provided with time-lapse video photography of a bowl of fruit that was decaying over one month and asked about the possible future alterations on the fruits. In the Community probe, a large colored illustration was presented to students and students were asked to detect a group of six different organisms. In the Scene probe, students were asked to identify a group of organisms for a specific location in a large colored photo of a woodland scene with a river, some grassland and 40 organisms. Then students were asked to select a primary consumer, a secondary consumer and a producer based on organisms' need and numbers. In the final probe; Eat, a picture with a line drawing of a large region that was composed of fields, mountains and woodlands and students were asked to predict the effects of changing the population of different species at different trophic levels in the food web. Audiotaped interviews and written answers of students to the probes were analyzed qualitatively via coding and examined for age-related patterns. Findings of the study showed that there was a little evidence of 16-year-old pupils' differentiating matter and energy flow in ecosystems. Moreover it was presented in the study that all of the participants did not use conservation of matter concept in ecosystems so students held some misconceptions like plants' biomass coming from solid substances like soil rather than atmospheric gas and water. In addition none of the pupils used process of respiration while explaining the cycling of mater and the flow of energy in ecosystems. However, they had information about the role of micro-organisms in decay even though some five-year-old pupils did not consider germs as living things. According to students' ages, changes in students' biological reasoning were categorized as changes in knowledge of phenomena, changes in ontology and epistemological changes. There were some ontological shifts in students' thinking regarding the concepts of cycles of matter including not only solids and liquids but also gases like air and considering energy as a biological concept instead of as a substance with a mass. Similarly there were some differences observed in epistemological explanations like the use of food webs. Researchers indicated that pupils see food web as linear causal mechanism with individual organisms rather than a deductive-nomological model including population of organisms.

Bailey and Watson (1998) were among the ones who studied on examining the ecological understandings of 100 junior pupils (ages between 7 and 11) as a pilot study.

Half of the students received a traditional lesson on habitat studies while the other half received a strategy based on drama/role play input. An active learning strategy called the Ecogame was adapted and used to develop basic ecological understanding in pupils. One class within each school got one session for playing the Ecogame, which requires students to gather data on cards representing their population, in order to test the Ecogame approach (drama/role play) against traditional approach. Students' understanding of ecology was assessed with a self-completion structured questionnaire including questions related to plant growth, decay, food chains, populations and pyramids of numbers, dynamic equilibrium, feeding relationships, transfer of matters and adaptation (p. 146). The results of the study showed that the scores of the students who play the Ecogame were 47% higher than the others who had a traditional lesson. For example there was a strong difference in students' understanding of the concept of population dynamics. The ones who played the Ecogame noticed that with a change in one organism, the populations of other organisms might have been affected since they saw gaining cards which represented their body substance in the game. Therefore researcher pointed out that in turn, the idea of cards leads to the prey and predator relationship which can support the concept of population dynamics.

In Hogan's study (2000), 52 students' system reasoning regarding food web perturbations and pollutant effects inside of an ecosystem were assessed. Participants constructed, observed and manipulated mini-ecosystems for a month and they were administered an analytic paper-and-pencil task as well as interviews before and after their project. The findings of the study demonstrated that students used mostly one-way linear reasoning for population dynamics indicating drawing arrows upward in a linear fashion from the bottom of the food web in response to perturbations within a food web instead of two-way or cyclic so they had deficit in models of patterns of relationships and reciprocal effects in ecosystems. However, in one of the questions which targeted a perturbation at the herbivore level, the most two-way linear responses were observed in which students followed the lines from the herbivores and went up and down at the trophic levels. On the other hand when students were asked what happens when hawks originally decreased, one student answered as more snakes and more mice then more hawks as a cyclic feedback. Moreover it was observed that some students only mentioned direct contacts of different pollutants with organisms rather than indirect effects. Therefore it was concluded that students had lack of knowledge of patterns of systems interactions and held misconceptions in systems reasoning in ecology because in both written tests and interviews, students mostly pointed out that the populations of prey would increase if predators decreased. The misconceptions identified in the study were those the students consider food webs in terms of individual rather than interconnected food chains, and that they concentrate on direct instead of indirect impacts of perturbations.

Eilam (2002) studied with 4 ninth grade students to investigate their learning difficulties in learning food chains in ecology. There were two separate classes as a control group and experimental group in which students were exposed to less hours of traditional lessons and carried out an inquiry task on ecology issues. In experimental group students integrated with a special curriculum to help students' involvement in a self-regulated process of inquiry. Data collected via questionnaires administered before and after process as well as video recordings of experimental classroom. The results of the study indicated a development in students' understanding of ecological concepts, mental improvement in the inquiry and understandings of complex relations as well as processes in experimental group students who actively involved in activities in the classroom. On the contrary mostly in control group, it was observed that students had lack of macro level knowledge in feeding relations as they consider abiotic phase as part of food chain and decomposers as feeding only on the last part of the chain. Similarly in micro level of feeding relations deficits were evident in understanding dynamic concept of molecular motion and molecules' breaking down and being rebuilt. Thus it was suggested that it was important to implement knowledge of cognitive research regarding learning process in schools.

Grotzer and Basca (2003) designed an intervention study to teach eight and nine year old students the concepts regarding ecosystem. They claimed that students had difficulty in understanding ecosystem concepts. Three lesson conditions were provided to students; one activities with discussion, activities only and no activities. Grotzer and Basca aimed to infuse these teacher-taught lessons into third graders. Ten students from each class were pre and post interviewed to reveal their understanding of ecosystem concepts. As a result the study demonstrated that students who participated in both activities involved lessons showed deeper understanding of the connectedness within ecosystems. The findings of pre-interviews showed that there was no significant difference between all three groups before the intervention regarding the connections between organisms in a forest or pond ecosystem. Moreover the connection types that students addressed were mostly one-step linear level like “The water insects eat green plants”. Yet only eight students stated a two-way connection regarding prey and predator relationships such as “If foxes disappear, mice could live more.” Therefore it was stated that students still consider food webs being focused on individual members instead of population issues of balance and flux. According to the pre-interview results regarding the nature of decay and matter recycling, there was no significant difference between all three groups. Most students identified the alterations that would occur in the dead plant at the level of appearance like “It will look wrinkled”. Only seven students described the changes in the structural-micro level like “It turns into soil”. However, two students touched upon the matter recycling by saying “It turns into soil which is needed for new plants to grow”. After interventions, post-interview findings indicated that although the students who received one activity with discussions showed a significant difference from those who had only one activity with no discussion and no activity class, it did not do enough for developing a better understanding of cyclic causal structure. Nevertheless, it was stated in the study that the combination of carefully designed activities with explicit discussions regarding causal structures and the nature of causality might be helpful in understanding connections between organisms and the nature of decay. Therefore the results recommended that it is significant to teach students the way to structure ecosystem concepts in addition to only transferring ecosystem knowledge.

Helldén and his colleagues conducted a series of study to uncover individuals' understanding of ecology or ecological process (1995, 1998, 2003, 2004, and 2005). For instance, Helldén (2004) studied with 24 Swedish students whose ages varying between 9 and 15 for 6 years. In this longitudinal study, students were interviewed 11 times, to determine their understanding of ecological processes. Students' conceptions of plants' life, decomposition of leaves and the role of flowers were examined. In order to examine students' ideas on plants' life, they grew plants in sealed transparent boxes together with Helldén. Then she asked questions like “what do you think that plants need to be able to grow in that box?" For decomposition interviews, he asked "What do you think will happen to the leaves on the ground in the fall?" And for the role of flowers in plant reproduction questions, he asked "Why do flowers have color?" By the time students were 15 and 19, Helldén got students listen to their answers when they were 11 and 15 in the second interviews after 6 years. Then he also asked students to express any development of understanding they realized by the time. According to the answers of the students, concept maps were developed and used as part of the data analysis. Ausubel's (1978) theory of meaningful learning principles were used in analyzing the interviews. The findings of the interviews on plants' life provide three categories of students depending on how they describe the plants' oxygen, carbon dioxide and air intake such as alternative ideas on the role of oxygen and air, limited understanding of the role of oxygen and carbon dioxide and a more complete understanding of the cycles in the box. Four of the students having alternative ideas on the role of air and oxygen thought that oxygen and air came from soil so they consider soil provides different supports for plants' life. And 10 students in fist interviews pointed out that the plants can live in the box since they need so little oxygen or that air or oxygen would always exist due to water cycle. 15 years of age, only 6 students in this category mentioned that the plants got their oxygen through their production in sealed box. In limited understanding of the role of oxygen and carbon dioxide category, students were aware of carbon dioxide and oxygen transformation but they were not able to indicate where carbon dioxide came from. Only one of the students could use the concept of dew being a part of water cycle in her description in her interviews for this category. Then within a more complete understanding of the cycles in the box category, 7 students at the age of 15 demonstrated a more or less complete understanding of the relationships between carbon dioxide and oxygen in the sealed box by mentioning cycle itself but most of them used a scientifically incorrect statement as carbon dioxide is transformed to oxygen instead of transmutation as a chemical reaction. When it comes to students' ideas on decomposition of leaves, students were also grouped under three categories as no organisms eating the leaf, towards a process with organisms involved and organisms involved in decomposition. Six students described a process without organisms in all interviews. Instead some of them indicated physical factors, age and fragmentations. Consequently, nine students being under the category of towards a process with organisms involved, those students started to indicate that leaves were eaten by organisms and turned into soil towards the ages of 13 and 15. Nevertheless five students in all three interviews talked about organism' feeding on leaves. Some of them mentioned Protozoa, invertebrates, fungi and bacteria as organisms but none of the students touched upon the fact that matter is conserved except one. Lastly for students' ideas about the role of the flower students were put under four categories as anthropomorphic and human centered ideas, ideas about plants' getting protection and resources, ideas about pollination and seed dispersal and ideas involving a more scientific explanation for pollination. Three students argued that the role of flowers was to make them more beautiful or to be used as decorations in the table during all interviews so they were categorized under anthropomorphic and human centered ideas group. Whereas three students thought that flowers provide protection and resources like being able to get nourishment from the wasp. 12 students at the age of 15 stated how pollen or seeds are transported by insects and dropped to the soil where a new plant would grow. In the last category of students named towards a scientific explanation for pollination at the age of 15, despite the fact that students' mentioning some human-centered ideas in previous interviews, at the age of 15 students in this category used scientific terminology as fertilization thorough the carriage of the pollen via wasps from one flower to the next flowers' stamen. In order to form a new embryo. Moreover when students were asked to reflect on their previous interviews, almost all students appreciated how much they learned about ecological processes both in school and out of school contexts. As a result, Helldén concluded that students developed, over 6 years, their understanding of ecological processes such as conditions for life, decomposition, the role of flower in plant reproduction (Helldén, 2004).

Jordan, Gray and Demeter (2009) investigated understanding of ecological processes using aquaria as a model closed system in a science classroom. They used worksheets completed by 45 seventh grade students during a general biology class to identify students' understandings and naïve ideas about ecosystems and cycles. Jordan et al. asked students to answer three questions including drawing of a system and possible interactions in an aquarium. When students were asked to define an ecosystem, some of the students only defined it as a place where everything lives, some only mentioned living and non-living things being a part of an ecosystem and sonly 24% of them gave sophisticated answers including both the interconnectedness of living and non-living things and the specific roles of living things; niche concept.   Then students were asked to draw a diagram to show the interactions in the fish tank. All students indicted at least one interaction between both visible and invisible items by using arrows. Lastly when students were asked whether the nitrification process is a system or not, 59% percent of students considered the process as a system. They have concluded that students' understanding of ecosystem concepts like systems and cycles may be limited by their combination of ideas. Therefore Jordan et al. suggested instructors having a sample system such as aquarium and developing a way of thinking clearly about systems to increase understanding of students regarding ecological concepts.

Differently from other studies conducted by students, Beals, Krall and Wymer (2012) examined 53 in-service elementary and middle school teachers' understanding of some basic concepts about energy flow through an ecosystem. They conducted a descriptive study including a multiple-choice instrument including non-scientific concepts as well. At the end of the study they found out that most of the teachers had an inadequate understanding of key-standards-based science concepts regarding energy flow through an ecosystem. Although they were expected to teach these concepts at the schools. Moreover in the study it was indicated that the students' answers from previous studies showed similarities with the teachers' answers. They have concluded that quality professional development can help teachers to develop their understanding of important concepts associated with the energy flow through an ecosystem.

Wernecke et al. (2018) proposed an instructional model combining two theories; learning through depictive representations and learning from errors based on negative knowledge theory in order to promote students' conceptual knowledge of energy. The study involved an intervention with pre-post design and 304 ninth grade students in three experimental groups. After pretest, the intervention prepared to present energy flow in ecosystems were applied and showed an energy flow diagram composed of a depiction of the energy transfer processes in an ecosystem which cannot be depicted directly. Students in Group 1 were asked to identify and explain the error and explain the energy flow as provided with an incorrect diagram without the error encircled.

Student in Group 2 were asked to explain the error and energy flow since they have shown an incorrect diagram with the error encircled. Students in Group 3 were asked to only explain the energy flow because they have been presented a correct diagram. Outcomes of the study indicated that providing students with the incorrect representation where the error encircled did not lead to any knowledge gain compared to the use of the same material without errors being encircled. However, it was also indicated that learning from errors fostered conceptual knowledge of energy more effectively than learning with a correct diagram since students had to identify the error in energy flow and explain it. It was suggested to provide students with an explanation and discussion of correct and incorrect diagrams as an important step.

Preston (2018) investigated the ways students interpret a simple food web diagram and its impact on elementary school students' understanding of the condensed biology concepts like reading a simple food web diagram. The data were gathered in three steps. First step was showing the toys; a bird, a snail and an artificial plant in order to test prior knowledge of students. In the second step, a visual-only food web diagram was shown to the students in order to test the importance of texts. As the third step, students were presented a food web with labels and text naming the organisms. The findings of the study revealed that students had difficulties of reading the food web diagram as they could not make sense of where to start reading, understanding arrow meaning and biochemical processes happening at the individual organism level and ecological processes at population level.

In a recent study Jin et al. (2019) examined how 596 secondary school students analyze and explain the interdependent relationships in an ecosystem and human's effect on these relationships. In the study a learning progression (LP) for system thinking in ecosystems was developed and used to measure students' performance. In order to develop and validate LP, students were administered an assessment which focused on students' practice of giving explanations about interdependent relationships in ecosystems and human effects on those relationships. Outcomes of the study showed performance gaps for students with low socioeconomic statues (SES) and those from urban schools. However, there were no performance gaps found between students who were traditionally under-served such as female students and students who enrolled in rural schools.

2.4.Studies conducted in Turkey

Researchers in Turkey also examined individual's understanding of ecological topics (e.g., Özkan, Tekkaya & Geban, 2004; Çokadar & Yılmaz, 2009; Soylu, 2006). For example, Özkan et al., (2004), investigated the impact of conceptual-change-texts-oriented teaching on seventh grade students (N=58 students)' understanding of ecological concepts. One group of students (28 students) taught by conceptual-change-texts-oriented instruction while the other group (30 students) received a traditional one. Researchers used interview protocols as well as an ecosystem concept test including 21 items developed by researchers. Researchers mainly aimed to investigate whether conceptual-change-texts-oriented instruction was helpful for eliminating students' misconceptions related to energy and energy flow on ecosystem, basic ecological processes, feeding relations in food chains on ecological concepts or not. Özkan et al. concluded that conceptual-change-texts-oriented instruction provided a significantly better understanding and elimination of misconceptions that students held on the concept of ecology.

Çokadar and Yılmaz (2009) conducted a study in order to examine the impact of creative drama-based instruction on seventh graders' science achievements in the ecology and matter cycles unit as well as their attitudes toward science in Turkey. To assess students' achievements, they have developed and used an ecological concept test to 45 students before and after treatment. In the study 45 students were in two classes as one of them being control and the other experimental. Çokadar and Yılmaz concluded that there was a statistically significant difference between groups in favor of experimental group after treatment with respect to achievement scores and median of attitudes toward science.

Soylu (2006) examined the effect of gender and reasoning ability of 8th grade students in the concept of ecology as well as their attitudes towards science. Data were collected by use of the Test of Ecology Concept (TEC), the Attitude Scale toward Science (ASTS) and the Test of Logical Thinking (TOLT). Findings of the study revealed that students had misconceptions regarding ecosystem, population, decomposers, food chain, food web, energy pyramid and energy flow. Moreover it a significant gender difference in favor of girls was founded based on students' understanding of ecological concepts and attitude towards science.

Çetin et al., (2015) investigated the impacts of conceptual change text-based instruction with ninth grade students. They investigated 82 students in a public high school in Turkey. In the study, they had an experimental and a control group in two separate classes. The control group received traditional instruction while the experimental group received conceptual change texts-based instruction. The treatment was given more than five weeks in a quasi-experimental design. After the treatment students have taken Ecology Concept Test, Attitude Scale towards Biology and Attitude Scale towards Environment. The results showed that the conceptual change texts-based teaching was more effective than the traditional one regarding ecological concepts. However, they did not find any significant effect of the treatment on the participants' attitudes toward biology and environment.

In a recent study, Ahi and Balcı (2018) investigated the knowledge of 29 pre-school children, whose ages ranged between four and five, regarding the concepts of forest and deforestation. Data source was a standardized open-ended interview. The results of the study revealed that students had lack of knowledge of forest and deforestation concepts. In addition, only one child spoke about the negative effect of deforestation on the atmosphere and only one child indicated landslides even though many of them indicated the negative effects of deforestation on animals. Moreover, as for the reason of deforestation children stated human based impacts such as heating, paper production and construction materials being used. Additionally, there was no correlation found between students' ages, gender and the concepts of forest and deforestation. It was suggested that ecological concepts should be implemented in pre-school lessons to promote environmental education with the help of outdoors based on life experiences.

2.5. Summary of Literature Review

In this chapter the related literature of PCK and ecosystem knowledge and understanding were broadly reviewed. Firstly the studies related to PCK were revealed in two parts as the ones done with pre-service teachers and those with in-service teachers. The studies including pre-service teachers were mostly qualitative studies. Researchers conducted these studies by using interview questions and observation protocols. Results have revealed that pre-service teachers need more time to gain experience and develop their PCK. Therefore in order to seek out the experienced teachers' PCK, researchers have done a serious investigations with them, too. In the second part studies conducted with in-service teachers were revealed. Researchers similarly used interview questions and observation protocol as well as some of them developed and analyzed a new instrument for examining experienced teachers' PCK. Most of the studies detected even in-service teachers need to develop their PCK since they might have limited knowledge about some components of PCK. Lastly since in the current study, the ecosystem topic was taken into consideration, previous studies related to ecosystem knowledge and understanding were broadly reviewed. The review showed that in most of the studies, researchers studied with students to test their knowledge, misconceptions or understating with respect to ecosystem related concepts. Hence one study was conducted with teachers to see their content knowledge on ecology concept.

In the current study, in-service science teachers' TSPCK regarding ecosystem concept was demonstrated in the light of information provided with the previous studies in the literature. In the next chapter, which method used to evaluate experienced science teachers' PCK on ecosystem concept and how the current study has done are demonstrated.

CHAPTER 3

METHODOLOGY

This study aimed to investigate experienced science teachers' topic-specific PCK (TSPCK) in relation to students' understanding regarding the concept of ecosystem. In this chapter overall research design, subjects of the study, the procedures of collecting data and the data analysis conducted to do the study are represented.

3.1. Design of the Study

In this study, a qualitative study design was used because researcher's goal was to examine science teachers' TSPCK regarding the concept of ecosystem. Therefore researcher used pre-interview questions and classroom observation notes to examine topic-specific PCK of science teachers.

The notes from interviews and observations were coded both inductively and deductively. Moreover researcher also took a photo during the classroom observation to enrich the description of the qualitative study. As a qualitative study, this study can be considered as a case study because two in-service science teachers from different schools were involved in this study. Therefore each of the participants provided a different case for the study as examples of phenomena. In this study, the cases can be identified as two science teachers teaching ecosystem topic. Hence the goal of the study was not comparing both teachers instead, was to examine topic-specific nature of PCK. Therefore two teachers were considered as a case.

3.2. Participant Selection

Since this study aimed at not making a generalization but getting a deeper understanding of two teachers as two different cases, nonprobability sampling was preferred for this study. For the study in order to reach participants purposive sampling was used. In PCK development having a real classroom experience is very important (Grossman, 1990). Moreover as the literature supported pre-service or beginning teachers have limited PCK (Abell, 2008; Lee et al., 2007; van Driel et al., 1998), in the study researcher preferred to study with experienced science teachers, having more than 5 years of experience (Akerson 2005; Borg et al. 2014; Arzi & White 2008; Gatbonton 2008).

The study conducted in two public schools in Ankara. The schools were in the same district and most of the demographic features (socio-economic status, the number of students etc.) were quite similar in two schools. Yet another issue for the participant selection was the topic of ecosystem's being placed in seventh grade (MNE, 2013). Therefore teachers who were currently teaching seventh graders needed to participate in the study. Moreover, as researcher should be present at the school especially for the pre-interview and observation to take notes, the participant teachers whose lesson hours aligned with the researcher's working schedule were chosen.

3.3. Participants of the Study

Two in-service science teachers participated in this study. Pseudonym names were used for each of the teachers. To illustrate, Ezgi represents the teacher in the Case 1 and Nilay represents the teacher in the Case 2. Ezgi had a class of 15 students whereas Nilay had 19 students in hers in the study. Each of two teachers' demographic information was given in the Table 3.1.

Table 3. 1. *Teachers' Demographic Information*

Teachers	**Years of teaching experience**	**Years of teaching science**	**Other teaching experiences on**	**Years spent in current school**	**Grades taught**	**Bachelor's degree in**
Ezgi	15	9	High school physics	1	5, 7, 8	Physics Education
Nilay	24	15	High school chemistry	6	5, 6, 7	Chemistry Education

3.4. Data Collection Procedure

There are basically three ways to collect data in a qualitative study which are the interview questions, observation protocols and documents (Merriam, 2009). For example, participants can express themselves verbally in interviews instead of writing down their thoughts. Moreover observations lead researcher to have a chance to monitor participants in their real context. In order to get a deeper understanding of experienced science teachers' PCK regarding ecosystem topic, data collected by the use of interviews and observation notes. Data collection tools and related aspects for the study are shown in Table 3.2.

Table 3. 2. *Data Collection Tools and Related Aspects*

Data Collection Tools	**Related Aspect**	**Time**
Pre-interview questions regarding ecosystem Draw an Ecosystem Test Word Association Test Ecosystem Concept Map	Teachers' Content Knowledge	At the beginning of the study
Pre-interview questions regarding PCK	Orientation towards science Knowledge of curriculum Knowledge of students Knowledge of instruction Knowledge of assessment	At the beginning of the study
The ecological concept test	Knowledge of students' difficulties	At the beginning of the study
In-class observation notes	Orientation towards science Knowledge of curriculum Knowledge of students Knowledge of instruction Knowledge of assessment	During the study

Data were gathered from experienced science teachers who taught ecosystem topic to seventh graders in two public schools in Ankara. Data gathering procedure lasted over a month. In the next section data collection tools are demonstrated.

3.4.1. Interviews

In interviews researcher and participant find an opportunity to focus on questions (De Marrais, 2004) and have a rich conversation, the interview is the best way for a case study (Merriam, 2009). Therefore in this study researcher preferred to use semi-structured interview questions where the researcher could ask follow-up questions when needed. In this study two different types of interview questions were used to gather data; one for content knowledge and one for pedagogical content knowledge of teacher regarding the concept of ecosystem. These two different interviews are explained in the following section. As the researcher herself was the interviewer she was coded as “I” while for the teachers their pseudo names were used for coding.

3.4.1.1. Pre-interview Questions Regarding Ecosystem

These pre-interview questions were used to identify topic specific nature of teachers’ PCK regarding the concept of ecosystem. The questions were prepared by the researcher. Those questions were prepared with respect to related literature mentioned in the previous part and ecosystem topic in the curriculum by Ministry of National Education (2013). Several open-ended questions asked teachers in order to examine their understanding of ecosystem concepts and processes (see Appendix B). Moreover, word association test and drawings (i.e. a concept map, an ecosystem, a food chain, a food web and an energy pyramid) were used as data collection tools.

3.4.1.2. Pre-interview Questions Regarding PCK

Pre-interview questions were also used to identify teachers’ pedagogical content knowledge on ecosystem concepts prior to teaching. The questions were derived from Content Representations (CoRe) originally developed by Loughran et al. (2004) and translated into Turkish and adapted into chemistry topics by Aydın (2012). In the purpose of the study, researcher prepared the questions by adapting the questions to ecosystem concept after taking her permission (see Appendix E). Briefly, CoRe included questions for identifying each component of PCK; five questions for orientation towards science, ten questions for knowledge of curriculum, seven questions for knowledge of students, thirteen questions for knowledge of instruction and six questions for knowledge of assessment (see Appendix A). Teachers' knowledge of students was further assessed by asking them to predict their students' learning difficulties as well as possible misconceptions or 'what their students were most likely to select as the "most popular incorrect answers' (see Lucero et al., 2017). This step was conducted utilizing the ecological concept test developed by Özkan (2001). The ecological concept and originally included 21 questions. For the purpose of the study, only first tier including concept knowledge related to ecosystem, environment and energy in an ecosystem were selected and an open-ended item was added about food of a plant. After showing the test, teachers were asked to identify the questions that students may answer easily and the ones that students may have a hard time in answering. Interviews lasted about one hour for each teacher.

During the interviews, researcher paid attention to being polite and respectful towards participants. Before the voice records began, teachers were told the aim of the study and made sure that they were volunteered to participate in the study. All of the interviews were conducted in the public school where teachers were working. Therefore, researcher conducted the interviews when the teachers were available. After the interviews, researcher transcribed the voice records verbatim and prepared them for the analysis of data.

3.4.2. In-class Observation Notes

Since PCK is what teachers had in their minds (Abell, 2008), there is a need for observing the classroom for analyzing the pre-interview questions in the real context. Moreover although teachers expressed their PCK on pre-interviews, it can be changed depending on the context and students' needs (Şen, 2014). Hence, researcher observed the classroom while teachers were teaching ecosystem topic. During the observation researcher took notes and recorded the phenomena in the class.

For observation researcher did not prefer to use any prepared checklist or tables because they sometimes cause researcher to miss some important points happening in the classroom (Şen, 2014). Accordingly, researcher tried to take notes of events, the interaction between students and teachers as well as the teachers' behavior as much as she could. These notes were used to compare the pre-interview questions and written for each teacher under the findings chapter.

Researcher observed each class. Observations were conducted in teachers' real classroom environment. Overall observations took three hours. Ezgi was observed for 80 minutes which were a two-hour of class duration and Nilay was observed for 120 minutes which were a three-hour class duration. This difference between two observations occur according to teachers' methods used and activities. Observations were held during the ecosystem topic was taught in the class by the teachers. Researcher did not take any videos or voice records during observations as there was no permission to do so. However, researcher could take a photo of the blackboard in Ezgi's class since there were no students or teacher were involved in the picture.

Another important point was researcher stance in the classroom during observations (Merriam, 2009). In this study researcher position was a complete observer where the researcher did not participate any activities rather only made observations without effecting the way teachers taught in order not to change or affect the real classroom environment. Thus researcher sat a seat placed in back of the class and did not disrupt the lesson flow. During observation, researcher took field notes to code and analyze data afterwards for triangulation.

In this part the data collection tools and processes were revealed. In the following part the analysis of data are demonstrated.

3.5. Data Analysis Procedure

In the data analysis process researcher tried to understand the data and express it in a meaningful way (Merriam, 2009). In this study for three main research questions, different analyses were conducted. In the following section the analysis of data were explained in detail.

3.5.1. Content Knowledge Analysis

Schwab (1964) defined the subject matter knowledge as two types; substantive and syntactic content knowledge. “The substantive structure of a discipline is the organization of concepts, facts, principles, and theories, whereas syntactic structures are the rules of evidence and proof used to generate and justify knowledge claims in the discipline.” (Abell, 2007, p.1107). Syntactic knowledge is related to Nature of Science (Khalick & Boujaude, 1997). However, researcher did not use a Nature of Science knowledge test to identify syntactic knowledge. Hence in this study teachers’ content knowledge was analyzed as substantive content knowledge.

Substantive content knowledge is referring to basic terms regarding ecosystem, plants’ food and corresponding concepts in this study. There were 19 question in total asked teachers to identify their substantive content knowledge with respect to topic-specific nature of PCK (see Appendix B). In coding process, researcher the used procedure followed by Şen (2014). When participants’ answer was parallel to scientific definitions, their answer was categorized as sound understanding. However, if teachers had a lack of understanding or knowledge, their answer was labelled as partial understanding. On the other hand, teachers’ answer were put under the category of naïve understanding if their answers were not parallel with the scientific definitions or if their answer contained a misconception. In other respects, if teachers did not have any answers, they were put under no response category. Table 3.3. represents the scientific definitions or explanations of the concepts related to study.

Table 3. 3 *Scientific Definitions of the Ecosystem Topics and Concepts*

Concepts in ecology	Definitions	Source
System	A system is an entity that maintains its existence and functions as a whole through the interaction of its parts	Assaraf & Orion, 2005, p.519
Ecosystem	All the organisms in a community and the abiotic environment with which the organisms interact (both the abiotic and biotic components of the environment)	Weathers et. al., 2012
	The interacting system made up of all the living and nonliving objects in a specified volume of space. Living organisms interact with their environment, exchanging matter and energy The dynamics of ecosystems include two major processes: The recycling of chemical nutrients from the atmosphere and soil through producers, consumers, and decomposers back to the environment. The one-way flow of energy through an ecosystem, entering as sunlight, converted to chemical energy by producers, passed on to consumers, and exiting as heat.	Reece & Campbell, 2011
Species	A set of individuals that share certain characteristics and can interbreed	Reece & Campbell, 2011
	A group of populations whose members have the potential to interbreed in nature and produce viable, fertile offspring; they do not breed successfully with other populations	Darwin, 1975
Population	All of the member of one species that live in a particular geographical area A group of organisms of a same species have certain structural, functional and behavioral traits in common dynamic groups of organisms that adapt to changes in environmental conditions by changing their size, distribution genetic makeup	Reece & Campbell, 2011
Community	An assemblage of all the populations of organisms living close enough together for potential interaction and described by its species composition	Reece & Campbell, 2011

Table 3.3 *Continued*

Habitat	The place where an organism normally lives out its life Wide array of resources necessary to sustain growth & reproduction: proper climatic condition, food, water, shelter & place in an arrangement appropriate to the organism's need	Reece & Campbell, 2011 Smith & Smith, 2015
Ecological niche	Sum of an organism' use of the biotic and abiotic resources in its environment. A way of life that is unique to that species the organism's "profession, a kind of job description function or role	Reece & Campbell, 2011 Starr & Taggart, 1992
Biological diversity	Species richness; the number of species in a community and relative abundance; the proportional representation of a species in a community The variety of life', and refers collectively to variation at all levels of biological organization. Thus, one can, for example, speak equally of the biodiversity of some small or large part of Marion Island, of the island as a whole, of the islands of the Southern Ocean, of a continent or an ocean basin, or of the entire Earth.	Reece & Campbell, 2011 Gaston & Spicer, 1998
Producer	Autotrophs; organisms that can produce their own foods, make their own food through the process of photosynthesis, sustain themselves, Autotrophs are primary producers of all ecosystems support all other trophic levels. Photosynthesis is a complex series of chemical reactions during which light energy is converted to chemical energy-light energy is captured by chlorophyll molecules to boost the energy of electrons.	Reece & Campbell, 2011

Table 3.3 *Continued*

Consumer	Organisms that cannot produce their own food and depend on other organisms get the nutrients & energy by feeding either directly or indirectly on producers Herbivores Primary consumers, Plant eaters Rely on plant materials Carnivores Meat eaters rely on herbivores and carnivores for energy source, Distinguished as secondary consumers as tertiary consumers, so on. Omnivores Eat both plants & animals (Food habits of many omnivores vary with the seasons, stages in life cycle, and their size & growth rate.)	Reece & Campbell, 2011
Decomposer	Organisms that digest molecules in organic materials and convert them into inorganic forms which can be reused by producers responsible for completing and starting of the cycle of matter: basis of the material cycling in the ecosystem They feed on/extract energy from dead organisms Necessary for the long term survival of any community, Without them, elements- K, N, P- would accumulated indefinitely	Reece & Campbell, 2011
Food chain	The sequence of the food transfer up the tropic levels Energy passes from one organism to the next in a sequence of food chain Within an ecosystem, progressively less energy is therefore available at each trophic level	Reece & Campbell, 2011
Food web	Network of interconnecting food chains Ecosystem involves a range of choices for each organism Many alternative pathways are possible. No one organism lives entirely on another, the resources are shared. Organisms-populations-in a natural ecosystem are involved in a complex of many interconnected food chain Organisms-populations-in a natural ecosystem are involved in a complex of many interconnected food chain	Reece & Campbell, 2011

Table 3.3 *Continued*

Energy pyramid	A graphical representation of the relationship between different organisms in an ecosystem. It shows the flow of energy from producers to primary consumers to higher trophic levels. Only about 10% of the energy stored at each trophic level is available to the next level. The maximum number of trophic level in food chain is limited by the 2nd Law of Thermodynamics No transfer of energy is completely efficient and some energy is always dissipated to the environment as heat	Reece & Campbell, 2011

Moreover in order to examine teachers' conceptions regarding ecosystem, teachers were asked to say 12 worlds that come to their minds as free word association test (WAT) which has been used in many studies (Ad & Demirci, 2012; Aydın & Tasar, 2010; Bahar & Özatlı, 2003) to determine participants' cognitive structures and conceptual changes (Hovardas & Korfiatis, 2006). After getting their WAT scores, the answers of the teachers were analyzed in details with regards to basis of semantic relatedness (Atasoy, 2004). Then, these words were categorized using the principle of semantic relation as suggested in many studies (Daskolia et al., 2006; Kostova & Radoynovska, 2008; Kostova & Radoynovska, 2010).

In addition, teachers were asked to draw a concept map on ecosystem in order to get a visual representation of how teachers organized, associated and described the relationships in basic ecological concepts (Zak & Munson, 2008). The data first analyzed qualitatively in the light of a holistic and visual approach (Kinchin, 2000a, 2001; McClure et al., 1999; Williams, 1998), in order to compare participants' concept maps with another and identify structure, content as well as organization (Zak & Munson, 2008). Secondly the concept maps were analyzed with respect to various propositions they included (Yin et al., 2005; McClure et al., 1999; Zak & Munson, 2008). Each proposition was composed of three parts as the originating concept, the linking words and the linked concept (Zak & Munson, 2008).

Besides WAT and concept maps, teachers were asked to draw an ecosystem in order to collect teachers' thoughts, understanding and point of view (Kurt, 2013; Levin & Bus, 2003; Pridmore & Bendelow, 1995). In this regards participants were asked to draw an ecosystem example and explain it. After getting data, a rubric named The Draw-an-Ecosystem Test which was developed by Flowers et al. (2015, p.850) was used to analyze teachers' drawings. Table 3.4 shows an example used in Flowers et al.'s study and researcher in this study also applied this scoring table for analysis of teachers drawing of ecosystems.

Table 3. 4a. *Flowers et al.'s rubric for analyzing teachers' ecosystem drawings (Flowers et al., 2015, p.850)*

Drawing Factors	Not present	Present	Basic Interactions	Complex Interactions	Explicit Interactions
	0 point	1 point	2 points	3 points	4 points
	Drawing does not contain pictures or words of this factor.	Drawing contains pictures or words without any apparent interaction with this factor.	Drawing contains pictures or words interacting by only touching this factor.	Drawing contains pictures or words interacting by complex methods with this factor.	Drawing contains pictures or descriptions (labels or arrows) with deliberate emphasis placed on the interaction with this factor.

Table 3. 4b *Sample example from factors indicated by DET rubric (Flowers et al., 2015, p.850)*

Human*		Any humans	Human standing on bridge or ground	Human walking on bridge, climbing tree	
Biotic		Animals, trees, flowers, insects	Trees touching grass, animals on ground	Animal running on grass, bird pinching in tree	
Abiotic		Mountains, rivers, sun, clouds, rain	Water touching ground	Wind blowing leaves, rain pooling on ground	
Human Built or Designed*		Buildings, automobiles ,bridges, swing sets	House touching grass, car touching driveway	Smoke from chimney, car driving on road	

*= not detected in the study

Teachers' drawings of food chain, food web and energy pyramid were analyzed according to the empirical studies (Barman & Mayer, 1994; Beals et al., 2015; Özkan et al., 2004). Each drawing was qualitatively analyzed based on the propositions they included and the answer for questions "Was sunlight identified as the major energy source?", "Was energy transfer in food web and food chains demonstrated correctly?" and "Were relationships among propositions identified?" were looked for. All of the drawing of teachers were reproduced by the researcher based on participants' original figures because the quality of the original drawings. However, researcher kept the original drawings (for Ezgi's original drawings see Appendix C, for Nilay's drawings see Appendix D) but did not use in reporting the findings instead, the reproduced figures were shown to clarify the results.

3.5.2. PCK Analysis

In this study Magnusson et al. (1999) PCK model was used in analyzing science teachers' PCK. All five components which the model provided were taken into consideration in the study. In the following part each of the five components' analysis are represented in detail.

3.5.2.1. Orientation towards Science

Most of the researchers (Avraamidou, 2012; Friedrichsen & Dana, 2003) claimed that orientation component of Magnusson et al. (1999) model of PCK as problematic and they considered it as having lack of theoretical and empirical background (Friedrichsen & Dana, 2005, Friedrichsen et al., 2010). Therefore Friedrichsen et al. (2005) suggested a transformed method for teacher orientation. In this new approach, they indicated that teachers' beliefs about the goals of teaching science can form their orientations (Friedrichsen et al., 2005). Regarding this approach in order to determine teachers' orientations towards science, teachers' beliefs about the goals of teaching science were used in this study. Five questions were asked teacher in the pre-interviews with respect to identifying their orientations towards science. Moreover observation notes were used to triangulate the data gathered via interviews.

Teachers' goals of teaching science were explored in two dimensions as central and peripheral goals in this study, since the beliefs about goals of teaching science is more complicated than science educators assumed (Şen, 2014). Central goals refer to the goals that have a direct impact on teachers' practice whereas peripheral goals refers to the ones that have a little effect on teachers' practice.

Moreover according to Magnusson et al. (1999) beliefs about goals of teaching science are limited with subject matter goals. However, there are also affective domain goals and general schooling goals (Friedrichsen & Dana, 2005, Şen, 2014). Therefore after teachers' central and peripheral goals were identified their beliefs were categorized as affective domain goals, general schooling goals and subject matter goals (Friedrichsen & Dana, 2005). Schooling goals represent preparation of students to university. In other respects, affective goals focus on attitude towards science and self-confidence while subject matter goals consider on transfer of content knowledge to the learner (Friedrichsen & Dana, 2005).

3.5.2.2. Knowledge of Curriculum

There are two dimensions of knowledge of curriculum (Magnusson et al. 1999) which are knowledge of goals and objectives and knowledge of materials. In this study researcher examined teachers' knowledge of curriculum with regards to these two concepts. Knowledge of curriculum was identified by interviews and observations by the researcher. Questions for the interviews were prepared analyzing the related literature and teachers' answers were both analyzed deductively and inductively. All schools in Turkey have to follow the same curriculum prescribed by Ministry of National Education. In Table 3.4., the codes used for analyzing knowledge of curriculum and their sources and sample excerpts are represented.

Table 3. 5 *Codes for Knowledge of Curriculum*

Codes for Knowledge of Goals and Objectives	Source	Example
The placement of ecosystem topic in the curriculum	McComas, 2002, 2003, Cherrett, 1989	Ecosystem is in the 5th unit in seventh grade.

Table 3.5. *Continued*

Vertical curriculum	Clark, 2000; Magnusson et al., 1999	Ecosystem has no connections with other topics in the seventh grade.
Horizontal Curriculum	Brown, 1990; Kindfield, 1994; Lewis et al., 2000	Ecosystem topic has a related topic in the eighth grade.
Ecosystem objectives	McComas, 2002,2003 Cherrett, 1989	*7.5.1.1. Define and exemplify the concepts of ecosystem, species, habitat and population* (MNE, 20013, p.35).
Ranking the objectives based on importance	McComas, 2002,2003; Cherrett, 1989; Bailey & Watson, 1998	*7.5.2. Biodiversity 7.5.2.1. Inquire the importance of biodiversity for the natural life* (MNE, 20013, p.35).
Codes for Knowledge of Materials	**Source**	
Sources used by teacher	Magnusson et al., 1999; Shulman, 1986; Yarden & Cohen, 2009; McComas, 2002,2003	Textbook Blackboard Online educational platforms
Aim of using sources	Yarden & Cohen, 2009, McComas, 2002,2003	To provide students with permanent knowledge with visuals.

3.5.2.3. Knowledge of Students' Understanding

In this study teachers' knowledge of students' understanding was analyzed in two categories. One category was students' required knowledge for learning and the other category was knowledge of students' difficulties. Teachers' knowledge of students' understanding was determined with interviews. The responses were analyzed with respect to PCK and teaching ecosystem literature. Students needed to know basic concepts related to ecology such as living and non-living things (Vold & Buffett, 2008), organisms (Randler, 2008), environment and human relationships (McComas, 2002, McComas, 2003), energy concept (Sander et al., 2006; Vance et al., 1995) as well as matter (Vance et al., 1995) and phases of matter concepts (Sander et al., 2006). Teachers' knowledge of students' difficulties was identified by interviews as well as supported via classroom observations.

Analysis of students' difficulties based on previous literature revealed that students may have learning difficulties in ecology because of the words used (Bahar et al., 1999; Magro et al., 2002). Moreover Adeniyi (1985) students had difficulties in especially four concepts; ecosystem, habitat, community and population because students confuse the meanings of them. Students not only have difficulties in considering the biotic factors in an ecosystem as interconnected but they also tend to disregard the abiotic factors and their impacts on an ecosystem (Grotzer et al., 2010). They also confuse system with cycle or flow concepts (Doménech et al., 2007; Jin & Anderson, 2012; Lin & Hu, 2003). In addition, previous researches showed that students also held misconceptions on ecosystem topic (Adeniyi, 1985; Gallegos et al., 1994; Özkan, 2001). In Table 3.6., students' misconceptions, sources of misconceptions, identification as well as remediation of them are represented.

Table 3. 6 Students' *Misconceptions Related to Basic Ecological Concepts*

Dimensions	Examples
Misconceptions	Plants are the only living thing which can produce food on their own (Adeniyi, 1985) Small animals are producers because they serve food for bigger animals (Adeniyi, 1985) Environment is a place where people live since it is a place that people must keep clean (Özkan, 2001) The source of plant biomass is dense material in soil and not air, which they consider as weightless (Ebert-Mayet al. 1997).
Misconceptions	Plants form the beginning of a food chain because they are small and they cannot eat animals (Gallegos et al., 1994) Bacteria are the source of energy in a food chain (Eilam, 2002) "grass → cow → milk → man" can be an example food chain because cow produces milk as a producer for man (Özkan, 2001) The interpretation of food web dynamics in terms of a food chain (Griffiths & Grant, 1985)
Misconceptions	The sun gives energy to plants before consumers take energy from plants (Adeniyi, 1985) The species at the top of a food chain have the most energy as energy accumulates up to the chain (Munson, 1994) Among lion, rabbit and man, man is the primary consumer because he consumes everything (Özkan, 2001) Plants get their energy from soil, air, sun, wind, water and other animals (Anderson, Sheldon & Dubay, 1990; Bell,1985, Eisen & Stavy, 1988; Smith & Anderson, 1984)
Misconceptions	In an energy pyramid, man occupies the base because he eats both animals and plants (Özkan, 2001) The number of producers must be more than that herbivores so that herbivores can be satisfied with enough food to eat (Adeniyi, 1985)
Sources of Misconception	Students' preconception of ferocity and size concerning producer and consumer (Özkan,2001) Usage of everyday language (Ben, 1985; Gilbert et al.,1982) Textbooks (Yip, 1998) Teachers (Sanders, 1993; Yip, 1998).

5.2.4. Knowledge of Instructional Strategies

In this study teachers' knowledge of instructional strategies were analyzed in two parts as knowledge of subject specific strategies and knowledge of topic specific strategies (Şen, 2014) in ecosystem. The answers of teachers for analyzing their knowledge of instruction gathered via interviews and class observations. Knowledge of subject specific strategies is in line with orientation towards science and involves the general instructional knowledge of science teaching whereas knowledge of topic specific strategies involves the strategies used for specific science topics (Magnusson et al., 1999). Moreover knowledge of topic specific strategies include two dimensions as knowledge of representations and knowledge of activities (Şen, 2014). In Table 3.6., some examples for knowledge of representations and activities are represented.

Table 3. 7. *Examples of Representations and Activities related to ecosystem*

Representations	**Examples**	**Source**
Visuals	Teachers can use branching, radiating and cycling diagrams for students to understand the connectedness in a food web system.	Grotzer, 1989,1993
	Teachers show pictures, slides, models and preserved animals.	Killermann, 1998
Videos	Teachers can show a time-lapse video for students to understand the mechanism and nature of decay or time delay.	Leach et al., 1992
Models	Students can build a model on a computer: a mussel/ a population /an ecosystem.	Westra et al., 2008
Subject Specific Strategies	**Examples**	**Source**
Problem based learning (PBL)	Teachers can possess a problem on habitat loss so that students can remember concepts of habitat and create alternative solutions for ecological problems.	Lewinsohn et al., 2014
Questioning	Teachers either can raise questions on ecosystem to students or ask students to bring their own questions to the class and discuss about them in the class so that students can discuss on ecology concept.	D'Avanzo, 2009

Table 3. 7. *Continued*

Experimentation	Simulated experiments; students can determine food webs and for observing population trends by using computers in analyzing,	Finn et al., 2002
	Field experiments; students can do plant fertilization experiments in school grounds to collect data,	
	Laboratory experiments; students can experiment ecology-in-a-bottle to evaluate ecological processes.	
Inquiry	Students can create a live model of ecosystem in an inquiry-based learning environment, both in class and laboratory	Eilam, 2012
	Students can create an aquaria model as a closed system	Jordan et al., 2009
Role play	Students take on roles of a living thing in a habitat then compete to survive through cards written eat or eaten by on them in a game called the Ecogame (Bailey, 1994).	Bailey & Watson 1998
	Teacher can use creative drama activities in which students can be a person walking in a park to teach living and non-living things in an ecosystem.	Çokadar & Yılmaz, 2010
Field trip	Teachers can use a field trip lesson to go to mountains or a park to promote knowledge of ecosystems encountered on the trip.	O'Neal & Skelton, 1994 Farmer et al., 2007

3.5.2.5. Knowledge of Assessment

Teachers' knowledge of assessment was determined via interview questions and observations in class. In this study knowledge of assessment analyzed in two categories as suggested by Magnusson et al. (1999). One of them was knowledge of dimensions of science learning which shows what topics are important and be should be assessed. Although it is important to assess students' content knowledge (Lankford, 2010; Magnusson et al., 1999), it is also important to assess interdisciplinary themes (Magnusson et al., 1999), science process skills (Magnusson et al., 1999; Mıhlandız et al., 2010), also nature of science (Hanuscin et al., 2010; Magnusson et al., 1999), and problem solving skills (Magnusson et al., 1999).

The other category for analyzing teachers' knowledge of assessment was knowledge of methods which points out various ways to assess (Magnusson et al., 1999). There are also two ways of assessing students; formative and summative assessments (Earle, 2014). With the help of formative assessments, teachers can assess students' understanding at the beginning of the lesson, in the middle of the lesson or at the end of the lesson. These assessments are generally interactive and done verbally. However, summative assessments allow students to assess their students' understanding at the end of the unit. Moreover these assessments are written tests unlike formative assessments.

In this study, as Şen suggested (2014), if teachers used both traditional and methods in formative and summative assessments, they were described as having a robust understandings of knowledge of methods. On the other hand, if teachers only used summative or formative assessments then they were reported to own partial understanding of knowledge of methods. Similarly, if teachers preferred using only traditional methods in summative or formative assessments, they were also described as having a partial understanding about knowledge of assessment. Researcher in this study could only observe formative assessments since teacher planned to do summative assessment at the end of the unit. Therefore, summative assessment knowledge of teachers were gathered by pre-interviews. In Table 3.7., some examples for summative and formative assessment techniques presented in the literature are represented.

Table 3. 8 *Examples of Summative and Formative Assessment Techniques*

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

3.6. Trustworthiness of the Study

In a qualitative study, researchers care about the participants as they interact with them unlike a quantitative study researcher care about the variables. Therefore in qualitative studies the terms credibility, transferability, dependability and confirmability were used (Lincoln & Guba, 1985) rather than validity and reliability (Merriam, 2009). In the following part credibility and transferability of this study are revealed.

3.6.1. Credibility of the study

For qualitative studies credibility means validity of a study (Lincoln & Guba, 1985). In this study in order to increase the credibility researcher used triangulation method as suggested by Creswell (2007). As Merriam (2009) indicates that triangulation occurs by using multiple methods, sources of data and theories to approve the data gathered in research. Therefore in this study researcher firstly used interviews and got teachers' answers recorded. Then she participated in real classroom context and took observation notes. The notes from class observations were used to triangulate the data gathered through interviews. However, since in this study Magnusson et al. (1999) model was used in explaining PCK, there were no other models used as a multiple theory. Moreover in order to get participants' feedback on the data to prevent any inconsistencies and biases as suggested by Meriam (2009), researcher mailed the transcribed data to participants. However, since respondents did not give any feedback, there were no approval of their speech or actions. In addition in order to increase credibility of the study researcher paid attention to adequate engagement in data collection (Merriam, 2009). Researcher firstly met participants and talked about the aim of the study. While conducting interviews or making observations, researcher had a chance to gather more information about the participants as well as the school context which were helpful for a thick description in a qualitative study.

3.6.2. Transferability

For qualitative studies transferability means external validity. It shows whether or not the findings of a study can be applied to the other studies (Merriam, 2009). Although a generalization of the findings is not a goal of qualitative studies, the results of the study still can be useful for other studies if they share a similar research question or context. To illustrate as Şen (2014) indicated, other researchers studying PCK of in-service teachers can benefit from this study since this study conducted with experienced science teachers to identify their PCK. Moreover in order to increase the transferability of the study researcher aimed to use a thick description as suggested by Merriam (2009). In addition two different science teachers who were working in different public schools were participated in the study. Therefore researcher tried to increase the variation of sample (Merriam, 2009).

3.6.3. Dependability

Dependability for qualitative research studies refers to reliability. Nonetheless, since this study includes humans as participants, replication of this study is not possible. Hence, replication the study is not an aim for qualitative researches. Therefore, there should be a consistency between the findings and the data which is names as dependability (Merriam, 2009). Some of the ways to increase dependability of a qualitative research are triangulation, peer examination and investigator position. In the credibility of the study section, these factors were discussed in detail. Additionally, inter-rater agreement with a professor who studies PCK and had a background in biology education was used for substantive content knowledge and PCK in this study. It was noted that inter-rater agreement for substantive content knowledge was 90% and for PCK was 85%.

3.7. Ethics

Prior to conducting the study, ethical clearance was granted from the University's Human Research Ethics Committee (see Appendix F). Later permissions were obtained from the Ministry of Education (see Appendix G) and the school principals. In this study, after determining the schools, researcher firstly called the school principals and asked for coming to school to conduct a study. After getting an appointment researcher talked to the school principals as well as the teachers about the aim of the study. Researcher got their permission to study with them and protected both participants' and schools' rights. They were chosen because of their willingness to participate in the study.

No one was hurt in this study (Fraenkel & Wallen, 2006). The real names of teachers were not used by giving them pseudo names as Ezgi and Nilay. Moreover researcher did not share the data with anyone and secured the data after gathering. Moreover researcher's aim was not judging or criticizing the teachers' work. Therefore in interviews, researcher meant to be kind so that participants do not feel attacked. Moreover the researcher paid attention to not being biased.

3.8. Assumptions of the Study

In this study it was assumed that;

1. Magnusson et al. (1999) model was effective for explaining teachers' PCK.
2. Teachers were natural during interviews and observations.
3. All responses of teachers were sincere.

3.9. Limitations of the Study

Limitations encountered during the study are listed as below:

1. This study is limited to 2 experienced science teachers working in the two public schools
2. In this study only substantive content knowledge was examined, there was no indication of syntactic content knowledge regarding ecosystems.
3. Researcher was not allowed to use any recording items during observations.
4. Researcher did not conduct post-interviews with participants because of participants' personal reasons and timing.

CHAPTER 4

FINDINGS AND CONCLUSIONS

In this chapter, the data obtained from the science teachers' content knowledge and topic-specific pedagogical content knowledge regarding ecosystems and their students' understandings on ecosystem are represented.

4.1. CASE 1: Ezgi's Content Knowledge and Topic-specific Pedagogical Content Knowledge Regarding Ecosystem

4.1.1. Ezgi's Background

Ezgi is a science teacher having fifteen years of teaching experience but only one in that school. She has a B.Sc. degree on physics education. She spent 9 years on science education. She indicated that she attended a scouting camp when she was a student and that is where her interest towards ecosystem comes from. She taught that biology concepts were easier both to teach and to be learnt by students when compared to physics and chemistry. She added that students found biology concepts more interesting and related with their daily lives. Moreover, she mentioned her special interest on ecological issues during interviews that made her follow documentaries, text-books and magazines about ecosystem.

4.1.2. Ezgi's Content Knowledge Regarding Ecosystem

Ezgi's Content Knowledge on ecosystem was investigated through interviews, drawings, and word association task (WAT) as well as concept map. During interviews, she was asked several questions related with basic ecological concepts and principles. At the same time, she was asked to prepare a concept map to reveal her content knowledge on ecosystem. Her responses, drawings and her concept map were used to understand her content knowledge on ecosystem which is an important factor enabling teachers to achieve effective ecosystem teaching.

In the pre-interviews, Ezgi answered nineteen questions related to concepts regarding ecosystem. Those answers were used to figure out Ezgi's knowledge about basic terms of ecosystems.

System is a broad term when considering the fact that ecosystem is a complex system. Therefore in order to get teachers' understanding and ideas on what a system is, Ezgi asked to define "system" in first question.

> I: How do you define a system? Can you give an example, please?
>
> Ezgi: *When we think about system, it is a very broad term. I may not define it exactly in the biology concepts but [I can give an example from physical science], for example, to form a compound machine, we combine more than one simple machine. So, we need to choose the things that will interact with each other. For example when we talk about education system, we do not mention only one thing. We mention the process of various things affecting the system. It is a very broad term from my perspective. [Nevertheless], we do not teach the 'system' concept at 7th grade.*
>
> I: What is it that makes your example a system?
>
> Ezgi: *How they [the factors of the system] interact each other.*

Ezgi's answer showed that she was aware of the fact that a system maintains its entity with its parts and functions as a whole (Assaraf & Orion, 2005). Therefore by giving an example of a combined machine and its interactions with its parts it is a fact that Ezgi had a sound understanding of what a system is. After getting Ezgi's understanding on system concept, her knowledge of ecosystems as a complex system is examined. The aim is to see whether Ezgi consider ecosystem as a system or not. According to Jin et al, (2019, p. 221);

> 'Ecosystems are complex systems because they have 'nested' hierarchies— subsystems at a smaller scale are combined to form a system at a larger scale. …….. all components in an ecosystem, including both biotic .. and abiotic

components … are connected. …..the complex relationships and interactions create emergent properties, ….. (Jin et al., 2019; p. 221).

I: Do you think that ecosystem is a system? Why or why not?

Ezgi: *As the name implies, ecosystem is a system. If we think system as an ecosystem, it is about environment. When we say 'system', it is the association of more than one factor relatedly in an organized way. There is no direct definition of system in the curriculum.*

To be brief, Ezgi defined system as a broad term by mentioning its various components. She gave education system and compound machines in physics as examples to a system. She expressed that the interaction between a system's compounds is what makes it a system as expressed above. As Assaraf & Orion 2005 mentioned, 'The expression ''system'' is related to vast of fields such as social, technological and natural systems so it is a very extensive concept. A system is a term that keeps its presence and operates as a whole through the interaction of its parts. Nonetheless these parts interacting with each other should have a specialized goal and all parts have to exist in order for the system to perform fully (Assaraf & Orion 2005, p. 519). However, she had some difficulties to perceive ecosystem as a system; her explanation for example did not focus on the interdependent relationships in ecosystems (Jin et al., 2019).

I: What is an ecosystem composed of?

Ezgi: *We divide it [ecosystem] into two as biotic and abiotic factors. Then we can get into details of each one of these [biotic and abiotic factors].*

Ezgi's answer showed that she both mentioned only the name of biotic and abiotic factors as an explanation of what an ecosystem is composed of. In line with her understanding of ecosystem as system, she did not mention any interactions among these factors and one-way of energy flow through an ecosystem. Therefore it can be concluded that she had a partial understanding of ecosystem. In attempt to take more information about the ecosystem, Ezgi was asked to list 12 words which come to her mind about ecosystem (WAT).

I: Can you list 12 words that come to your mind when we say ecosystem?

Ezgi listed 15 words in total when she was asked to list words for word association test (Table 4.1.1.).

Table 4.1. 1. *Ezgi's concepts as shown in WAT*

Groups of concepts	Concepts that were mentioned in regard to each category
Biotic	Living things Biotic factors: which properties the living things should have to live in which ecosystem
Abiotic	Non-living things Earth Various regions of Earth Properties of soil Properties of water Amount of light Temperature
Ecosystem types	Terrestrial ecosystem Aquatic ecosystem Desert ecosystem Polar ecosystem
Other terms	Ecology System

As seen in the table, the concepts that Ezgi listed were grouped in four. She listed both living and non-living things in an ecosystem. Ezgi's answers were categorized in three concepts as biotic, abiotic and ecosystem types as she mentioned related words. Moreover for the other two words one category named other terms was formed for grouping the other words Ezgi mentioned. However, she did not speak of any energy concepts related to ecosystems.

In order to see to what extent Ezgi associate concepts of ecosystem with each other, she was asked to construct a concept map on an ecosystem (Figure 4.1.1.)

I: Please draw and explain an ecosystem concept map.

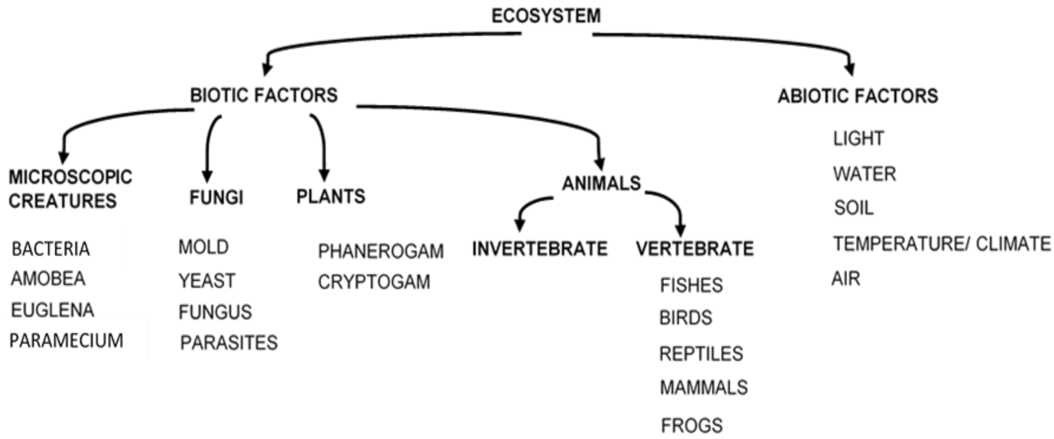

Figure 4.1. 1. Ezgi's concept map about an ecosystem

Ezgi created a concept map on ecosystem and its components without writing relationships of the components with each other. Her map characterized by 2 chains with no connection between biotic and abiotic factors as well as biotic factors. Moreover she did not include basic ecosystem terms like species, population and habitat. Although she listed the biotic and abiotic factors in ecosystem, she did not express any energy concepts and food chains. Moreover she neither has shown any linking words in the arrows she drew, nor linked the originated concepts to one other. Her map, which looks like a flow chart, suggesting an isolated conceptual understanding. What is more, her explanation of the map further shows her limited understanding. As depicted below, her explanation mainly focused on curricular objective. For example, while constructing her concept map, Ezgi mentioned that teaching biotic factors at Grade 7 requires following the objectives stated at Grade 5.

[Recall that objectives in 5th grade are: at the end of the unit students will be able to Exemplify and classify living things according to their similarities and differences, Search environmental problems which are caused by human activities and make a suggestion to solve them, Plan and present a project related to solving an environmental problem located in immediate environment (MNE, 2013, p.35)].

Following excerpt shows her explanation for the question of ecosystem concept map drawing.

> "We [science teachers] do not include fungi here [under the category of microscopic things] but we state that some types of fungi are microscopic. We exemplify the gymnosperms, and teach their life cycles. We do not get into details of phanerogams as gymnosperms. . We only mention the parts of phanerogams. We also give the general examples of invertebrates and vertebrates living on land, in water, and in the air in 5th grade and the topic animals continues in the 8th grade. We teach the herbivores, carnivores, omnivores and the nutrition flow later."

As an extension of previous question, Ezgi was asked to draw and explain an ecosystem to determine how she will express her knowledge of ecosystem components.

I: Please draw and explain an ecosystem.

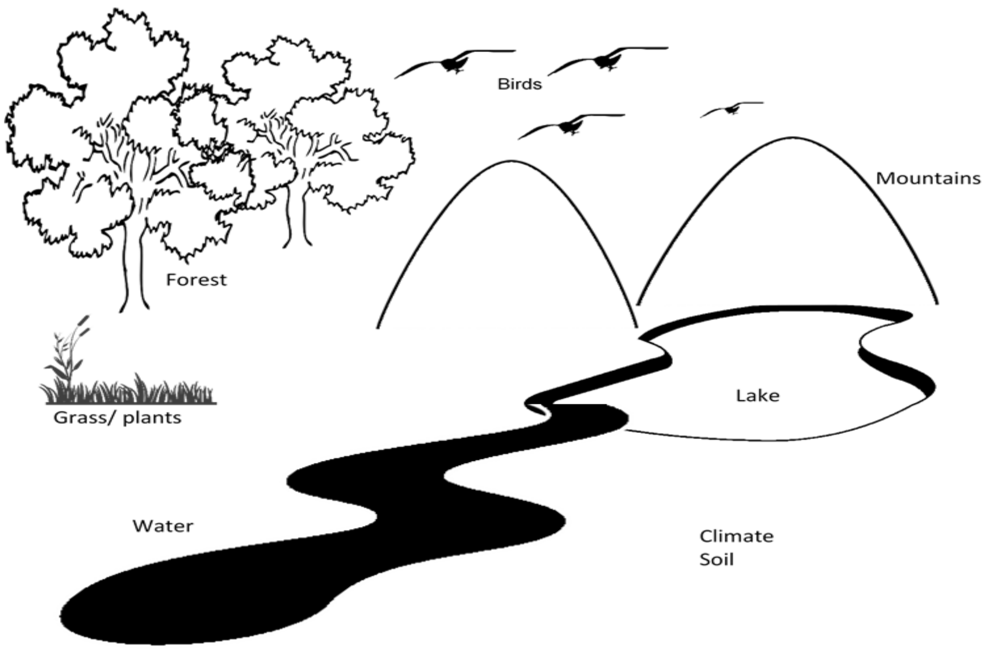

Figure 4.1. 2. Ezgi's drawing of an ecosystem

After completing her drawing she said “Ecosystem does not need to be as large as, I drew; even ‘under a rock’ can be an ecosystem.” However, in Ezgi’s drawing, again there was no indication of interactions among biotic (living) and abiotic living which are the most important components of an ecosystem. Her drawing also failed to demonstrate the relationship between the living things. Overall, she drew an isolated ecosystem which only had discrete entities.

As a follow up question, Ezgi was asked to explain components of her ecosystem. She identified forest, lake, trees, soil, climate, and the properties of the soil as compounds of her ecosystem. Stated differently, she only mentioned what she drew on her ecosystem before.

Briefly, she drew trees and grass as well as water flowing in the ground or soil. She did neither show basic interactions of living and non-living things nor did she mention any interactions among the components. She did not add any additional component for example like human or human built, like house components or factories, in her drawings. Therefore she only included a variety of natural elements in her drawings.

Table 4.1. 2 Ezgi's DET scores (*see Flowers et al., 2015*)

Components	**Score**
Human	0
Biotic trees touching grass, birds flying in the air	2
Abiotic water touching ground	2
Human built	0
Total Rubric Score	4

Gaining 4 points, implying that, she experienced some difficulties in identifying components of ecosystems, mainly biotic and abiotic. She did not add any extra components.

As a follow up question, Ezgi was asked to explain the events/processes and connections of these events if there are any.

> I: Which events occur in your ecosystem? Is there a connection between these events?
>
> Ezgi: *First of all, the existence of the living things depends on the non-living things. Firstly, we need to discuss the features of the non-living things and think about which living things can live in that environment depending on non-living conditions such as climate, temperature, soil and air. Also there is a continuous interaction between living and non-living things, in terms of both feeding relations and living conditions [such as finding shelter and food, and appropriate climate]. There is an ecological balance and any increase or decrease in one of them [living or non-living things] could affect the other.*

Although her responses to interview questions, concept map and drawing did not include any interactions, she mentioned very briefly (and on surface) presence of relationship among main components of ecosystem. When asked about the events that occur in her ecosystem she only addressed that living and non-living things are always in interaction with regards to living conditions and feeding relations. However, she did not come up with the idea of energy flow in the ecosystem. When we summarize the results of her concept map and drawings, it was seen that her ecosystem concepts involved following figures;

Table 4.1. 3. *Ezgi's ecosystem concepts stated both in WAT and DET*

Groups of concepts	**Concepts that were mentioned in regard to each category**
Biotic	Microscopic things; • bacteria, • amoeba, • euglena, • paramecium Fungi; mold, yeast, fungus, parasites Plants; phanerogams, cryptogams Animals; invertebrates, vertebrates; • fishes, • birds, • reptiles, • mammals, • frogs Forest, Grass
Abiotic	Light, Water; lake Soil, Temperature, Climate, Air, Mountains

After the WAT, concept map and drawings, Ezgi's ecosystem understanding can be identified as partial because she defined ecosystem without mentioning flow of energy, cycling of matters in ecosystem and nature of relation. In addition, as she expressed interaction between biotic and abiotic components in ecosystem, she stated that these components live in harmony in ecosystem. However, she did not reflect it on her drawing. Likewise she did not draw or give any examples of living things rather than birds in the ecosystem example. In fact, she did not give any specific ecosystem example rather she gave earth as ecosystem example.

Following part documented Ezgi's response to the questions about basic concepts of ecosystem such as species, population, community, habitat, ecological niche and biological diversity which were not mentioned by Ezgi previously.

4.1.2.1. Ezgi's Knowledge regarding Basic Terms about Ecosystem

I: What is a species? Please give an example.

Ezgi: *[Species is] the main unit of classification. There are some conditions in order to be called as a species [such as] sharing the same ancestral features, showing the same properties, being able to reproduce living things that can breed. [For example] human is a species, cat is a species. (Note that in scientific term the cat Ezgi mentioned about is named as Felis domesticus).*

The answers of Ezgi for the definition of species, which mentioned the characteristics and ability to produce fertile offspring (Reece & Campbell, 2011; Darwin, 1975), showed Ezgi's sound understanding of species. As an example, she also mentioned dogs, daisies, horses and donkeys in addition to cat and added that mules are not defined as species because they cannot reproduce (classroom observations data),.

After defining species, Ezgi was asked to describe and exemplify a population.

I: What is a population? Please give an example.

Ezgi: *The assemblage of the same species living in a specific area. For example the anchovies living in the Black Sea.*

While describing the population Ezgi specifically mentioned the same species living in a particular area (Reece & Campbell, 2011). In the class observations, she mentioned that we can call anchovies living in the Black Sea as an example of population. However, we cannot do so for fishes living in the Black Sea because it [fishes living in the Black Sea] includes more than one species of fishes. Likely *Pearl mullets* living in the Lake Van, water fleas living in fresh water and black pines in Uludağ [a mountain located in Marmara region of Turkey] are provided as other examples of population. In addition she said that while roses in the garden, and tulips in the garden are examples for population, red flowers in the garden does not constitute a population. After receiving her ideas about population, she was asked to define a community by giving examples.

Ezgi: *We do not teach community, this concept [community] is not included [in the science curriculum]. I knew community but I forgot it…… so I do not know. I did not teach it for a long time so I do not remember it……If I read about it, I can remember ……*

Accordingly Ezgi had no understanding of concept. . Since she mentioned that it was not included in the curriculum, Ezgi did not mention community while teaching ecosystem in the class.

Next question evaluates her knowledge of habitat.

I: What is a habitat? Please give an example.

Ezgi: *The place where the living things are found…. in short, it's [the living things] address…… Where it lives ... its living area. For example there are mainstream examples in the text-books like Pearl mullets live in the Lake Van so 'the Lake Van' is the habitat of them [the Pearl mullets].*

Ezgi's answer showed that she had a sound understanding according to Reece & Campbell (2011) definitions of habitat (see Table 3.3.). In addition, in the classroom observations, it was noted that she asked "Where can penguins be found naturally?" to her students. Her students answered as '….in the South Poles'. Then she asked habitat about scorpions and fishes. After getting answers soil for scorpions and water for fishes, she said that

"I actually asked you [students] the address of these living things. Habitat is the address where they [living things] survive and reproduce. Where we can find a living thing on earth is its habitat." Next Ezgi wrote on the board that "the *Pearl mullets* which are living in the Lake Van" and "*The pearl mullets* are living in the Lake Van." Then asked her students what living things and Lake Van refer to. .' The class ended up by discussing that the first sentence emphasizes on the place, habitat, and the second the living things, population. During the class, Ezgi also asked students to determine the habitats of penguins, deer, small worms, camels and cactus. Students' answers were poles for penguins, forest for deers, under the soil or rock for worms, deserts for camels and cactuses. Then, Ezgi summarized their answers by saying "A habitat can be small as under a rock or it can be as big as a desert. It is where a living thing can be found when it is searched for." Ezgi also asked whether only one species lives in a habitat or not. Students' answer was that there could be more than one species living a habitat. They gave the example of tree species like pine and others. In the following question, Ezgi was asked to define an ecological niche.

I: What is an ecological niche? Please give an example.

Ezgi: I do not remember.

As in the case of community, Ezgi's ecological niche definition shows no understanding. Moreover in the classroom observations, it was observed that she did not share any information about ecological niche with her students. Thus it can be said that Ezgi generally defined the terms correctly that are currently included and taught in the curriculum. However, she said that she could not remember community and ecological niche terms as they are not taught in the class anymore. Therefore it can be said that her knowledge of ecosystem limited to concepts that are mentioned in the curriculum or objectives of the unit.

I: What is biological diversity? Please give an example.

Ezgi: *In a specific area, actually we do not have to restrict it, we can include maybe the whole world and the living things or let's say, take the Amazon forests, and we talk about the diversity of the living things there [in the Amazon forests] . So it is the diversity of the living things.*

This response showed that Ezgi is not clear about definition of biological diversity. She did not specify the kinds of living things in the Amazon forests. She did not includ ecological or genetic diversity in her definition. Instead, she only mentioned species diversity without giving any specific examples. Although her response appeared to be superficial, class observations data provided more information about her knowledge on biological diversity, In the classroom, Ezgi expressed that when an ecosystem is considered, there can be more or less variety of living things in it [ecosystem]. Then, she added that compared to the poles there are more variety of living things in a forest. . She also asked her students whether diversity of living things depend on non-living things or not. After receiving yes response from the students, Ezgi concluded that diversity of living things depends on non-living factors such as temperature, soil, and water. Therefore, Ezgi's understanding of biological diversity was categorized as partial.

In order to better understand Ezgi's ecological concepts, she was asked questions related to components of ecosystems, such as producers, consumers, decomposers and their relationship. The related interview excerpt was provided below:

4.1.2.2. Ezgi's Knowledge related to Energy Flow in an Ecosystem and Corresponding Concepts

In order to determine teachers' knowledge related to energy flow in an ecosystem and its components, Ezgi was asked to describe, exemplify or draw some of the concepts related to ecosystem. First of all, producers were asked since they are the ones that capture light energy and produce energy by converting inorganic materials into organic materials.

I: What is a producer? Please give an example.

Ezgi: *[A producer is] A living thing that can photosynthesize and produce food. Generally green plants or photosynthesis occur in the green parts of the plants. We also teach cyanobacteria and spirulina in the 8th grade.*

> I: You said, producers produce food. What is the food of a plant?
>
> Ezgi: *The food that plant produces by itself.*
>
> I: Can you tell me the importance of the producers in an ecosystem?
>
> Ezgi: *They form the first step of the food chain. Therefore in case of there are no producers, there will not be living things.*

According to Ezgi's answer, her understanding of producer was partial because she did not express them as autotrophs even though she mentioned that plants as the first step. When it comes to the food of a plant question, she neither specifies the 'food for plant' nor refers to the reaction of photosynthesis. Stated differently, she did not mention food production process. She did not talk about energy conversion process either.

However, in classroom observations it was noted that, Ezgi asked students "If there were no plants, would there be consumers?" and one of the student answered as "No.". With this question Ezgi tried to point out the importance of producers in an ecosystem but she did not explain it in detail. Therefore Ezgi's understanding of producers can be categorized as partial. Next she was asked to define another related concept which is consumer.

I: What is a consumer? Please give an example.

Ezgi: *The living things that have to feed with readily available food since they do not have chloroplast.*

> I: Can you talk about the importance of consumers in an ecosystem?
>
> Ezgi: *We can consider the cycle of materials, could producers live on their own? They could but the material cycle would have been destroyed. The*

producers could live [on their own] but the consumers are dependent on the producers. Consequently, when we consider plants, they would live (on their own without consumers) but the balance would be destroyed [without consumers].

Ezgi's answer showed that she defined consumer correctly without mentioning types of consumers; herbivores, carnivores and omnivores and giving any specific examples. Moreover while talking about the importance of consumers, she mentioned the material cycle by emphasis was given importance of producers. Therefore her understanding of consumers can be categorized as partial understanding. However, in classroom observation, researcher noted that Ezgi only mentioned consumers by expressing consumers cannot live on their own but they have to rely on plants, similar to interview data. In the next question Ezgi was asked to define next component, which is decomposers

I: please explain decomposers by giving examples and mentioning their importance.

Ezgi: *They [decomposers] supply the conversion [of matter] by decomposing the substances in a dead organism….. They are very important in order for the substances in the nature to be regained to the soil and air.*

Ezgi's definition of decomposers showed that although she expressed a conversion, she did not indicate that organic materials is converted into inorganic forms so that they can be used by plant. Moreover her answer did not include material cycle as decomposers start the cycle of matter by extracting energy from dead organism and provide long term survival of communities. No examples were also provided. In classroom observations, there was no indication of decomposers. Therefore Ezgi had a partial understanding of decomposers when scientific explanations take into consideration. In the next question, her conceptualization of energy flow in an ecosystem was assessed through asking several questions related to food chain and food web, which involve producers, consumers and decomposers.

I: Please explain food chain by drawing and giving an example.

Ezgi: *The food chain shows the feeding relations of the living things.*

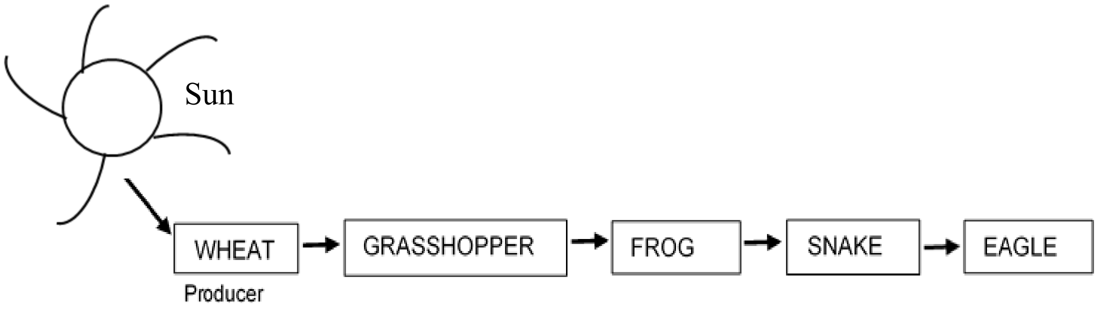

*Figure 4.1. 3.*Ezgi's drawing of a food chain

> Ezgi: *The Sun is not written in the food chain but all in all the source is the Sun, we can show it as the source of energy. The producers are always written in the first place like wheat. In the second place a living things which is fed by the wheat, we give generally these examples [grasshopper]. These examples are plenty in the text books as well. [In the food chain] There might be a frog eating the grasshopper, a snake eating the frog and an eagle eating the snake. We dig into the details of it [in the class in grade 8].*

She gave one more example as an alternative to her drawing, including wheat, human and lion.

> Ezgi: *In this example, there is an herbivore in the second place but an alternative food chain could be as wheat, human and lion so it is not mandatory to write an herbivore to the second place [like grasshopper in the drawing], we get into these details in the class in the eighth grade.*

While describing and drawing of a food chain, Ezgi was able to address the trophic levels of organisms correctly. However,, she never mentioned about decomposers. While describing and drawing the food chain she only mentioned energy as coming from sun and did not express what happens to that energy in a food chain. In order to examine her understanding of food chain, Ezgi was asked to form a food chain with given examples if possible.

I: When given “nectar, a butterfly, a bird, decomposers”, do you think they form a food chain as given in the order?

Ezgi: *We do not include the decomposers in the food chain. We write them in the energy pyramid but there is a producer [nectar] we can write in the first step eventually. The butterfly is an herbivore, if we write it in the second step, there might be a carnivore [which is] bird eating that butterfly. If we do not write decomposers, we can form [the food chain].*

Ezgi’s answer demonstrated that she was able to form a food chain with naming producer, primary consumer and secondary consumer. However, she expressed that decomposers were not written in food chains as she did not draw or mention them before. In the given example, decomposers were placed at the top of the food chain, which was wrong. She did not realize that, at least in this question, decomposers operate at all level of the food chain. Therefore she had a lack of understanding and misconception about the food chains. Since previous questions, she relates material cycles with the organisms of the community. Therefore, in the following question, she was asked to explain possible relation between material cycles and food chains to identify her knowledge of energy flow and the cycle of matter driven as species interact with each other in food chain (Miller & Spoolman, 2009).

> I: Is there any relationship between matter cycles and food chains? Explain please.
>
> Ezgi: *Food chain, for sure as an energy flow is comprised by the way of feeding and because this energy provides transfer between molecules, this energy or matter is transferred from herbivore to carnivore and omnivore among the living things. However, decomposers led to matter cycles by engaging in when living organisms die in every step. Therefore, matter cycles start after those living things died. However, the water cycle is different, of course. Water should not be considered as only a non-living thing because it is involved in structure of the living organisms. We also teach sweat and wastes.*

According to Ezgi, material cycles and food chains are related to each other. Actually she expressed the energy flow correctly and she even pointed out that decomposers take place in every step of food chain although she said that decomposers were not written in food chains. Therefore from Ezgi's answer it can be concluded that she knew the scientific explanations but harbor some doubt in reflecting it on her drawing of a food chain. After that since in an ecosystem food chains interconnect and form food webs (Miller & Spoolman, 2009), Ezgi was asked to define and draw a food web.

Ezgi: *For example in many forests, there are not only those five [wheat, grasshopper, frog, snake and eagle] living things. Since many living thing live together, more than one food chain [therefore] occur and most of which intersect with each other..... A living thing can be function in several food chains in a food web. So we teach complicated feeding association as food web by giving examples of living things and schemas.*

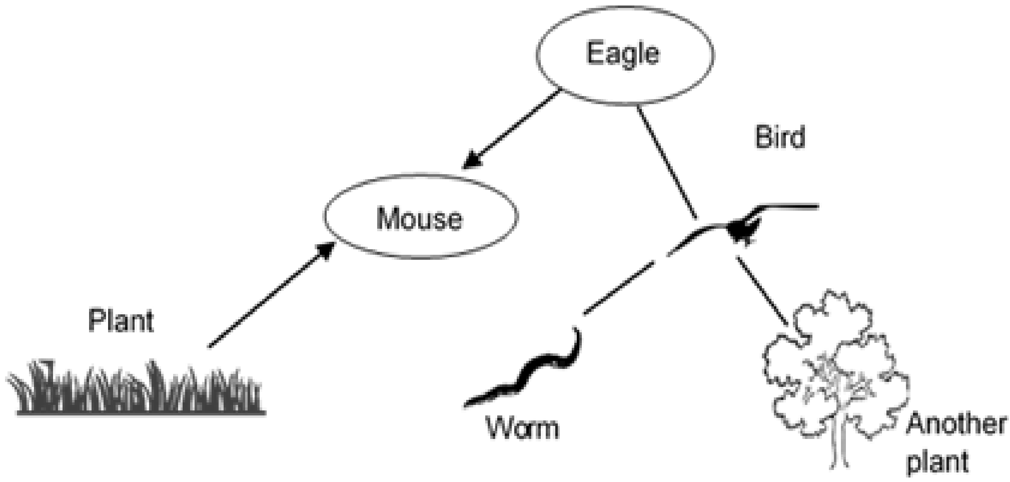

Figure 4.1. 4. Ezgi's drawing of a food web

Ezgi: *We draw many living things in the food web. I mean, we generally do not make a straight line but put a plant picture in a forest. We put a mouse eating plant, an eagle eating the mouse. There is another plant here [showing her drawing]. Let's say, we draw a bird eating the other plant. That bird can eat the worm at the same time and that warm can eat another plant. Yet again the eagle can also eat the bird so we intersect them. by this way, we show not only how the food chains intersect with each other, but also one living thing can be found in many food chains in the food web.*

As it is seen in Ezgi's food web drawing she had difficulty in drawing of arrows correctly. For example, one arrow that she drew from plant to mouse was correct unlike the one she drew from mouse to eagle where she put the arrow in the opposite direction. Some of the arrows did not even have any pointed ends. Therefore, ın her drawing, it was not clear to see the relations between worm, bird and another plant. Yet, while speaking about her drawing, Ezgi mentioned the interactions of who eats whom correctly. To clarify her conceptualization of energy concepts, Ezgi was asked to draw the energy flow in an ecosystem and explain it.

I: Please draw the energy flow in a food chain and explain.

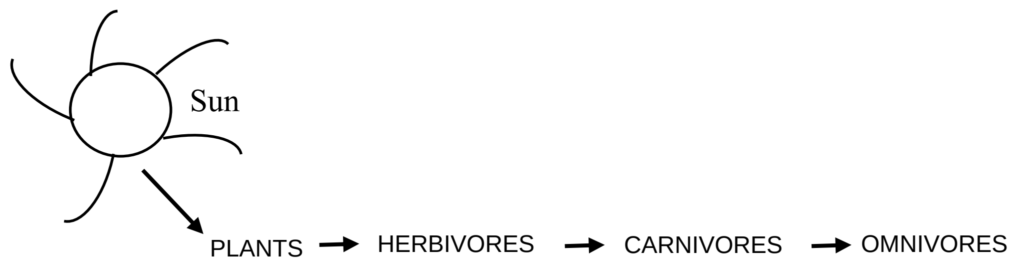

*Figure 4.1. 5.*Ezgi's drawing of energy flow in an ecosystem

> Ezgi: *[In the lesson] we generally say that, plants [benefit] from the sun energy but also mention about the cyanobacteria and algae because it is not only the plants which photosynthesize. After that we list as herbivores, carnivores and omnivores and we can create both a food chain and energy pyramid with them.*

Ezgi also mentioned how she touches upon food chain in her lesson by saying "If they [textbooks, or questions on the exam] provide living things, we form the food chain [using given organisms]. We teach the food web in the ecosystem after teaching numerous complicated food chains. In this way, we teach the energy pyramid. We indicate the decomposers in the energy pyramid and 90% and 10% flow [of energy] in every step."

The answer of Ezgi for the energy flow and drawing was partially correct, because, once again she did not mention decomposers neither in her drawing nor in her explanation. As a follow up, she was asked to draw and explain an energy pyramid that she mentioned at the end of her explanation for energy flow in food chain.

I: What is an energy pyramid? Please draw and explain an energy pyramid.

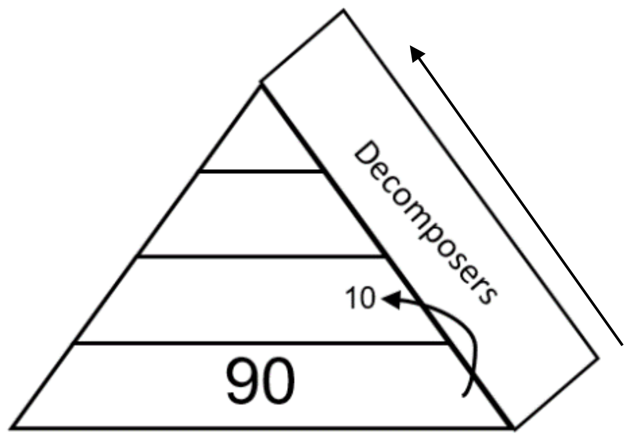

*Figure 4.1. 6.*Ezgi's drawing of energy pyramid

Ezgi: *It shows the energy flow. Energy flow is, of course, from the producers to consumers or to omnivores, in order.*

Ezgi’s drawing of energy pyramid was scientifically correct. She also mentioned the energy loss as 90% of each level [in fact 90% of energy is dissipated to environment as heat] and only 10% pass from producers to consumers. Then for understanding Ezgi’s energy pyramid drawing better she was asked to clarify the place of decomposers.

I: Can you talk about the take place of decomposers in your energy pyramid?

Ezgi: *They involve in every step since plants also die, animals, too and humans, all of them [will die]. We also explain it in the eighth grade.*

Although she was not mentioning decomposers as a component of a food chain, she pointed out that the decomposers take place in every step of energy pyramid since in all steps organisms die. But she did not give any information about the role of decomposers on dead bodies. Accordingly, she was requested to explain the interactions of producers, consumers and decomposers.

I: In what ways, do producers, consumers and decomposers interact with each other? If any?

Ezgi: *The producers produce food by doing photosynthesis that is why we call them producers. The consumers cannot produce food so they have to take the food that producers produced. The decomposers are also consumers but we can say that as they consume the dead organisms, [by this way] they help the cycle of matter.*

Ezgi's answer implied that she knew the interactions between producers, consumers and decomposers. She even mentioned the material cycle in her explanation. Then, Ezgi was asked to explain the reason why pyramid of energy is in the shape of pyramid?

> Ezgi: *Its shape is pyramid because the number of plants are the most according to the biomass. And they are the producers so they are at the bottom, as well as they are the source of energy. We write them at the bottom and the energy level is consumed 90% upward in every step by transferring 10% or since 90% [of energy] decrease, we give the narrowing shape as a pyramid not a perpendicular.*

I: Is the length of a food chain limited? In other words, are there any factors limit the length of a food chain?

Ezgi: *No. We list the living things threefold or fivefold that is given to us [as an example in the text books]. We give these examples but there are more than five living things in the nature. As all carnivores and omnivores eat each other, there is no limit.*

Although mentioned during interviews, in classroom observations, it was noted that Ezgi did not mention food chain, food web and energy pyramid in the class since it was not prescribed in science curriculum (MNE, 2013).

General summary

Overall, Ezgi's responses to the questions revealed that she possesses either lack of or partial understanding regarding many of the ecological concepts. For example, Ezgi's responses revealed her lack of comprehension on biological diversity because her definition was more associated with species diversity, genetic diversity and evolutionary diversity were underestimated. Furthermore she had deficit in explaining decomposers as she mentioned a 'conversion' but not explained the meaning of 'conversion' as conversion of organic materials into inorganic form. On the other hand, she explained most of the ecological concepts properly such as species, population, habitat, and energy pyramid. However, in her habitat definition, for example, she did not address the components of habitat such as food, shelter and space that organism can reproduce and live. But she did give a specific example to the habitat; Van Lake for *pearl mullets*, for instance. There were also some concepts where Ezgi held naïve understanding (or holistic understanding) in the concept of food chain. She had difficulty in identifying plants' food, place of decomposers in a food chain, showing direction of energy flow (or feeding relation) in a simple food web. Ezgi thought that decomposers were not written in food chains although she put them in every step in energy pyramid. Thus while she was asked to form a food chain with nectar, butterfly, bird and decomposer she stated that food chain could be formed if the decomposer was not written. While explaining the energy pyramid she was able to state the energy loss in every step as well as the correct trophic levels of producers, consumers and decomposers in energy pyramid. Although she acknowledged that 'within an ecosystem, progressively less energy is available at each trophic level', she had difficulty in relating this knowledge to explain the reason why there are rarely more than 5 or 6 trophic levels in any ecosystem (Miller & Spoolman, 2009) by saying that there was no limit to the food chain.

In addition she did not answer two of the questions related to ecological niche and community. Although she is an expert teacher, 15 years of experience, she expressed that she did not remember those concepts because they are not included in the current curriculum (MNE, 2013) so she did not teach them in the class anymore. Therefore she said that if she looks at the terms she could easily remember.

In this section Ezgi's CK regarding ecosystem was introduced and in the next section; Ezgi's topic-specific pedagogical content knowledge regarding ecosystem will be documented. In Table 4.1.5. Ezgi's topic-specific PCK summary was shown and in the following section Ezgi's topic-specific PCK findings after pre-interview and classroom observation are revealed.

4.1.3. Ezgi's Topic-Specific Pedagogical Content Knowledge Regarding Ecosystem

Ezgi's topic-specific Pedagogical Content Knowledge (TSPCK) on ecosystem was investigated through both interviews (CoRe) and classroom observations. During interviews, Ezgi was asked several questions related with five parts of pedagogical knowledge. Then, she was monitored by the interviewer in the class to get her pedagogical knowledge on ecosystem. Ezgi' responses and observation notes taken in classroom observations were used to understand their pedagogical knowledge on ecosystem which is the factor enabling teachers to achieve an effective ecosystem teaching.

In the pre-interviews Ezgi answered thirteen questions related to curriculum knowledge, six for difficulties and constraints while teaching ecosystem, seven for students' knowledge and understanding, thirteen for teaching strategies, and six for measurement and assessment techniques. The data were summarized in the Table 4.1.5.

Table 4.1. 4. *Summary of Ezgi's Topic-specific Pedagogical Content Knowledge*

Pedagogical questions/prompts (CoRe)	**A summary of Ezgi's TSPCK**
What you intend the students to learn about this idea?	The concepts like species, population and ecosystem, Ecosystems in the Earth, The interactions between living and non-living things in those ecosystems.
Why is it important for the students to know this?	Knowing the [concepts] of ecosystems is an advantage for students …..Maybe while deciding their future professions… they could be interested in this area… about environment or animals or plants. That could be an alternative for them as a career choice [after learning ecosystem topic].
Difficulties connected with teaching this idea	I think that the concept is not so difficult to teach because it is a concept that students can understand more easily compared to the other concepts [presented in the science curriculum]…..it is the topic that attract their interest. Children always wonder about animals, [for example]. I have no concern in teaching this topic because I think students understand [the topic] and they become succeed. However, the preparedness level of every student is different or their interests are not the same… so the ones who are good [at the ecosystem topic] understand the concepts better. In previous science curriculum [2008] there were very detailed explanations of the objectives but the one we follow this year [2013] has included neither explanations nor limitations about the objectives. Now it [the 2013 curriculum] is a kind of elementary [level] compared to the previous one… so teachers follow both the objectives and the textbook.
Knowledge about student thinking which influences teaching about this idea	The students, most of the time, confuse population with habitat. For me, it is due to their deficit in Turkish language. They distinguish the difference [between population and habitat] after solving a couple of examples We have already taught this topic in previous grades to these students…so they need to know the basic concepts like how to classify the living things, how they feed and where they live such as in the sea and on the land.

Table 4.1.4 *Continued*

Other factors that influence your teaching of this idea	We have difficulty in using time [allocated to teach ecosystem concepts] effectively because the first science units of seventh grade [before ecosystem unit] are difficult so we have to spend more time for those than ecosystem unit. Honestly speaking, I am not very good at creating new activities for the [ecosystem] lesson because creating new activities requires a considerable effort and preparation before the lesson. If we did not have such a dense curriculum or time pressure, I would have prepared an activity. Therefore, we [as teachers], unfortunately, have to follow ready to do activities in the lessons.
Teaching procedures (and particular reasons for using these to engage with this idea)	First at the beginning of the lesson, I ask questions to determine students' level of preparedness. Then, I start teaching the objectives progressively starting from the species and move in the order [as specified in curriculum]. I constitutively use the text book approved by the ministry of national education in the class. I also use crammers because the textbook did not include sufficient amount of activities or because we aim to provide students with knowledge with visuals. The crammers aim to prepare students for the national exams because students have an [high school entrance] exam ahead of them. Other than that, if we have enough time, I try to show students some visual aids from morpa campus and eba [educational informatics network]. As well as we show interesting 3D videos or documentaries (which are advanced level for students and out of objectives). These videos support students' knowledge and make it permanent [to promote long term retention].
Ways of ascertaining student understanding or confusion about the idea	Nowadays there are some various, puzzle and schema-like, questions including more visuals in the text-book. We use these activities both during and at the end of the lesson from the book or smart board. Moreover the crammers that we use also contain activities, which are not directly on question and answer test type. We take these tests in the lesson flow, either following the book or from the smartboard. We actually need to do evaluation in the

Table 4.1.4 *Continued*

	end of each chapter but most of the time, we do not have time to do that. If time left, we should do something to get a feedback [from the students] and summarize the chapter. I will check whether students distinguish four basic concepts [species, habitat, population and ecosystem] or not by testing whether students distinguish different ecosystems from each other and know the characteristics of living and non-living things as well as the interactions between them. I have to check if students learn after each concept step-by-step although there might be a general examination at the end of the unit [on ecosystem] If students did not learn the term I in the beginning they could not learn the next.

4.1.3.1 Ezgi's Orientation towards Science

In order to understand Ezgi's orientation towards science, her beliefs about goals of science teaching were examined. Ezgi's beliefs about goals of science teaching were collected through pre-interview questions and in-class observation. Ezgi's beliefs about goals of science teaching were revealed as central and peripheral goals in general and then these goals were classified as schooling goals, affective goals and subject matter goals. In this section Ezgi's answers to pre-interview questions about goals of science teaching were presented.

4.1.3.1.1 Ezgi's Beliefs about Goals of Science Teaching

There were six pre-interview questions to gather Ezgi's beliefs about goals of science teaching. First of all, the reason why Ezgi teach science was asked.

> I: Why do you teach science in middle school? What does science teaching mean to you?
>
> Ezgi: *Actually [I teach science in order] to teach students the nature, I mean in general {to teach] science and the cause-effect relationships. And [I teach*

science in order] to raise students' understanding about what occurs when they [students] look at their surroundings. Moreover when we consider the academic way, [I teach science in order] to prepare students to high school and university.

Ezgi's answer shows that her emphasis of teaching science is on subject matter because her central goal was to teach students science and the cause-effect relationships. Moreover she added that she also wants her students to be prepared for high school entrance exam. Therefore her central goal focuses on schooling goals and subject matter goals of teaching science.

I: Why do you teach ecosystem concept then?

Ezgi: *Mainly to make them [students] understand living things, their surroundings and to make sense the world. [For example] what kinds of living things are found in different ecosystems. This is very important [for students] to recognize the world in some way. [Therefore] I see it important for my students in order for them to know their surroundings.*

Ezgi stated her reason for teaching science based on subject matter and affective goals. She pointed out the importance of raising awareness of students towards their surroundings and teach them living things in different ecosystems. Therefore her central goal of teaching ecosystem was affective goals.

I: Which skills or knowledge do you expect your students to gain after learning science?

Ezgi: *There are objectives for every grade level. We [are responsible for teaching] teach those objectives gradually at each grade. There is already a spirality in curriculum. We try to teach [the concepts] step by step [at each grade level].*

Ezgi stated the objectives prescribed for teaching science in the curriculum. Therefore her expectation for students' understanding after learning science was based on subject matter goals.

I: How did you decide the goals you emphasized to teach science?

Ezgi: *There are already some objectives we should follow. We face with some limitations and obligations for teaching that objective however. But I try to teach [the concepts] by associating them with daily life and nature. I especially lay emphasis on it. Students always ask "What are we going to do with this knowledge?" I start the lesson by giving answer to the question.*

I: What is the role of teacher and learner in science teaching?

Ezgi: *Actually what supposed to happen is that teachers should be a guide. I mean… students should learn through inquiry [asking question] but of course the instructional method can be changed according to the preparedness level of students. It [the method] can also depend on the topic under consideration in general.*

In classroom observation, however, it was seen that Ezgi used a teacher-centered instruction to teach the subject which was in line with one of her central goals; subject matter. In the next section, Ezgi's knowledge of difficulties and constraints while teaching ecosystem is be reported.

I: Do you think that teaching of ecosystem is difficult or not? Why or why not?

Ezgi: *I think that the concept is not hard to teach because it is a concept that students can understand more easily compared to the others and have an interest for. Children always wonder animals.*

I: So do you mean that you do not have any concern about teaching ecosystem?

Ezgi: *Yes. I think that students will understand [the topic] and do well. However, the preparedness level of every student is different or their interests cannot be the same so the ones who are good [at the ecosystem topic] understand the topic better. But if students have no special effort, whatever we do in the class, it may not lead to an academic success… we at least help them widen their horizons.*

I: Which factors, if any, do you think that will affect your teaching in ecosystem subject?

Ezgi: *One of the most important factors is students themselves. Rest of them are the topic itself, visuals, the course book and our [teacher's] explanations are enough for students to understand the topic. If it was another subject [except ecosystem], experiments, activities and the school conditions would also be influential of course…*

To conclude, Ezgi does not hold any concern about teaching ecosystem. She thinks that with the help of visuals, course book and her explanations, students can understand the topic easily. Moreover she adds that the biggest factor affecting her teaching is students and their preparedness levels for the lesson. According to Ezgi, not only those students who are interested in the ecosystem topics understand better but also those who are not interested in broaden their horizons on the subject. In the following section Ezgi's knowledge of curriculum is documented.

4.1.3.2 Ezgi's Knowledge of Curriculum

Ezgi's knowledge of curriculum was examined via the pre-interviews, and in-class observation notes. In this section, Ezgi's knowledge of goals and objectives and knowledge of materials about ecosystem were reported.

4.1.3.2.1. Ezgi's Knowledge of Goals and Objectives about Ecosystem

Ezgi was able to indicate the place of the ecosystem concept in the curriculum for seventh grade. Moreover she correctly told the previous and following subjects of ecosystem and she explained the horizontal and vertical connections in the curriculum. Ezgi said that she was dependent on the curriculum and did not exceed the degree of knowledge prescribed in the curriculum while teaching ecosystem in the class.

First of all, Ezgi was asked the reason why ecosystem placed in the curriculum to understand whether she knows the reason or not.

I: Why do you think that ecosystem is placed in the curriculum?

Ezgi: *Actually ecosystem subject begins in the fifth grade in the most recent science curriculum (i.e. 2018) but this year we follow curriculum 2013 and we teach ecosystem definition in seventh grade. Due to the spiral nature of the curriculum, the ecosystem subject continues in the eighth grade. We teach it gradually [increasing in complexity], the beginning level is in the seventh grade for students to know the ecosystem concept. As the science curriculum changes frequently, we have to follow the objectives because we get on with the curriculum.*

As Ezgi indicated the ecosystem concept was placed in seventh grade and due to the spiral nature of the curriculum there were succeeding topics related to ecosystem concepts in the science curriculum. However, she only mentioned about the spiral curriculum and not any other goals like understanding of complex systems such as ecosystem. She neither talked about preceding topics of ecosystem in the science curriculum.

These responses also explain the next interview question which is in which grade level and unit the ecosystem subject is taught? Her responses were Grade 7 and Unit 5. Then, she was asked to topics which were taught just before and after the ecosystem at Grade 7. It can be said that she remembered the relation of objectives between 5th grade and 7th grade. The first objective in 5th grade was exemplifying and classifying living things. Since living things are one of an ecosystem's major components, it is important that students learn it and Ezgi reminded it in the class.

Ezgi: *The previous subject is light and the following one is electricity.*

Briefly Ezgi correctly explained the place of ecosystem topic in the curriculum (2013) she followed during the interview. Table 4.1.5 presents the intended objectives for ecosystem and related topics in 2013 curriculum. As it is seen in the table, ecosystem concepts first introduced in the seventh grade in the fifth unit.

I: Is the ecosystem subject associated with any other subjects, units or grades in the curriculum?

Ezgi: *In seventh grade, there is no similarity [light-ecosystem- electricity] it is a distinct topic and seems dissimilar to the other topics. There is not much relation in this grade level. [However,] Regarding units, there is a proceeding topic in eighth grade.*

To summarize Ezgi's knowledge about goals and objectives in the curriculum, she thought due to the spiral nature of curriculum ecosystem topic continues in the next grade. However, she stated that it is isolated in the seventh grade. Ezgi was asked about horizontal and vertical curriculum of ecosystem. As Ezgi stated, in the Grade 7 there was not any related topics to ecosystem unit and there was a related subject in the eighth grade including producer and consumer concepts as well as material cycles. [Note that food chain and energy flow and material cycles take place in the fifth unit of 8^{th} grade named as living things and energy relations.] Therefore she was aware of horizontal curriculum of ecosystem. However, she did not mention the previous levels' (Grade 4-6) topics related to ecosystem. Therefore Ezgi's knowledge of why ecosystem concepts were placed in the curriculum was limited.

In addition to other dimensions of knowledge of goals and objectives, Ezgi's knowledge about objectives of ecosystem was asked by the question:

I: What are the basic prescribed objectives for teaching ecosystem in the curriculum?

Ezgi: *To teach the concepts like species, habitat, population, ecosystem and several types of ecosystems in the earth and the interactions between living and non-living things in those ecosystems.*

I: Could you rank these objectives according to their importance?

Ezgi: *I mean maybe we can check how many objectives there are but all in all firstly we these concepts [species, habitat etc.] will be taught then the ecosystems will be exemplified.*

In fact in the science curriculum there are four objectives in total prescribed for the seventh graders to learn (MNE, 2013, p.35). She pointed out the first objective only which is '*7.5.1.1. Define and exemplify the concepts of ecosystem, species, habitat and population'*,

However, she did not mention the other three which are '*7.5.2.1. Inquire the importance of biodiversity for the natural life'*,*7.5.2.2. Discuss the factors threatening bio-diversity based on the research data and suggest solutions, 7.5.2.3. Search and exemplify plants and animals that are extinct or facing the risk of being endangered in Turkey and the world*

She failed to state objectives related to biodiversity, extinct and endangered species. Hence Ezgi had lack of knowledge of objectives prescribed for teaching ecosystem for seventh grade in the curriculum.

Table 4.1. 5. *Intended objectives for ecosystem and units preceding and following ecosystem in 7th grade*

Prescribed content for teaching ecosystems curriculum 2013		
Unit	**Learners must be able to**	**Restrictions**
4	7.4.1. Mirrors	a. Do not get into image drawing in special rays.
	7.4.1.1. Observe mirror types and give examples for their area of use,	b. Indicate the fact that the properties of an object's properties (big/small, reverse/straight) can be changed depending on the distance of object's to the mirror on concave mirrors.
	7.4.1.2. Compare the images on flat, convex and concave mirrors,	
	7.4.2. Light Absorption	
	7.4.2.1. Explore that light can be absorbed by an object as a result of its interaction with the object,	
	7.4.2.2. Infer that white light occurs as a combination of all light colors,	
	7.4.2.3. Associate the reason of object's being seen as black, white and colored with the reflection and absorption of the light as a result of observations,	Do not mention color filters.
	7.4.2.4. Give examples for innovative applications of sun energy in daily life and technology and discuss the importance of using sun energy in using sources efficiently,	

Table 4.1. 6. *Continued*

Unit	Learners must be able to	Restrictions
5	7.5.1. Ecosystems	
	7.5.1.1. Define and exemplify the concepts of ecosystem, species, habitat and population,	
	7.5.2. Biodiversity	
	7.5.2.1. Inquire the importance of biodiversity for the natural life,	
	7.5.2.2. Discuss the factors threatening bio-diversity based on the research data and suggest solutions,	
	7.5.2.3. Search and exemplify plants and animals that are extinct or facing the risk of being endangered in Turkey and the world	
6	7.6. Electrical Energy	
	7.6.1. Bulb connection types	
	7.6.2. Conversion of electrical energy	

I: Does the curriculum give place to any constraints for teaching ecosystem or possible misconceptions?

Ezgi: *I namely simply know the preparedness level of students since I did not start to teach the subject yet and I also did not teach these students before, that is why I will test it [the possible misconceptions that students held] by question and answer sessions in the classroom when I first start the chapter.*

I: What are the misconceptions or constraints placed in the curriculum?

Ezgi: *In previous science curriculum [2008], there were very detailed explanations of the objectives but the one we follow this year [2013] has included neither explanations nor limitations about the objectives. Now it [the 2013 curriculum] is more basic [level] compared to the previous one… so as a teacher I follow both the objectives and the textbook.*

Ezgi expressed that unlike the previous science curriculum (2005) the current curriculum that she follows did not contain any constrains or students' possible misconceptions for teachers to pay attention. She was right when only the seventh-grade level was considered because in previous grade levels or in the eighth grade, there were some constraints for teachers to take into consideration.

In conclusion, although Ezgi did not state any relations of ecosystem topic with other grade levels and provide only one objective prescribed in the curriculum, she knew the place; the grade level and the unit of ecosystem topic. She also correctly identified the previous and upcoming units of ecosystem in the seventh grade. Moreover she explained the horizontal connections in the curriculum. In addition she was able to explain vertical connection in the curriculum. Ezgi seemed to follow the curriculum strictly and tried not to exceed the degree of knowledge prescribed in the curriculum while teaching ecosystem in the class. Therefore it can be said that she had lack of previous objectives intended to teach in vertical science curriculum.

4.1.3.2.2. Ezgi's Knowledge of Materials

Ezgi's knowledge of materials as a part of her knowledge of curriculum was determined by asking her what types of materials she uses while teaching and the reason for using them.

> I: Which sources do you use while teaching the ecosystem subject?
>
> Ezgi: *I constitutively use the textbook approved by ministry of national education in the class. Other than that, if we enough time, I try to show students some visual aids from morpa campus and eba [educational informatics network]. But I do not directly get students to watch videos. Firstly, I teach the concept or get ahead with videos fragmentally. Moreover, I use crammers.*

> I: Why do you use these sources?
>
> Ezgi: *Because there is not enough activities in the textbooks or because we aim to provide students with permanent knowledge with visuals. The crammers aim to prepare students for the exams because they have an [high school entrance] exam ahead of them.*

As stated in the classroom observations, it was seen that she used textbook, morpa campus and black board. In morpa campus Ezgi showed a video about ecosystem then ask students to answer related questions provided after the video. She used black board to write examples and draw figures as shown in Figure 4.1.6. The figure in the picture shows a dichotomous living things schema drawn by Ezgi in the class to show what students have learned in 5^{th} grade about living things.

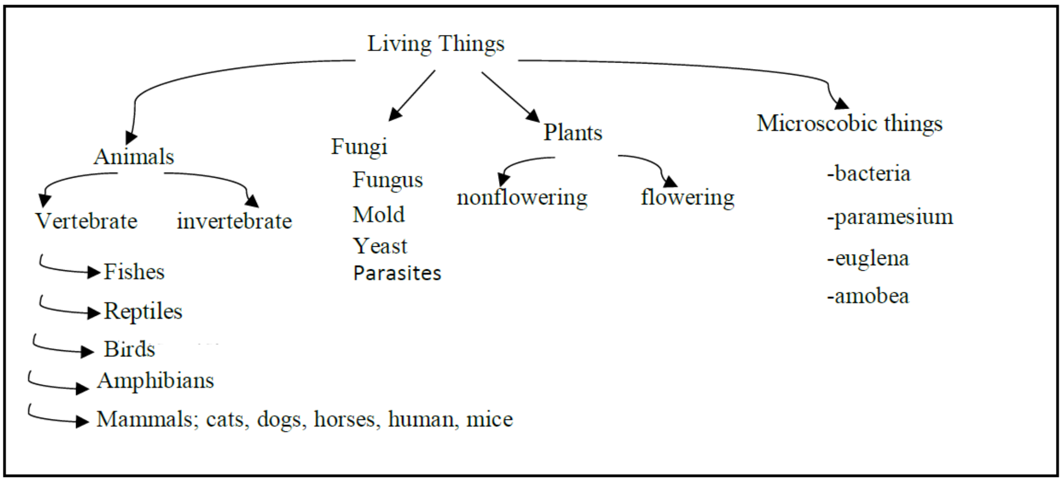

Figure 4.1. 7. Ezgi's drawing from the in-class observation

4.1.3.3 Ezgi's Knowledge of Students' Knowledge and Understanding

Ezgi's understanding of this component was revealed by analysis of two sub-components which are knowledge of requirements for learning and knowledge of students' difficulties.

4.1.3.3.1. Ezgi's Knowledge of Requirements for Learning regarding Ecosystem

> I: According to you what is the prerequisite knowledge that students need to know in order to understand the ecosystem? Could you explain your answer?
>
> Ezgi: *We already teach topics related to ecosystem in the previous grades. They need to know some basic information like classification and feeding styles of living things and their living areas; they live in water or on land.*

According to Ezgi, students need to know concepts like classification and feeding behaviors of living things. She mentioned that students need to know these concepts because students learnt them in previous grades.

> I: What are the most important concepts or points students need to learn in ecosystem? How did you determine those?
>
> Ezgi: *The most important… I actually cannot rank them in order because they are all related to each other. First teaching the underlying concepts then the*

ecosystem concept… How to say it? Like inductively. First giving the pieces of information and then allowing students to comprehend the whole which is ecosystem.

I: Which concepts do you expect your students to learn and what do you think they will do with this knowledge?

Ezgi: *When students are watching a documentary in their daily lives, for example, "What are the environmental factors affecting the desert or marine or polar ecosystems?", "Which living things can live in these ecosystems based on that environmental factors?" or "What do those living things need to live there?". That kind of...we aim to broaden students' horizons to the highest level about the issues they encounter in their daily lives.*

According to Ezgi's answer, it can be inferred that her goal of teaching ecosystem is related to students' daily lives rather than academic achievement.

I: What kind of advantages does knowing ecosystem provide to the students? Why?

Ezgi: *It is definitely an advantage. Maybe when they decide their professions in the future, they could be interested in this field, about environment or animals and plants. That could be an alternative for them after learning these [knowledge about ecosystem].*

I: How do the students use their knowledge if they do not decide to study or work in this field?

Ezgi: *As I mentioned before, they develop a different point of view. Perhaps they will go to different places over the world, they could predict what they can come across. Or they can choose where to go and feed an animal then I think they understand it [the ecosystem concept] in their daily lives.*

Ezgi expressed the importance of teaching ecosystem topic by stating the need to know different types of ecosystems as a knowledge to use in case of living another place or having an ecosystem related job.

4.1.3.3.2. Ezgi's Knowledge of Students' Difficulties regarding Ecosystem

Two different data collection tools were used to uncover Ezgi's knowledge of students' difficulties, namely interviews and ecosystem concept test. Findings were reported below.

> I: Which concepts do you think that students may have a hard time in learning ecosystem?
>
> Ezgi: *They mostly confuse the population with habitat concepts. One of them is the place [where] living things live and the other is the population of living things living in that region. They confuse them most of the time.*
>
> > I: What is the reason for students to have a hard time in learning these concepts according to you?
> >
> > Ezgi: *It is due to the use of everyday language in scientific context and it seems from insufficiency of their knowledge in Turkish language. They distinguish the difference after solving a couple of examples about whether the statement means a living thing or the place it lives.*

Ezgi's answer revealed that she assumes her students to confuse the concepts habitat and population. The reason she stated for that confusion was students' deficit in Turkish. However, she expressed that students need to a couple of practices on questions related to population and habitat concepts to understand it explicitly.

In classroom observation it was observed that Ezgi asked students whether they have heard the concepts habitat or population before and some students said that they have. Then she said; "You probably remember those terms from your social sciences classes." to students. Then she wrote some examples on the board to clarify which statement means habitat and which means population (see examples stated under Ezgi's CK for more information). Then Ezgi was asked how she determines students' misconceptions.

> I: How do you determine misconceptions of the students? Which methods do you use to determine it?

Ezgi: *I examine the previous knowledge of students by questioning method. If they have any misconceptions, I try to make my students to realize it by themselves. But if there were no answer, I explain it by giving examples. I do it in this way.*

I: Do you try to eliminate the misconceptions you determined? If yes, how?

Ezgi: *I use questioning method to understand whether the knowledge in the students' mind is correct or not.*

I: Do you think that this method is sufficient?

Ezgi: *I think for that topic [ecosystem], yes.*

Ezgi's method to determine any possible misconceptions was questioning. She added that she gets her students to realize their misconception by themselves but if they do not she explains the misunderstood ideas herself. According to Ezgi questioning method is sufficient to determine and eliminate the misconceptions of students. In class observation it was seen that she used questioning method and only verbally explained the answers of students.

However, she did not mention to approaches such as concept maps or drawings to determine misconceptions. To eliminate misconceptions, she did not also use conceptual change approach, analogies, and conceptual change texts. In the next section Ezgi's knowledge of students' understanding and difficulties based on the ecological concept test is revealed.

In order to examine her knowledge of students' understanding and difficulties, In pre-interviews Ezgi was also shown an ecological concept test including items related to ecosystem, plants' food, concepts like habitat, species and population, food chain as well as energy pyramid. And she was asked to predict questions which students are more likely to success or fail. After checking out the test, she indicated that the questions about energy transfer in an ecosystem would be hard for students to answer correctly because they will be taught energy concept in the eighth grade. She also added that even though the food chain concept was not taught in seventh grade, students might have had an idea about it. Therefore she guessed that questions related to definition of food chain and examples of food chain were the ones students might answer correctly. To clarify these findings, same test should be applied to the students.

4.1.3.4 Ezgi's Knowledge of Instructional Strategies

Knowledge of instructional strategies was examined via pre-interview questions and in-class observation notes. Results of the sub-components of knowledge of instructional strategies which are knowledge of subject specific strategies and knowledge of topics specific strategies (knowledge of activities and knowledge of representations) were presented in this section.

4.1.3.4.1. Ezgi's Knowledge of Subject Specific Strategies

I: Which strategies or methods do you use while teaching science in general and why?

Ezgi: *In the beginning of the lesson, I ask questions to determine the preparedness level of students. Then I teach the objectives progressively starting from the species and move in the order [as specified in the curriculum].*

> I: How do you learn to use these strategies? Did you develop them yourself or learn from another source (person, crammer etc.)?
>
> Ezgi: *I am graduated from the faculty of education [so I learned them in undergraduate level courses] and proceeded by experiencing in years [as a teacher], these [knowledge of instruction] are established things. And of course, we use the things [instruction methods] tried and gave positive results [by other colleagues].*

Her response showed that Ezgi's mostly used teaching technique was questioning to determine the preparedness level of students and the direct instruction method takes the second place among other strategy options. She indicated that she learnt to use these methods from her college education and teaching experiences.

I: Which method do you use while teaching ecosystem? Why?

Ezgi: *I primarily examine eba but when I compared an educational internet platform and eba, morpa campus is more detailed and it generally attracts students' interests. Also, if we have time, we watch interesting 3D videos or documentaries which are advanced level for students and out of objectives. These videos support students' knowledge and make it permanent. Also, we can take questions from the videos. [Note that in eba there were questions provided after videos for students to answer.]*

> I: How good are you at providing students with examples and alternative explanations when students get confused?
>
> Ezgi: *I definitely answer students' questions immediately when I determine if they have further questions or detect any misconceptions. If their questions were not answered immediately, they may forget it [their questions] or their concentration remained in the question [not in the lesson]. They cannot follow the rest of the lesson or they continue [their education] with the wrong knowledge. I consider solving it [the question] at the beginning and answering their questions immediately. And I actually encourage students to find their mistakes by themselves and the reasons why they think like that.*

In classroom observation it was noted that Ezgi mainly used direct instruction and questioning for teaching ecosystem as she mentioned. Also she used morpa campus to show some videos and to solve questions provided there. Ezgi stated that she used crammers as well as some visuals from morpa campus and eba in addition to the science-book approved by ministry of national education. In the class observations partly support this finding that during instruction she actually used both the text-book and the pictures and videos in the class. However, she did not use any crammer book and eba during the lessons observed.

> I: What kind of a connection, if any, is there between your objectives and the method you chose? To what extend your choices represent your objectives?
>
> Ezgi: *It depends on the content of the topic as I said before; this [ecosystem topic] does not include too much activities or any experiments. Giving examples both from daily life or the living things that students are familiar*

with, connect it [the lesson] with students' daily life. I try to retain it [the lesson] by questioning.

I: Is there any areas that you see the application of ecosystem in daily life? Do you use it in your teaching?

Ezgi: *Its application as I mentioned if you remove a rock from the soil, you can also see an ecosystem under it. You can see an ecosystem when you look at whole Earth so it [ecosystem] is definitely related [to students' daily life].*

In classroom observations Ezgi used examples from daily life as she stated in the interviews. For example she mentioned under a rock, a village she remembered from her childhood and lakes in Ankara for ecosystem.

I: How good are you at engaging students with the lesson? Why do you think you are good/bad? How did you decide?

Ezgi: *I cannot say I am a hundred percent successful since it changes according to the class size and the preparedness level of students. Some of the students always want to participate into the lesson. I try to engage the ones who are willingness to participate even when they do not raise hand to speak.*

I: How do you determine whether your teaching is effective or not?

Ezgi: *[I determine the effectiveness of my teaching] from students' appropriate questions. Sometimes students ask questions which are above their level of understanding. We sometimes cannot answer to these kinds of questions [higher order questions] in order not to violate objectives but we [should] give an appropriate answer to satisfy their curiosity. Because violating objectives by answering the question may result in students' ability to answer even a simple question wrong by thinking in a complicated manner. This is due to the extra information they learned.*

As mentioned above Ezgi's teaching was based on subject matter and schooling goals. Hence she used direct instruction by using text-books and videos from morpa campus. Students were passive during the instructions and were only mainly answering what

Ezgi asked them. Therefore Ezgi used direct instruction and questioning method while teaching.

4.1.3.4.2. Ezgi's Knowledge of Topic Specific Strategies

Knowledge of topic specific strategies was reported under two dimensions in terms of Ezgi's knowledge of representations and Ezgi's knowledge of activities. Firstly, findings of Ezgi's knowledge of activities and then Ezgi's knowledge of representations about ecosystem are presented.

4.1.3.4.2.1. Ezgi's Knowledge of Activities

I: Do you use any activities regarding ecosystem subject?

Ezgi: *A different activity… As an activity I did not come up with an idea right now but I can get students watch videos and visuals… We have difficulty in using time efficiently because the first science units of seventh grade, [which are systems in human body, force and energy, properties of matter and reflections in mirrors] are difficult. [Note that time allocated for ecosystem less than the other units in seventh grade which is 10 lesson hours].*

Ezgi indicated that she did not allocate any time to create and do any activities specific to ecosystem topic because the time dedicated to ecosystem topic was limited [6.9% of time allocated for all units in seventh grade] compared to other topic in the seventh grade [such as 20.9% for properties of matter and 19.4% for systems in human body units].

I: How good are you at finding effective activities? Why do you think that you are good/bad? How did you decide?

Ezgi: *I honestly cannot say that I am not very good at creating new activities for the lesson because there is a need for a serious preparation before the lesson to do so. If we did not have such a dense curriculum or time pressure, I would have prepared an activity. Therefore we unfortunately have to follow readily available activities in the lessons.*

I: How do you know/decide whether an activity or strategy you planned to do is efficient or not?

Ezgi: *By monitoring students' appropriate and inappropriate behaviors during the activity, and if right answers are coming to the questions, the activity becomes successful in the end. What and how much students gained can be easily understood by observing students' behaviors. We can use measurement tools for evaluating students but we can also to do so by observing them; needing any kinds of measurement tools.*

To conclude Ezgi stated that she used questioning method to teach ecosystem topic as well as to determine and eliminate misconceptions of students if there is any. However, she did not mention any other methods like role play, problem-based learning and field trip. On the other hand she expressed that she immediately answered her students' questions in the class in order to get their attention without letting them distracted by their questions. According to her, since the ecosystem topic was not a topic that needs an experiment or a special activity, she used this method to teach it. To determine effectiveness of her lesson, she stated that she simply observes her students' behaviors in the classroom, for example according to her, rate of correct response was one of the indications of effectiveness. In this section Ezgi's instructional strategies were reported and in the following one her knowledge of measurement and assessment techniques is introduced.

4.1.3.5 Ezgi's Knowledge of Measurement and Assessment Techniques

I: Using which measurement techniques do you assess students' understanding?

Ezgi: *We primarily use test and questioning activities from smart board and tests found within or at the end of the course book chapter because nowadays there are tests containing puzzle and schema-like questions including more pictures. Yet the other crammers we use also have entertaining activities which are not directly on question and answer test type. We take these tests in the* *lesson flow, either following the text-book or from the smart board. We actually need to do evaluation in the end of each chapter but most of the time we do not have time to do that. If time left, we should do something to get a feedback [from students] and summarize the chapter.*

I: Why do you use these measurement techniques you mentioned before?

Ezgi: *Students naturally become more eager as it [ecosystem concept] attracts students' attention.*

Ezgi's answer revealed that she used tests from books and educational sites. She pointed out that she used smart board to project the question or quizzes for students to see and solve. She gave the reason to choose them as these questions' ability to attract students' attention more. However, she complained about the fact that to time left for an end of chapter evaluation, getting feedbacks from students and summarizing the unit. In class observation it was monitored that while teaching the subject, Ezgi asked students to open their text-book and answer the short quizzes presented there [in the text-book]. After students answered the questions Ezgi answered the questions with the class as a big group discussion. In addition she used morpa campus site by projecting the questions on smartboard. Therefore she used formative assessment in the classroom. Then she was asked about the ways she uses the results of these assessments in the following question.

I: How do you use the assessment results? What do these results tell you about?

Ezgi: *The results of assessment are very important while giving students grades [in addition to their participation to class because we also take students' participation into account]. But some students were introverted and prove themselves only in written examinations. We try to find a compromise.*

Although Ezgi expressed the importance of the assessment scores in the class, she only mentioned about the grades by adding that those students who are less active in the classroom were able to show themselves in written examinations. When she was asked about the assessment techniques she did not mention the written examinations for ecosystem topic. Then in the following question, she was asked about creating new assessment techniques.

> I: How good are you at finding new assessment techniques? Why do you think you are good/bad? How did you decide?
>
> Ezgi: *Written examinations are already used to assess students' achievement. But students' making wrong and right in questions in the class is not important. I assess students' participation and attention to the lesson. I encourage participation of the silent ones with some guidance.*

Ezgi spoke out the written examination when it comes to finding new assessment techniques. However, she also added that she used her in class observations to assess students' processes like participation and following the lesson.

> I: What exactly do you aim to assess while measuring students' knowledge about ecosystem?
>
> Ezgi: *At first there are four basic concepts [systems in human body, force and energy, properties of matter and reflections in mirrors] we are going to teach in the beginning. Do students distinguish them? Then there are ecosystems in the world and distinction of these ecosystems and characteristics of living and non-living things especially their interactions. We will check whether we could teach these [ecosystem concepts] or not at the end of the lesson.*
>
> I: When do you measure students' understanding? Why did you choose this time?
>
> Ezgi: *We have to check if students learn after each concept step-by-step although there might be a general examination at the end of the unit [on ecosystem]. If students did not learn the concept in the beginning and we continue without giving them an opportunity to ask, they will not learn the rest.*

Although Ezgi mentioned her aim to teach ecosystem topic was not only to teach the objectives but also broaden their horizons, she only talked about assessing the objectives. For example she expressed how it was important for students to know the subject in situations like traveling or living another place in the world or feeding an animal. However, she just stated four basic concepts in ecosystem as well as ecosystems' characteristics and interactions between living and non-living things in an ecosystem. In the following question it was asked when she prefers to use the assessment.

Ezgi indicated the need for assessing students after each concept and a general examination at the end of the unit, although she complained about the limited time for activities and assessment before. In classroom observation, it was noted that she asked her students to solve the related questions found in the text-book. Moreover she gave an exercises page in the text-book as homework for students. She did not mention how she uses home works as an evaluation. In addition she used true false questions in morpa campus such as by giving the floor to volunteered students so it can be said that she not only used visuals and different schema and puzzled-like questions but also the true-false and multiple choice questions. Moreover she gave a homework for a summative assessment of the day. In this section Ezgi's content knowledge and pedagogical content knowledge regarding ecosystem was introduced and in the next section; Nilay's content knowledge and pedagogical content knowledge regarding ecosystem are be documented.

4.2. CASE 2: Nilay's Content Knowledge and Pedagogical Content Knowledge Regarding Ecosystem

4.2.1. Nilay's Background

Nilay is a science teacher for more than 15 years in her 24 years of teaching life. She has a B.SC. Degree in chemistry education. She has been teaching science for 6 years in that school. She attended TEMA (The Turkish Foundation for Combating Soil Erosion) conferences. And her interest towards ecosystem comes from her childhood years as she indicated that she was enjoying to observe the nature.

4.2.2. Nilay's Content Knowledge Regarding Ecosystem

Nilay's Content Knowledge on ecosystem was investigated through interviews, concept map and drawing. During interviews, they were asked several questions related with basic ecological concepts and principles. At the same time, they were asked to prepare a concept map and draw an ecosystem, food chain, food web and energy pyramid to reveal their content knowledge on ecosystem. Their responses and their concept maps were used to understand their content knowledge on ecosystem which is important factor enabling teachers to achieve effective ecosystem teaching.

In the interviews Nilay answered nineteen questions related to concepts regarding ecosystem. Those answers were used to figure out Nilay's knowledge about basic terms of ecosystem. Teachers' drawings reproduced by the researcher based on participants' original figures.

The first concept asked to define is "system".

I: How do you define a system?

Nilay: *[Is it] A small system in an ecosystem? I mean, we can say an organization which has interrelated associations.*

> I: Can you give an example, please?
>
> Nilay: *Even a school is a system.*

I: What is it that makes school a system?

Nilay: *Student factor, teacher factor, all nested in each other since it is an embedded structure.*

I: Do you think that ecosystem is a system? Why?

Nilay: *Ecosystem is a system because there are many living and non-living things [in it] which interact with each other in it.*

She defined system as an organization since it has various interrelated organizations in it. She gave school as an example to a system. She expressed that the interaction between students and teachers make her example a system. Therefore it can be said that Nilay had a sound understanding of a system.

According to Nilay's answer ecosystem as a system because ecosystem has living and non-living things interacting each other like she mentioned that a system has interrelated components in it. Then in the next question Nilay was asked about the components of an ecosystem.

I: What is an ecosystem composed of?

Nilay: *Like I said before, living things, air, water, soil, sunlight, temperature etc.*

Nilay mentioned that living and non-living things are the components of an ecosystem by giving examples to some non-living things like air, water, soil, sunlight and temperature. In order to explore Nilay's understanding further, she was asked to say 12 words that come to her mind about ecosystem (WAT). She was able to list ten words for that question. Her answers were shown in Table 4.2.1 in group of concepts.

Table 4.2. 1. *Nilay's concepts as shown in WAT*

Groups of concepts	Concepts that were mentioned in regard to each category
Biotic	Plants Animals Population Species
Abiotic	Air Water Soil Sunlight Temperature
Other terms	Habitat

After getting her answers we categorized them under three groups as biotic, abiotic and other terms as seen in the table 4.2.1. Habitat is put under the other terms because the concepts like habitat is a place so it did not belong to abiotic or biotic groups were put. All in all when we looked at her WAT answer and definition of ecosystem, it can be said that Nilay had a partial understanding of ecosystem because she only pointed out some natural elements such as soil and water besides naming a few living things such as animals and plants. However, most of the components were missing. Moreover she did not mention how living things and non-living things interact in an ecosystem and energy flow or material cycle in an ecosystem. In order to understand Nilay's cognitive structures based on concept of ecosystem, she was asked to develop a concept map of ecosystem.

I: Please draw an ecosystem concept map.

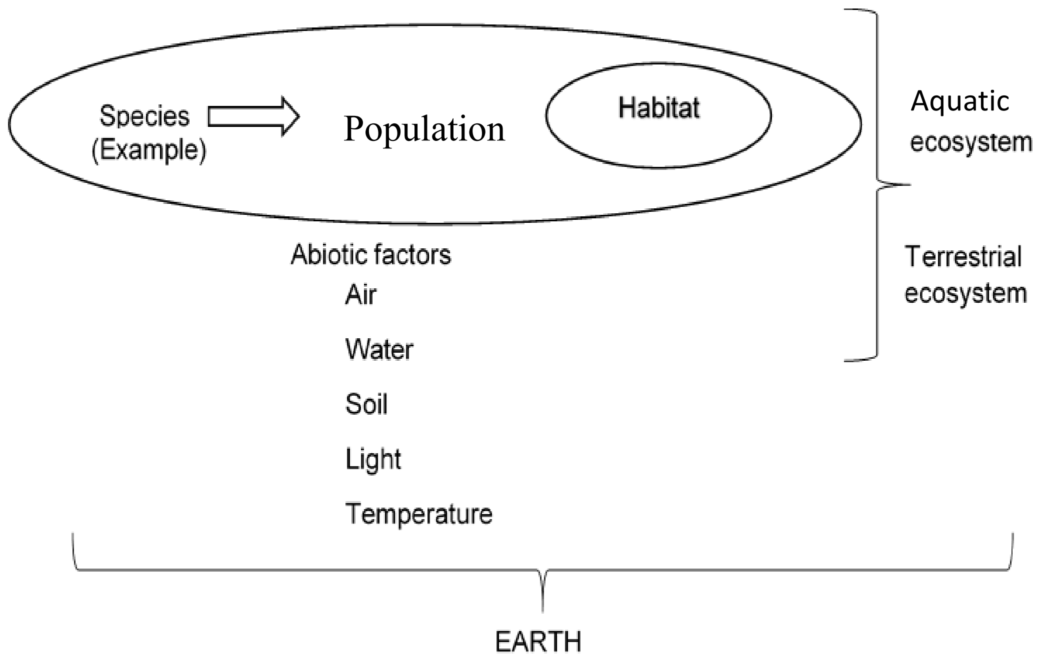

Figure 4.2. 1. Nilay's drawing of ecosystem concept map

Nilay: *First of all in the concept map we need to give the examples of species. We will say when species come together, they form population. They need to have an area to live. We will define that [area] as habitat. And then besides living factors, non-living things affect them [living things], should I write them [abiotic factors] on concept map? Let's write them [abiotic factors] like this [one under the other as seen in the concept map she drew]. After that, we give the examples of ecosystems as aquatic ecosystem and terrestrial ecosystem. And when I get all of them together, I guess I conclude that it [the ecosystem] is a huge Earth.*

Nilay's concept map focus on one particular aspect of ecosystem; living and non-living things. While forming a concept map, Nilay mentioned some abiotic factors like air and water but she did not exemplify the biotic factors. She only included species and population in her map. Moreover she did not identify the arrows and linking words in her concept map. However, she gave two examples to ecosystems (i.e. aquatic ecosystem and terrestrial ecosystem) and clearly expressed that Earth is the biggest ecosystem where we live. To get more information, then, she was asked to draw an ecosystem and explain its components (see Figure 4.2.2.).

I: Please draw an ecosystem and explain. What are the components of that ecosystem?

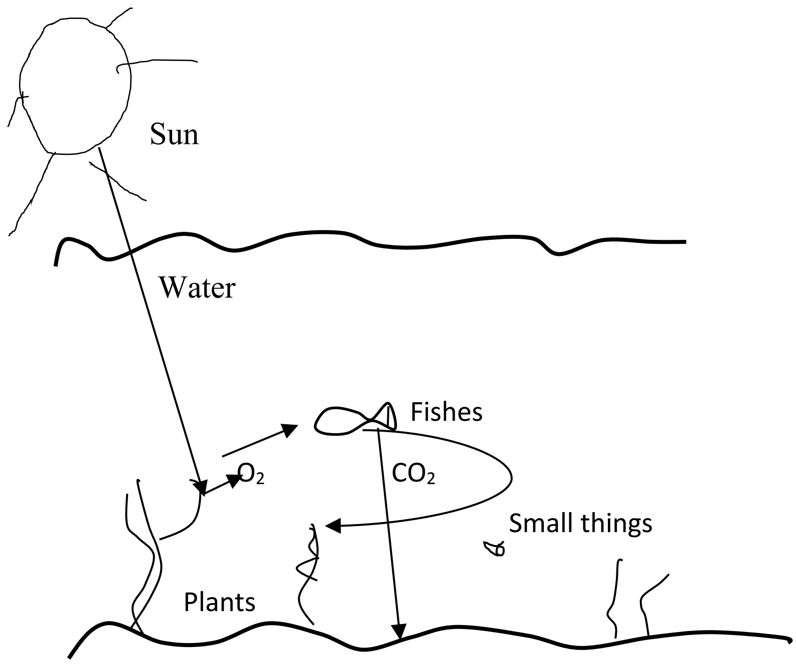

Figure 4.2. 2. Nilay's drawing of an ecosystem

Nilay: *Let's draw plants here [under the water] and small things, too. We need sun light, of course. There is air. Oxygen produced here [from plants] and carbon dioxide given off [from fishes to the soil].*

According to Nilay's drawing, her DET score was calculated as 4 over 16, the Table 4.2.2 shows DET evaluation of Nilay's ecosystem drawing.

Table 4.2. 2. Nilay's DET scores

DET rubric	**Score**
Human	0
Biotic plants touching ground, animals swimming under water)	2
Abiotic water touching ground	2
Human built	0
Total Rubric Score	4

Nilay's DET score showed that she had difficulties in her drawing of ecosystem with her score of 4 form DET rubric. It was seen that she had no extra components on her drawing.

In Nilay's drawing there was a distinct ecosystem which mainly emphasizes biotic factors like fishes, plants and other small things. Moreover, there were only sun, water and plants in the water's ground. However, beside only basic interactions of living and non-living things like fishes swimming in the water, there were no indication of human or human built in the drawing. Thus, Nilay scored 4 according to DET rubric (see Table 3.4.). Then Nilay was asked to explain the energy flow in the ecosystem.

> I: Please draw and explain the energy flow in an ecosystem.
>
> Nilay: *Let's say like this [showing the ecosystem picture she drew above]; plants get energy from the sun and as the plants grow, fishes feed on them. Then let's say these [wastes from fishes] go to the bottom again [to the soil].*

Unlike her explanation of system and ecosystem which did not emphasize the interaction between its parts, Nilay's drawing and responses to energy flow question indicate some clues about her understanding of such interaction. For example, when asked about energy flow, Nilay explained some feeding interactions in her ecosystem. She correctly defined sun light as the energy source but she did not mention what happens to wastes that went back to the soil. When as to explain the processes that occur in her ecosystem and the connections of these processes, she stated that animals' waste such as their dropping probably become fertilizer for plants.

> I: Can you explain which processes occur in that ecosystem? Is there a connection between these processes?
>
> Nilay: *There is already a connection among them. There is a living area for all the organism [living things] not only for fishes. There is a material exchange as well. For sure, there is a sun light as it [living things] is needed. There are plants that they [fishes] can feed on. So, they are all linked to each other, animals' waste such as their droppings probably become fertilizer for them [plants]. Students can also increase the number of [such] examples.*

In short although Nilay defined ecosystem without mentioning flow of energy and cycling of matters in ecosystem, her answers to remaining pointed out that she was actually knowledgeable about the material cycle and energy flow in an ecosystem. In brief, according to Nilay, ecosystem is a system which includes living and non-living things interacting with each other. She exemplified the ecosystems as aquatic ecosystem and terrestrial ecosystem in her concept map. She mentioned the cycling of oxygen and carbon dioxide in her ecosystem drawing. In her drawing she showed energy transfers in the ecosystem with arrows she drew when she was asked to. Yet there was no human indication in none of her definitions and drawings.

In class observations, similarly, it was noted that Nilay mentioned that an ecosystem included both living and non-living things. She used a factory as an analogy for an ecosystem to emphasize the system in the factory that helps factory continue to work. Moreover, she said that fishes do oxygen interchange with plants in the water. Likewise, Nilay also gave students the same example that the Earth is a huge ecosystem. However, while talking about the interactions in an ecosystem she said that humans are not included in ecosystems. Therefore, it can be said that although Nilay had a partial understanding of ecosystem as well as what system is and naïve understanding on human interactions in ecosystems.

Then Nilay was asked to define some other concepts related to ecosystem and give examples for them.

4.2.2.1. Nilay's Knowledge regarding Basic Terms about Ecosystem

I: What is a species? Please give an example.

Nilay: *The individuals that have features special to them and own characteristics which lead to breeding. I will give anchovy [as an example] for species.*

Nilay defined species as individuals having certain characteristics for reproducing and gave anchovies as an example. In classroom observations, it was noted that species were defined as the smallest unit of an ecosystem. However, she did not explain the term smallest unit in detail. It was noted that Nilay assigned some students to prepare and make an informative presentation about ecosystems in the class. While students were giving information about ecosystem in their presentation, Nilay was making comments and asking students questions when she felt necessary. The students who were in charge of making presentation on ecosystem by Nilay gave cats, dogs, mice, horses, frogs, penguins, spiders, snakes, flamingos, tigers, lions, camels, pandas and rhinos were given as examples of species in their presentations. Therefore it can be said that Nilay had a partial understanding of species with her example of anchovies. Then she was asked to define population.

I: What is a population? Please give an example.

Nilay: *The community that species form. Let's say herd of sheep.*

I: What is a community then? Can you give an example?

Nilay: *The community of the living things existing there [living area]. We can say ants.*

Nilay used the term 'community' in defining the population. Hence there was not much about in her population definition. This answer partly implied that Nilay perceive Population same as community'. Hence there was not much about in her population definition, yet. She provided a correct example which as herd of sheep. She did not explain the characteristics of population, mention any certain functional traits of species in common and include the environmental conditions of population. In classroom observations, Nilay gave examples of 'lions in Africa'. She said that while "Animas in Africa" cannot be an example of population, 'lions in Africa' can. Likewise she added that "Fishes in the Black Sea do not refer to population but anchovies in the Black Sea do." She seemed to be knowledgeable about the concept that 'All of the member of one species that live in the same area at the same time make up a population'.

Although all of the examples were accurate for defining population, she had a naïve understanding in defining it. Moreover in the class some of the factors that change population size like births, deaths, food deficit and migrations were talked about. In addition the damage that human gave was touched upon for breaking the population equilibrium. These findings revealed that she was aware of the fact that populations are dynamic groups of organisms that adapt to changes in environmental conditions (Reece & Campbell, 2011). It was observed that budgies, bees in a hive, saurels in the Marmara Sea, sheep, oaks and anacondas in forest and parrots in meadows were given as examples of population by students.

Her understanding of community, however, remained to be unclear. Nilay defined community by using the word 'community' again. Her example for the community (i.e. ants) is not clear either. Since communities consist of many species, which interact in a number of ways. In other words, they include all the organisms, not only ants, inhabiting a particular area (Reece & Campbell, 2012). Although she did not indicate potential interactions of the assemblages of all the populations during interviews, in the class, Nilay expressed the difference between population and community (although it was not a prescribed objective in the curriculum 2013) by saying "When we say fishes in the Black Sea, it defines a community but we say only anchovies in the Black Sea, it defines population." Hence as she defined community partially correctly and gave adequate examples, she had a partial understanding of community. Next she was asked about habitat.

I: What is a habitat? Please give an example.

Nilay: *A living area. What should we say? Soil…soil is a habitat for ants.*

Nilay correctly defined the habitat as a living area of an organism with the example of soil for ants. She did not give any additional information about habitat such as the resources, food supplies or living conditions of the place and shelter. In classroom observations Nilay presented an example of an aquarium in İstanbul [İstanbul Aquarium] which includes rain forest and pole regions as habitat. She mentioned that in that rain forest, the necessary conditions like humidity were for survival of living things. Moreover she added that habitat does not have to be a big place. Then she gave an example of a tree and asked which living things live in the tree. And students answered that a tree can be a habitat for squirrels, worms, beavers, birds and some monkeys. She additionally gave a couple of examples like an ocean for fishes, whales and sharks as well as other living things that live under water and soil for worms and moles. In the next question the ecological niche definition and examples were asked.

I: What is an ecological niche? Please give an example.

Nilay: *We defined it as the work /job that living things do. That could be, for example, decomposers aerate the soil while continuously fixating the nitrogen in the soil. They are very hardworking [animals] for me.*

Nilay appeared to have a good understanding of ecological niche. However, it was observed that she did not teach the term ecological niche in her lesson as it was not included in the 7th grade science curriculum. On the other hand she mentioned that beavers construct dams in their habitat while talking about living things and their habitats. In the last question related to basic concepts of ecosystem, Nilay was asked to define biological diversity.

I: What is biological diversity? Please give an example.

Nilay: *A variety of living things living in a certain region. Flowers and insects specific to that region could all be examples.*

Nilay's answer showed that she only expressed species richness in her definition of biological diversity. Yet she did not express any genetic or ecological diversity. Therefore it can be said that Nilay had a partial understanding of biological diversity. In classroom observations, it was monitored that Nilay defined biodiversity as the richness of number of organisms living in various ecosystems in a region. She added that climate conditions, soil structure water and geographical conditions determine the biological diversity. She mentioned about the factors threatening biological diversity like increase in population, unsustainable use of natural resources and forest fires.

In summary, Nilay's answers showed that she had either sound or partial understanding about many of the basic terms related to ecosystem. She defined system, community, habitat, and biological diversity partially whereas had a sound understanding of ecosystem and ecological niche. However, she also had some naïve understanding on human interaction on ecosystem and population. After definitions of basic ecological concepts, Nilay asked questions related to the energy flow and corresponding concepts in an ecosystem. The related interview excerpt was provided below:

4.2.2.2. Nilay's Knowledge related to Energy Flow in an Ecosystem and Corresponding Concepts

According to organisms' status of producing or consuming energy in an ecosystem, they can be placed on a trophic level (Cebrian, 2015). Therefore in order to examine teachers' knowledge based on energy flow in an ecosystem and its components, Nilay was asked to describe, exemplify or draw some of the concepts related to ecosystem. First of all, producers were asked as they capture light energy and produce chemical energy by converting inorganic materials into organic materials.

I: What is a producer? Please give an example.

Nilay: *Plants, of course. Those which produce their own foods.*

I: What is the food of a plant?

Nilay: *Plants produce their own food by bringing together the sun energy with the minerals and water they took from soil and carbon dioxide while producing their own food.*

I: Can you explain the importance of the producers in an ecosystem?

Nilay: *They are very important because if they do not exist, no one can exist either.*

Nilay did not mention photosynthesis reaction and explain energy converted from sunlight to chemical energy by photosynthesis. Her ideas on how producers are important in an ecosystem was not defined well. She did not mention plants as autotrophs and the first step of energy flow. However, in classroom observations it was noted that she talked about producers verbally by mentioning them as living things producing their own foods. Therefore it can be said that Nilay had a partial understanding of producers. Then she was asked to define consumers.

I: What about consumers? Please give an example.

Nilay: *I will not give the human as an example, let's say bears. [Consumers are] The living things that consume ready foods.*

I: What is the importance of consumers in an ecosystem?

Nilay: *They consume.*

According to Nilay, consumers are living things that consume ready foods. However, she did not mention types of consumers; herbivores, carnivores and omnivores although in class observations she pointed out these types. Yet she was not clear about the importance of the consumers in an ecosystem. Therefore she had lack of understanding of consumers. In the next question she was asked about decomposers.

I: What is a decomposer? Please give an example.

Nilay: *We can say nitrogen fixating bacteria as decomposers. Let's put in this way; they provide deterioration of food wastes.*

I: What is the importance of decomposers in an ecosystem?

Nilay: *In fact they have an important place in order for balance in the nature to last and especially for producers.*

Nilay's definition of decomposers revealed that even though she mentioned just one example for decomposers, she did not indicate how exactly decomposers work. She did not mention the fact that decomposers a) form the basis of the material cycling in the ecosystem and responsible for completing and starting of the cycle of matter and b) convert organic materials into inorganic ones (Smith & Smith, 2015). In classroom observations, it was monitored that Nilay asked students about types of decomposers and got the answer of fungi only. She requested another example from the students but she could not get any. Then she asked her students to search decomposers for the next lesson. In other word, she did not give further explanation and finished teaching the concept of decomposers.

In the next question she was asked to draw and define a food chain.

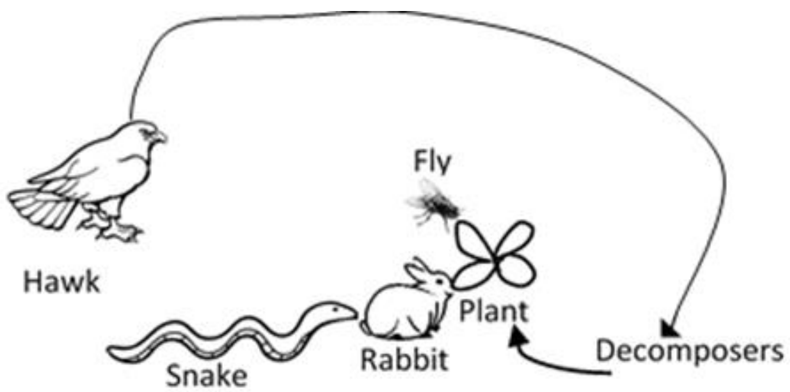

Figure 4.2. 3. Nilay's drawing of a food chain

Nilay: *Let's draw a fly. Flies settle on plants etc. Then, should I draw a rabbit? Should there be a snake eating the rabbit? Snakes can eat rabbits. After that, let us have a hawk eating that [the snake], a chain like this [formed]. Then, when this [the hawk] dies, it will mix into the soil and decomposers will decompose it. By this way, dead body will become useful again. What can be the other examples? I should start with a plant, of course. What can it be? A sheep, a bear eating the sheep etc.*

Nilay's drawing of food chain and her explanations showed that she had a lack of understanding of food chain for three reasons. First of all, she did not indicate the source of energy as sun by neither drawing nor mentioning it during interviews. Secondly, she did not put appropriate arrows to show the direction of energy flow in her food chain diagram. Lastly, although included decomposers as a part of the food chain she put it on the top, after hawk, which is a common misconception. Then she was given nectar, a butterfly, a bird, and decomposers to form a food chain if possible, to explore her understanding of food chain more.

I: When given "nectar, a butterfly, a bird, decomposers", do you think they form a food chain as given in the order?

Nilay: *A butterfly eats nectar, a bird eats the butterfly, and after the bird dies then decomposers may be there [at the end].*

Similar to the previous question, Nilay included decomposers at the top of the given food chain. Therefore, depending on her responses to questions ask in the study, it can be concluded that she had a naïve understanding of place of decomposers in a food chain. These means that she has difficulty in relating the role of decomposers in a food chain. In the following question she was asked to define whether or not food chain related to the cycle of matter.

I: Is there any relationships between matter cycles and food chains? Please explain your answer.

Nilay: *Of course, I mean the water cycle must exist so that the food chain can continue. Air must exist for the conversion of carbon dioxide to oxygen.*

According to Nilay there is a relationship between food chains and the cycle of matter. However, she was not clear about the reason why matter should cycle for a food chain to continue. In the next question, her understanding of food web was assessed.

I: Please draw a food web and explain.

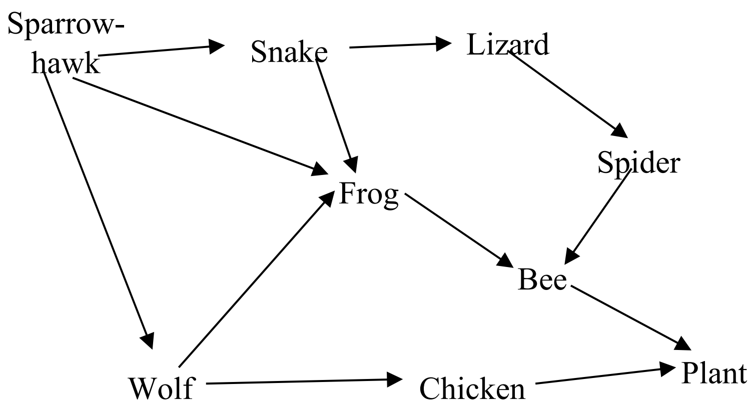

Figure 4.2. 4. Nilay's drawing of a food web

> Nilay: *In the food web, there will not be a single line like this [pointing on a single food chain that she drew previously]. Everyone will eat each other. Let us draw a plant and an ant eats the plant. Or let it be a bee. The bee benefits from the plant. Then this bee, can be caught by a frog. Then let there be a chicken eating that [same plant as bee feed on], a wolf eats the chicken and frog as well. Let there be a spider, which can be eaten by a lizard. Lizard is then eaten by a snake and let this snake also eat that [frog]. Then, what can consume the snake? [Are there any animals] bigger than snake? Let's say a sparrow-hawk which eats both frog and wolf etc.*

As it can be seen from Nilay's drawing that she wrongly depicted the direction of energy flow among the components of her food web by placing arrows into the opposite direction. According to her drawing, for example, both snake and wolf were eaten by frog. Nevertheless her explanation was correct, another shortcoming of her drawing and explanation is that she did not mention the sun as a main source of energy and decomposers in her food web. Therefore it can be said that Nilay had a naïve understanding of food webs and energy flow in food webs. Since energy concept is missing in her explanation, in the following question Nilay was directly asked to draw energy flow in an ecosystem.

I: Please draw the energy flow in a food chain and explain.

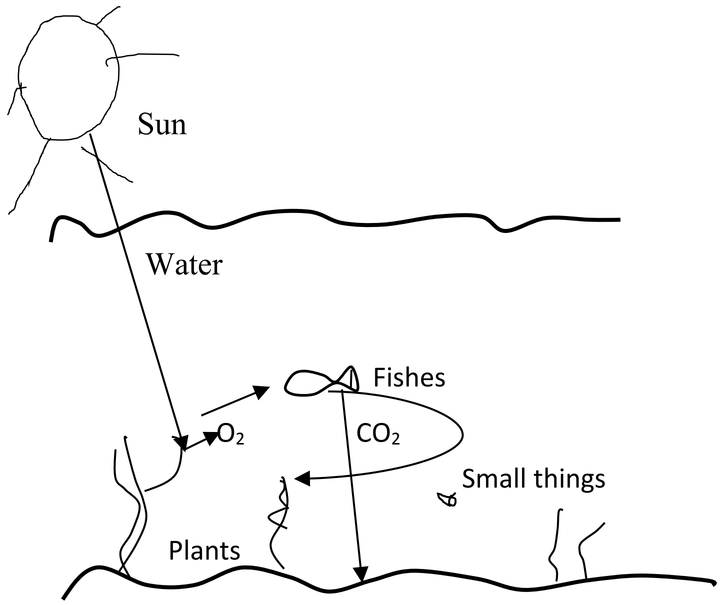

Figure 4.2. 5. Nilay's drawing of energy flow in an ecosystem

Instead of drawing the new one, Nilay used her ecosystem drawing to show how energy flow in an ecosystem. She said "The sun gives out its energy to the plants and plants use carbon dioxide from fishes with sun light and produce oxygen. Then fishes and other small creatures use oxygen. After fishes die, or produce wastes, their wastes go to the bottom [of the sea]."

Nilay's answer showed that she actually knows the source of energy in an ecosystem is sun although she did not mention it before. Moreover she was able to point out the energy flow between producers and consumers. However, in this step, she did not focus on energy transfer between producers and consumers but consumers' use of oxygen produced by plants. Again she did not mention decomposers, instead she mentioned that the wastes of fishes go to the bottom, she did not also indicate the fact that fishes are not the only one that produces wastes or die after a while. There were also plants and others in her drawing. . In attempt to get detail information, she was requested to describe the interactions among o producers, consumers and decomposers.

> I: In what ways, do producers, consumers and decomposers interact with each other? If any?
>
> Nilay: *While producers are producing their own food by themselves, consumers feed on them. And they [living things] have a lifespan. After they [living thing] die and merge with the soil, decomposers can make them [dead organisms] more useful.*

Nilay’s answer revealed that she knew the interactions but while explaining how decomposers work, she was not explicit. Then she was asked to draw and explain an energy pyramid in order to identify whether Nilay’s understanding of organisms’ trophic levels which they hold according to their levels of consuming or producing energy (Campbell, 2011).

> I: What is an energy pyramid? Please draw an energy pyramid.

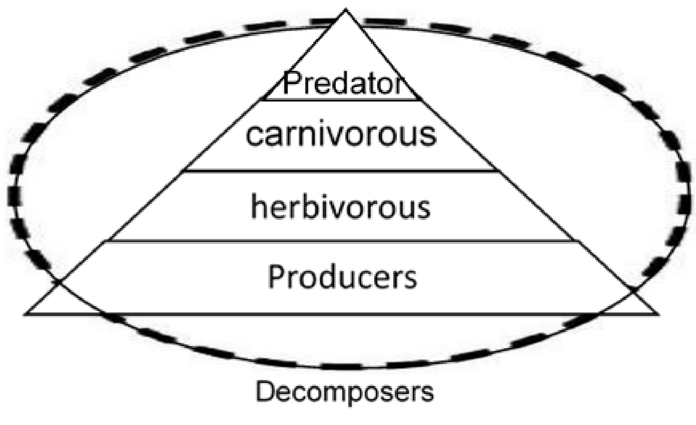

*Figure 4.2. 6***.** Nilay's drawing of an energy pyramid

Based on the trophic levels, Nilay's drawing of energy pyramid can be accepted as correct. However, she did not place decomposers at a level at first until she was asked about it in the following questions.

I: can you Explain Where do decomposers take place in your drawing.

Nilay: *When we gather all of their [the all living things' in the energy pyramid] dead wastes, decomposers make [usable] products out of each of them.*

When Nilay was asked to form a food chain, she put decomposers at the top but here in the pyramid of energy question, she explained it appropriately by saying that decomposers should be in every level.

Then in order to examine her reasoning for the shape of the energy pyramid, she was asked to explain it in the following question.

I: Why is its shape a pyramid?

Nilay: *Its shape is a pyramid because energy level is higher at the bottom and we see that this [the energy level] decreases as moving upwards.*

While explaining the reason of the shape of energy pyramid, Nilay stated that it was because of the decrease in the amount of energy when moving from producers to consumers. Yet she did not mention the reason or amount of that the energy decrease. Next in order to see if she was able to express her knowledge in 2^{nd} law of thermodynamics, she was asked following question:

I: Is it possible to invert the energy pyramid upside down? Please explain.

Nilay: *No, because the sequence of feeding relation or feeding rank is toward upwards.*

Following the 2^{nd} law of thermodynamics, pyramids of energy cannot be inverted, since there is always a loss of energy into environment (as respiratory heat) at each transfer. Therefore Nilay gave the correct answer without reasoning it correctly. Next there were more questions regarding the 2^{nd} law of thermodynamics like;

I: Is the length of a food chain limited? In other words, are there any factors limit the length of a food chain?

Nilay: *No, it is not limited.*

Although Nilay mentioned the decrease of energy towards the upper trophic levels in energy pyramid, she did not use her knowledge in answering this question. However, she was not right in her answer because the energy loss in every succeeding trophic level of energy pyramid is a limit to the food chain. Then she was asked whether it is possible to recycle energy in an ecosystem or not.

In classroom observations, it was noted that Nilay did not mention food chain, food web and energy pyramid in the class since it was not prescribed as to be taught in seventh grade in science curriculum (MNE, 2013).

To sum up, Nilay correctly defined the term species and stated anchovies are examples to species. Moreover when we asked, what habitat is, she responded that habitat is a living area. She gave soil as an example habitat for ants. Although ecological niche is not prescribed for teaching in the curriculum, she correctly described it by indicating decomposers' important jobs in aerating the soil.

However, she had a naïve definition of population. While defining population she expressed that it is a community that species form but she gave correct example for population by saying sheep. In addition she exemplified community correctly, yet she did not define it properly. She did not mention any potential interactions in community.

Lastly she had difficulty in defining and providing examples for the concepts of producers, consumers and decomposers. When asked what producer is, she defined it correctly but neither did she mention its food as glucose nor state their importance scientifically correctly. Although Nilay explained what the consumers were correctly, she did not explain the importance of consumers in an ecosystem. Moreover she did not mention that consumers do not produce their own foods instead she simply said they consume ready foods the kinds of consumers such as omnivores and herbivores were not mentioned as well. Although she gave a correct example for biotics, she did not mention about interactions of them in a community. So it can be said that she has partial understanding about community.

She gave a sheep and bear eating sheep as a food chain example in addition to what she drew to explain a food chain. Although she mentioned flies settle on plants, she did not directly indicate flies feed on plants but she only drew a fly on the plant she drew. In both questions; drawing of a food chain and forming of a food chain with nectar, a butterfly, a bird, decomposers, we can see that Nilay placed decomposers at the end of the food chain. Therefore as we can say that she has a misconception about decomposers. When Nilay drew a food web, she placed arrows in the wrong direction. For example in her food web, although chicken is fed by a plant, she placed the arrow from chicken to plant. Thus she has a misconception on how to point arrows while drawing a food web.

In this section Nilay's ecosystem content knowledge was introduced and in the next section; Nilay's topic-specific pedagogical content knowledge regarding ecosystem is documented.

4.2.3. Nilay's Topic-specific Pedagogical Content Knowledge Regarding Ecosystem

In the table Nilay's summary of PCK was shown.

Table 4.2. 3. *Summary of Nilay's PCK*

Pedagogical questions/prompts	**A summary of Nilay's PCK**
What you intend the students to learn about this idea	My first aim is to raise environmental awareness. …… I think that people's impact [on ecosystem] should have been included in the curricula since they have lots of negative effects on this ecosystem. Think about endangered species…. the only reason for species get endangered is the human being. That is why we need to realize what we have done in the ecosystem.
Why is it important for the students to know this?	It helps students to have a clear understanding of environment, and see that even a small creature in the nature has an enormous role in it [ecosystem] helps them to figure out that all of the creatures live in a harmony. The students see the nature from a different view. Then maybe one day in the future, somewhere, they will have to use their knowledge [on ecosystem] they have learned, to protect the environment.
Difficulties connected with teaching this idea	For me, teaching ecosystem topic is not difficult. If we go outside, students can see that there is an ecosystem even in the school garden. Since it [ecosystem] is a subject that students can associate easily with their daily life …. So it is not difficult [to teach ecosystem topic].
Knowledge about student thinking which influences teaching about this idea	The students confuse habitat and population, for example. But when we provided students with appropriate example for habitat and population, they do not confuse them anymore. I guess the reason for that confusion is that the students do not use these concepts in their daily lives. Students should associate the subject with the living things topic because in the ecosystems, not only non-living things, but also living things play a crucial role. In this subject students are supposed to learn types of species, producers and

Table 4.2.3. *Continued*

	consumers so we should teach living things as a prerequisite knowledge.
Other factors that influence your teaching of this idea	I have concerns about if I cannot raise an environmental awareness because I am afraid of that in the future the environment will take a revenge from us. I support the lesson with question and answers or argumentation but I think that the visuals are more effective. Because it is better for students to grasp how fishes and plants in a lake live together. This concept [ecosystem] is not associated with [the concepts taught in] other grades. There was a unit on living things, we saw it [living things unit] there [in the fifth grade], of course, when teaching matter concepts such as soil and water I combine these topics [with ecosystem].
Teaching procedures (and particular reasons for using these to engage with this idea)	First of all, I teach according to the content [prescribed in the science curriculum]. I always ask the why/ how types of questions since I did not observe development of a student [in the lesson] who cannot answer a why type question. Next I want them review the lesson. Questions found at the end of the chapter help me but I do not give homework from another crammer. There are web sites that students obtained visuals [documents]. Generally, our course book is sufficient [for visuals]. I use eba [educational informatics network] and an online platform providing educational videos to support my teaching. Other than these, we do not use any materials. Generally, as I said, we use visuals or videos of an ocean when teaching it [ocean] but otherwise I draw simple figure on the board.
Ways of ascertaining student understanding or confusion about the idea	The first one is the end of chapter questions [found in the textbook] as I mentioned before. The second one is, reviewing the topic…. To increase the efficiency of the lesson, we review the previous course in the in the first ten minutes of the each lesson… The end of chapter tests functions as a [course] summary. I can easily detect

Table 4.2.3. *Continued*

	unattended students while discussing end of chapter tests. I actually can say that I try to measure students' understanding every lesson, every time. I do not spare a very special place for this [measuring students' understanding]. It already shows up according to the lesson flow. In this way [measuring students' understanding all the time] students become more active. In other way they become more concentrated on questions so they focus on solving the question rather than learning. I do not want it [students' focusing on answer rather than learning]. I do not want to raise students only marking A, B, C or D [in a multiple choice test].

In the following section Nilay's TSPCK findings after pre-interview and classroom observations are revealed in detail.

Nilay's topic-specific Pedagogical Content Knowledge on ecosystem was investigated through both interviews and classroom observation. During interviews, the teachers were asked several questions related with five parts of pedagogical knowledge. Then, they were monitored by the interviewer in the class to get their pedagogical knowledge on ecosystem. Their responses and observation notes were used to understand their pedagogical knowledge on ecosystem which is the factor enabling teachers to achieve an effective ecosystem teaching.

In the pre-interviews Nilay answered thirteen questions related to curriculum knowledge, six for difficulties and constraints while teaching ecosystem, seven for students' knowledge and understanding, thirteen for teaching strategies, and six for measurement and assessment techniques.

4.2.3.1 Nilay's Orientation towards Science

In order to understand Nilay's orientation towards science, her beliefs about goals of science teaching were examined. Nilay's beliefs about goals of science teaching were collected through pre-interview and in-class observation. Nilay's beliefs about goals of science teaching were revealed as central and peripheral goals in general and then these goals were classified as schooling goals, affective goals and subject matter goals. In this section Nilay's answers to pre-interview questions about goals of science teaching were presented.

4.2.3.1.1 Nilay's Beliefs about Goals of Science Teaching

There were six pre-interview questions to gather Nilay's beliefs about goals of science teaching.

> I: Why do you teach science in middle school? What does science teaching mean to you?
>
> Nilay: *I wish my students to learn science so that they can use this knowledge in every part of their lives. However, there is an examination system [high school entrance exam] that we cannot go beyond what is asked in the exam. I desire my students to become successful in that exam but of course, my main goal is that they use their knowledge in their everyday lives. My goal is teaching life.*

Nilay's beliefs about teaching science focused on schooling goal. She indicated that her main goal is to teach her students information which they can use in their lives. On the other hand she also pointed out the need for success in high school entrance exam that students have to take.

> I: Which skills or knowledge do you expect your students to gain after learning science?
>
> Nilay: *First a living thing should know itself. Then it [living thing] should know its surrounding [where the living things live] and develop skills to survive. Therefore students consider it [learning about themselves and their surroundings] not as a lesson but as an important information for living.*

I: How did you decide the goals you emphasized to teach science?

Nilay: *I decided them with the help of my teaching experience by the time. When I compound feedbacks from my students and some tips in concepts that I pay attention something like that came out.*

Nilay emphasized the importance of learning science for surviving. Hence Nilay's central goal is to prepare learner for life by teaching him/her skills to survive. Although mentioned schooling goals in the previous question, she did not, mention any schooling goals in answering this question of. Nilay added that she decided these goals thanks to her experience in science teaching:

I: What about the role of teacher and learner in science teaching?

Nilay: *For me, teacher has an important role…we help them [students] gain a perspective …they learn how to look at their surroundings from a different point of view. When they [students] read a book in literature or social sciences lessons, they [students] learn it word for word [by rote]. However, by teaching a different point of view, I think that I get my students see both themselves and their environment in a different view. Therefore I think that I should be active [while teaching] in the class. When it comes to students, they should also be active in the class…… as for they need to learn by participating activities and experimenting.*

Nilay's answers showed that she considered the role of teacher as transferring scientific knowledge to the learner by being active in the class and keeping students not busy reading passages from the textbook all the time. Moreover she emphasized that students should not be passive in the class since they need to learn by practice.

I: Take the concept ecosystem specifically, what does teaching ecosystem mean to you as a science teacher? Can you explain your answer, please?

Nilay: *I think it [ecosystem concept] is not an unfamiliar concept as we live in a big ecosystem. We only symbolize abstract concepts and help students see their own roles in the world they live.*

I: Why do you teach ecosystem concept?

Nilay: *We can say in order to make them [students] to see their roles [in life].*

In brief, according to pre-interview questions, Nilay's beliefs about goals of science teaching were generally based on schooling goals as she wanted her students to learn their roles in their surroundings, to connect scientific knowledge and daily life as well as to teach her students to survive in real life.

In the next section, Nilay's knowledge of difficulties and constraints while teaching ecosystem are reported.

I: Do you think that teaching ecosystem subject is difficult? Why or why not?

Nilay: *For me, teaching ecosystem topic is not difficult. If we go outside, students can see that there is an ecosystem even in the school garden. Since it [ecosystem] is a subject that students can associate easily with their daily life …. So it is not difficult [to teach ecosystem topic].*

I: Do you have any concerns about teaching ecosystem?

Nilay: *I have concerns about if I cannot raise an environmental awareness because I am afraid of that in the future the environment will take a revenge from us.*

I: Which factors do you think that will affect your teaching in ecosystem subject?

Nilay: *I support the lesson with question and answers or argumentation but I think that the visuals are more effective. Because it is better for students to grasp how fishes and plants in a lake live together. There are no difficulties or factors that restricting me in teaching ecosystem. I already do not use a method that will make teaching difficult.*

In conclusion, Nilay's answers showed that she did not think that teaching ecosystem was difficult as it was related to students' daily lives. She taught that her using visuals and questioning method was enough to teach the subject. However, she added that she was only concerned about the environment and about not being able to raise students' environmental awareness. Hence we can think that Nilay had an affective goal as in her peripheral goals. In the next section Nilay's knowledge of curriculum is reported.

4.2.3.2 Nilay's Knowledge of Curriculum

In this section, Nilay's knowledge of goals and objectives and knowledge of materials were revealed. Nilay's knowledge of curriculum was examined via the pre-interviews, and in- class observation notes.

4.2.3.2.1. Nilay's Knowledge of Goals and Objectives about Ecosystem

First of all, Nilay was asked the reason why ecosystem placed in the curriculum to understand whether she knows the reason or not.

I: Why do you think that ecosystem is placed in the curriculum?

Nilay: *My first aim is to raise environmental awareness. …… I think that people's impact [on ecosystem] should have been included in the curricula since they have lots of negative effects on this ecosystem. Think about endangered species…. the only reason for species get endangered is the human being. That is why we need to realize what we have done in the ecosystem.*

I: In which grade the ecosystem subject is taught?

Nilay: *7th grade.*

I: Which unit is the ecosystem subject placed in the curriculum?

Nilay: *4th or 6th unit.*

I: What are the previous and following topics of the ecosystem subject?

Nilay: *Before ecosystem students learn light concept and there is electricity concept after this [ecosystem].*

Nilay's answer showed that she knew in which grade ecosystem was taught and what the previous and following topics of the ecosystem subject were. However, she did not remember the unit on which ecosystem topic is placed. In fact, it was placed 5th unit but she hesitated between 5 and 6. Moreover it can be said that her view of the reason to teach ecosystem was based on environmental concerns like awareness of endangered species and the hazards people gave to the world rather than curricular based.

> I: Is the ecosystem subject associated with any other subjects, units or grades in the curriculum?
>
> Nilay: *There is no association with other grades. This year we… There was [an association] in fifth or sixth grade. Since curriculum changes so frequently that I cannot remember. We already teach it [the concept] according to our text-book in Grade 7. We can associate it [ecosystem unit] with living things, we had living things unit. Then, of course, when teaching matter concepts such as soil and water I combine these topics [ecosystem and matter].*
>
> > I: Why do you think that associating ecosystems with living things is useful for teaching it [ecosystem]?
> >
> > Nilay: *It is useful because in the ecosystem besides non-living things, the role of living things is also very big. In this subject, students are supposed to learn some species, producers and consumers so we use living things in the first place. That is why we associate living things unit in the first place.*

Although Nilay said that there was an association of ecosystem in the fifth or sixth grade, she could not remember it [the grade level] very well. She attributed it to the frequent changes in science curriculum. Hence she could not remember vertical connections of curriculum and did associate it only horizontally with the properties of matter unit. When she was asked to associate ecosystem topic with other science topics she stated that she associated ecosystem with living things and matter unit because ecosystem included both living and non-living things.

I: What are the basic prescribed objectives for teaching ecosystem in the curriculum?

Nilay: *Primarily students know the species around them. Then species, ecosystem, habitat concepts then there is biodiversity. And students need to exemplify the ecosystems. We have objectives about the factors causing diminish of biodiversity.*

In the curriculum there are four objectives in total (see Table 4.1.4) prescribed for the seventh graders to learn. She pointed out the two objectives;

> *7.5.1.1. Define and exemplify the concepts of ecosystem, species, habitat and population,*
>
> *7.5.2.2. Discuss the factors threatening bio-diversity based on the research data and suggest solutions,*

However, she did not mention the following objectives;

> *7.5.2.1. Inquire the importance of biodiversity for the natural life,*
>
> *7.5.2.3. Search and exemplify plants and animals that are extinct or facing the risk of being endangered in Turkey and the world*

Therefore, Nilay partially knew the objectives prescribed for ecosystem in science curriculum.

I: Could you rank these objectives according to their importance?

Nilay: *Students' knowing that we also take place in an ecosystem is the most important. Next they need to know the other ecosystems [which they do not live in] additionally. And they need to know the species endanger as a result of negative effects [of human behavior].*

I: Does the curriculum give information related to constraints for teaching ecosystem or possible misconceptions?

Nilay: *Frankly, these [misconceptions] appear during the teaching in the class so we determine those [misconceptions] by this way [observing in lesson]. But, in the past, ministry of national education provided us with teacher manual* *along with textbook; now, [this year], we teach according to the existing curriculum.*

According to Nilay the curriculum did not inform teachers about the constraints or misconceptions anymore. Nilay was correct when it comes to ecosystem topic in the existing curriculum because when it was checked there were no indications of misconceptions or any constraints about ecosystem topic in the seventh grade.

4.2.3.2.2. Nilay's Knowledge of Materials

I: Which sources do you use while teaching the ecosystem subject?

Nilay: *There are web sites that students obtained visuals [documents]. Generally, our course book is sufficient [for visuals].*

I: Why do you use these sources?

Nilay: *I mean I benefit from them as a support to my instruction I use eba [educational informatics network] and morpa campus [an online platform providing educational videos] to support my teaching. Other than these, we do not use any materials.*

As Nilay expressed that her students did internet researches for visuals, in class observations, it was noted that students showed their presentations including some visuals and explanations about ecosystem topic. Moreover, although Nilay stated that she used eba and morpa campus to support her instruction during classroom observations for ecosystem topic, she neither used eba nor morpa campus, and instead she got her students to present the topic first and then she had students to write some notes on their science notebooks. In the next section Nilay's knowledge of students' knowledge and understanding is revealed.

4.2.3.3 Nilay's Knowledge of Students' Knowledge and Understanding

Nilay's understanding of this component was revealed by analysis of two sub-components which are knowledge of requirements for learning and knowledge of students' difficulties.

4.2.3.3.1. Nilay's Knowledge of Requirements for Learning regarding Ecosystem

> I: What is the prerequisite knowledge that students need to know in order to understand the ecosystem subject according to you? Could you explain your answer?
>
> Nilay: *Students should know living things at first and the non-living things which living things are interacted with. They already know these beforehand and now they will associate it with ecosystem because an ecosystem is composed of both living and non-living things.*

According to Nilay students needed to know living and non-living things since these topics were taught previously. Therefore, it can be said that her answer was correct and based on science curriculum.

4.2.3.3.2. Nilay's Knowledge of Students' Difficulties regarding Ecosystem

> I: Which concepts do you think that students may have a hard time in learning ecosystem?
>
> Nilay: *The students confuse habitat and population, for example. But when we provided students with appropriate example for habitat and population, they do not confuse them anymore.*
>
> > I: What is the reason for students to have a hard time in learning these concepts according to you?
> >
> > Nilay: *It is because that the word is a new one for them.*

Nilay stated that students might only confuse habitat and population terms since those are new words for them. However, she added that she could clarify the confusion by explaining the terms. In classroom observations there was no specific emphasis on distinguishing habitat and population was noted.

I: Are there any misconceptions of students regarding ecosystem?

Nilay: *There might be, yes. For example we said that species and population are confused. There are many of them in science like mass and weight are confused. So here in this topic; species.*

I: What is the reason for students' misconceptions?

Nilay: *Although I have no such observation, the reason for that confusion is that the students do not terms in daily life.*

I: How do you determine misconceptions of the students? Which methods do you use to determine it?

Nilay: *From their answers, by using questioning method.*

I: Do you try to eliminate the misconceptions you determined? If yes, how?

Nilay: *Absolutely. I say over again and give examples. When appropriate I ask a feedback about what they have done with this in their daily lives.*

I: Do you think that this method is sufficient?

Nilay: *If the students are interested; yes but if not as you know we cannot enhance many methods.*

Although Nilay indicated that students might have a misconception about population and species since students did not use those terms in their daily lives. Thus she indicated that to determine any possible misconceptions, she used questioning method. Moreover she said that she used explanations and feedbacks from students to eliminate misconceptions. However, she did not mention to quizzes, discussions, short tests, concept maps, and two tier diagnostic tests to determine misconceptions. Moreover, she did not also use conceptual change approach, analogy, and concept map.

> I: What are the most important terms/points students need to learn? How did you determine those?
>
> Nilay: *The same things I have just mentioned. I decided these by looking at the whole unit.*
>
> I: Which concepts do you expect your students to learn and what do you think they will do with this knowledge?
>
> Nilay: *Primarily students need to know the species around them. Then students need to exemplify the ecosystems composed of these [species].*

Although she mentioned other basic terms related to ecosystem like habitat and population she only pointed out the species when she was explaining the concepts that she expected her students to learn.

> I: What kind of advantages does knowing ecosystem provide to the students? Why?
>
> Nilay: *It helps students to have a clear understanding of environment, and see that even a small creature in the nature has an enormous role in it [ecosystem] helps them to figure out that all of the creatures live in a harmony.*
>
> I: Why is it important for students to know ecosystem subject?
>
> Nilay: *The students see the nature from a different view. Then maybe one day in the future, somewhere, they will have to use their knowledge [on ecosystem] they have learned, to protect the environment.*
>
> I: How do the students use their knowledge if they do not decide to study or work in this area?
>
> Nilay: *I think that all whichever area students choose to study, they need to know this information because we live in this world and we have no other place*

to live. And it is a subject that students should know that they need to protect it [the world we live].

Nilay's answers revealed the fact that she considers her students' having an environmental understanding and figuring out every things' role in environment as the biggest advantage for students. Moreover she added that it was important for students to learn ecosystem topic since they need to protect environment. Her answers were once again environmental based rather than academic. In classroom observations Nilay tried to give an emphasis on how people give damage to the world like forest fires and global warming. She also recommended her students to go outside, to the nature and sit on grass to feel a part of it. In following section results of Nilay's predictions and students' answers to the ecological concept test are demonstrated. Nilay thought that students might confuse what plant food is, that the questions related to energy flow, food chain and primary consumers would be hard for students to answer. On the other hand Nilay stated that students would be more likely to answer the questions related to basic ecological concepts such as environment, population, decomposers, energy source of plants, ecosystem definition and the source of all ecosystem. To clarify these findings, same test should be applied to the students.

4.2.3.4 Nilay's Knowledge of Instructional Strategies

Knowledge of instructional strategies was examined via pre-interview questions and in-class observation notes. Results of the sub-components of knowledge of instructional strategies which are knowledge of subject specific strategies and knowledge of topics specific strategies (knowledge of activities and knowledge of representations) were presented in this section.

4.2.3.4.1. Nilay's Knowledge of Subject Specific Strategies

I: Which strategies or methods do you use while teaching science? Why do you use these methods or strategies?

Nilay: First of all, I teach according to the content [prescribed in the science curriculum]. I always ask the why/ how types of questions since I did not observe development of a student [in the lesson] who cannot answer a why type question. Next I want them review the lesson. Questions found at the end of the chapter help me but I do not give homework from another crammer.

> I: How did you learn to use these strategies? Did you develop them yourself or learn from another source (person, crammer etc.)?
>
> Nilay: *I experienced that this is the healthiest way in years. I engage students with the lesson while teaching. I am not the only active person during the lesson. They likewise give examples like "we went there and this happened". Then they actually realize that the subject is something they already knew. I developed this strategy on my own.*

Nilay indicated that she uses direct instruction and questioning method that she learnt from her education in university and her experiences in teaching. She added that with questioning method she can engage students with the lesson and she developed he method herself. In class observations it was noted that she actually gave homework for some of the students to prepare a presentation on ecosystem topic. And while students were presenting their homework she added more information or examples or asked additional questions to the class. Moreover it was also observed that she got her students to write some notes that she told.

4.2.3.4.2. Nilay's Knowledge of Topic Specific Strategies

I: Do you use any activities regarding ecosystem subject?

Nilay: *We could do this, for example. We could go out to the school garden by looking at small grasses, worms and ants around soil and trees. We can express these are also small ecosystems.*

I: How good are you at finding effective activities? Why do you think that you are good/bad? How did you decide?

Nilay: *I do it from the beginning like so; I draw the experiments we cannot do in the class. We, for example, raise the temperature in the thermometer and monitor it all together. We even make one to keep time as if we are already doing the experiment. I mean there are not many things I generated myself but we make it natural like this. About ecosystem we can go out as an activity if we are to do one.*

Nilay mentioned a possible activity for ecosystem which was going outside of the classroom to the garden as a field trip. However, while teaching ecosystem concept it was observed that she did not use any activities. On the other hand she did not mention any other activities like role play, experimentation and problem based learning.

I: Do you use visuals, simulations or graphics while teaching ecosystems? Can you explain?

Nilay: *Yes, yes definitely. Generally, as I said, we use visuals or videos of an ocean when teaching it [ocean] but otherwise I draw simple figure on the board*.

Although Nilay expressed that she would use some videos or visuals while teaching, it was monitored that she did not specifically demonstrate any visuals. However, since she got her students to do some presentations, there were some pictures and videos in their presentations.

I: How much alternative examples or explanations do you use when students are confused?

Nilay: *As a number? I explain. As long as I believe the sincerity of the student and student wants to learn, I repeat.*

I: How do you know/decide whether an activity or strategy you planned to do is efficient or not?

Nilay: *Students' excitement, probably.*

I: What kind of a connection is there between your objectives and the method you chose? To what extend your choices represent your objectives?

Nilay: *I think it is effective, I can see that from the increase in their comprehension. Feedbacks and the answers to the questions I asked. I do not want to talk about directly focused on the exam questions. I can see if they know or not by associating the topic with the fifth or sixth grades. I measure it in that sense, too.*

I: Is there any areas that you see the application of ecosystem in daily life? Do you use it in your teaching?

Nilay: *There are many in daily life, anywhere. Just even vineyards or orchards are areas for us. I lead students as well. I try to lead them to somewhere else in many subjects when the subject is space, for example.*

As Nilay stated, it was observed that she leads her students to go see a lake in Ankara in order to observe an aquatic ecosystem. Moreover she also gave various example of their experiences like an aquarium in İstanbul she visited and her experience with nature when she was younger.

I: How good are you at engaging students with the lesson? Why do you think you are good/bad? How did you decide?

Nilay: *I am good at that. I mean how, let me say students' feedbacks, parents' reactions. I hear them saying they enjoy your lessons and learn, that is it.*

I: How do you determine whether your teaching is efficient or not?

Nilay: *I also enjoy at that moment and say yes. Just a blink in their eyes. I feel it. I do not know if it is professional formation or deformation.*

Nilay's answers showed that in order to understand whether her lesson was efficient or not she used feedbacks from both students and parents. To conclude, Nilay used teacher centered methods to teach ecosystem since she seemed to have lack of knowledge related to a variety of student-centered strategies. Although she mentioned a field trip activity, she did not use it in the classroom. Moreover she only let her students to be prepared for the lesson and present their knowledge in the class. While students were presenting, she was also students some leading and probing questions.

In next section, Nilay's knowledge of measurement and assessment techniques is revealed.

4.2.3.5 Nilay's Knowledge of Measurement and Assessment Techniques

> I: Which measurement techniques do you use to assess students' understanding?
>
> Nilay: *The first one is the end of chapter questions [found in the textbook] as I mentioned before. The second one is, reviewing the topic…. To increase the efficiency of the lesson, we review the previous course in the in the first ten minutes of each lesson… The end of chapter tests functions as a [course] summary. I can easily detect unattended students while discussing end of chapter tests.*
>
> > I: Why do you use these measurement techniques?
> >
> > Nilay: *The end of chapter tests works like a summary. If I miss one student while teaching that point, I catch him/her there [at the end of the chapter].*

Nilay mentioned that she used end of chapter tests and questioning method while reviewing the chapter in the class as an assessment. She added that tests that are applied at the end of chapters help her to summarize the chapter. Moreover, she also expressed that asking questions about the last lesson at the beginning of the new lesson advances the lesson's efficiency.

> I: How do you use the assessment results? What do these results tell you about?
>
> Nilay: *I actually do not have any different expectations. I mean the student who understood in the class succeeds and the other does not. I do not err much. The feedbacks in the class match with the exam results.*
>
> I: How good are you at finding new assessment techniques? Why do you think you are good/bad? How did you decide?

Nilay: *I can generate questions, new exam questions. I cannot preapre tests, I did not apply them maybe that is why. There are already many existing tests.*

According to Nilay since there are already a vast number of tests, she did not produce multiple choice questions. Instead she preferred to write open ended questions. Then she was asked about her aims in assessing students' knowledge regarding ecosystem.

I: What exactly do you aim to assess while measuring students' knowledge about ecosystem?

Nilay: *I completely want to see the necessity of respecting nature for real. Actually, this unit is very important for that matter. A student who raised environmental awareness needs to know how much s/he takes a role in that ecosystem and what to respect. We can see them by looking at a grass or an ant.*

Although Nilay indicated that her main goal was to assess if students gained environmental awareness or not, she told that she used tests or open-ended questions before. However, it is not possible to assess students' behaviors by applying them a test or asking questions.

I: When do you measure students' understanding? Why did you choose this time?

Nilay: *I actually can say that I try to measure students' understanding every lesson, every time. I do not spare a very special place for this [measuring students' understanding]. It already shows up according to the lesson flow. In this way [measuring students' understanding all the time] students become more active. In other way they become more concentrated on questions so they focus on solving the question rather than learning. I do not want it [students' focusing on answer rather than learning].*

Nilay's answer revealed that she uses her observations to assess students any time in the lesson. Also, she added that when she chose to apply a test, students focus only on the test and not on learning the subject. Consequently, before she was asked about the ways she used to assess students, she said that she used tests and questions in the class.

However, in classroom observations it was noted that she only used her observations and oral questions to assess students. To sum up, although Nilay wanted to make her students gain environmental awareness, she did not mention the ways to assess it. In this section content knowledge and pedagogical content knowledge of Nilay regarding ecosystem concepts were revealed. In the next section a summary of the results is demonstrated.

4.3. Summary of the Results

In this section participants' results which were presented above are compared and revealed based on research questions. First of all, participants' content knowledge is compared and summarized. Then participants' pedagogical content knowledge of ecosystem concept with the emphasis on students' understanding of ecosystem is compared and revealed.

4.3.1. Science Teachers' Content Knowledge regarding Ecosystem

Science teachers' content knowledge was gathered via pre-interview questions prepared by researcher. Content knowledge questions included definitions and drawing related system, ecosystem, basic ecological terms and energy flow in an ecosystem and corresponding concepts.

All of the participants had sound understanding about the concepts system, species and habitat. However, although they both correctly defined and exemplified a system, they could not fully explain an ecosystem as well as its components and the interactions between these components. ın addition in their ecosystem drawings they both scored 4 according to DET since they did not mention any human effect in their ecosystems and also indicated only basic interactions. Therefore their understanding of ecosystem was partial.

In addition to ecosystem, all participants also had partial understanding on concepts regarding biological diversity and producer. They both explained biological diversity as species richness without mentioning ecological or genetic diversity.

Moreover, all participants had naïve understanding of decomposers, food chain and food web drawings. They both did not include decomposers in their food chain or food web drawing yet they neither fully explained how decomposers work in nature. Similarly, both teachers drew arrows in wrong directions when showing the energy flow in a food web. In addition, they both thought that there is no limit of food chain which was a naïve idea with respect to 2nd law of thermodynamics. Lastly, they both thought that energy in an ecosystem can be recycled which again not true regarding 2nd law of thermodynamics.

Ezgi had a sound understanding of matter cycle in food chain, energy pyramid and consumer different than Nilay while Nilay had a partial understanding of energy pyramid, food chain and consumer. Moreover, Ezgi did not answer the questions asking community and ecological niche while Nilay had a partial understanding of community and a sound understanding of ecological niche.

Nilay also had naïve understanding on the concept population which she defined as community unlike Ezgi. Moreover, Nilay's understanding with respect human interaction was also not true since she thought that human only damages nature so it is not included in ecosystems. On the other hand, Ezgi did not even mention any of human interaction in ecosystem concepts.

To conclude, science teachers' content knowledge was gathered via pre-interview questions and supported with classroom observations in this study. Teachers had both sound understanding on system and habitat, partial understanding on producer, biological diversity and ecosystem and naïve understanding on energy limit in food chain and the fact that energy can never recycled in nature. In the next section participants' pedagogical content knowledge is summarized.

Table. 4.3. 1. *Teachers' understandings of ecosystem concepts*

Teachers' understanding	Sound	Partial	Naïve	No answer
Nilay	System Species Habitat	Ecosystem Biological diversity Decomposers	Population Food chain Food web	-
Ezgi	System Species Habitat	Ecosystem Biological diversity Decomposers	Food chain Food web	Ecological niche Community

4.3.2. Teachers' Pedagogical Content Knowledge regarding Ecosystem

Science teachers' pedagogical content knowledge was gathered via pre-interview questions and classroom observations in this study. In order to understand their PCK, five components which are orientation towards science, knowledge of curriculum, knowledge of students' understanding, knowledge of instructional and strategies knowledge of assessments were used.

4.3.2.1. Orientation towards Science

In this study teachers' orientation towards science means their beliefs and goals in teaching science. Central goals and peripheral goals were the sub categories of teachers' goals of teaching science. During pre-interviews Ezgi mentioned her central goals as schooling and subject matter goals for teaching science. In addition she mentioned affective goals as she wanted her students to raise their awareness towards environment in addition to subject matter goals of teaching ecosystem. However, in the observations it was seen that she taught the subject with regards to her central goals of teaching science which were subject matter and schooling as opposed to what she mentioned affective goals for teaching ecosystem in pre-interviews. However, her goals were central to her teaching and no peripheral goals were identified, yet since she mentioned affective goals for teaching ecosystem but did not choose her teaching system according to it we can say that Ezgi's affective goal of teaching ecosystem was peripheral. Similarly to Ezgi, Nilay had schooling and subject matter goals as her central goals for teaching science. Moreover her central goals for teaching ecosystem were schooling according to pre-interviews. In addition she mentioned a peripheral goal as her goal of teaching ecosystem since she wanted her students to be respectful to the environment and learn the lesson for the exams as well. In class observations it was seen that Nilay chose her method parallel to her central and peripheral goals of teaching ecosystem.

4.3.2.2. Knowledge of Curriculum

Teachers' knowledge of curriculum was categorized as knowledge of goals and knowledge of materials used in this study. Only one of teachers pointed out the spiral curriculum as she mentioned that the concept ecosystem had connections in the eighth grade. All the participants could correctly pointed out the place of ecosystem unit in the curriculum as well as the previous and following units. However, only one of teachers could connect the topic horizontally while both of them mentioned vertical connections. Moreover both of the participants partially stated the objectives in the curriculum. Therefore they could rank them in the order of importance partially as they remembered. Hence they both had limited knowledge about objective in the curriculum. Both of the teachers used text-book and blackboard in their teaching. One of them also used visuals and videos from an internet site and the other asked her students to prepare a presentation about ecosystem. One of the teachers did not exceed the objectives of ecosystem topic prescribed in the curriculum while teaching but the other one taught community concept although it was not included.

4.3.2.3. Knowledge of Students' Understanding

None of the teachers mentioned environment and human relationships, organisms, energy concept and matter as well as phases of matter as prerequisite knowledge for learning ecosystem. However, they both claimed that living and non-living concept was prerequisite. As students' difficulties both students mentioned the terms used in ecosystem concept as a difficulty. One of them claimed that students can confuse terms population and habitat while the other indicate the terms population and species. None of them mentioned other concepts like cycle and flow. None of the teachers mentioned the numerous misconceptions students can have in topic related to ecosystems since most of them were related to the concepts that students will learn in the eighth grade such as food chain, food web and energy pyramid. Both of the teachers indicated the daily language barrier as a source of difficulty. None of them mentioned textbooks, teachers or students' preconceptions. In addition their knowledge of identifying and eliminating students' misconceptions as they both only mentioned questioning and saying over. However, none of them indicated constructivist strategies such as concept map. Moreover teachers were asked to predict students' answers before they take the ecological concept test and results showed that teachers were knowledgeable about students' difficulties and understanding of ecosystem topic in a given test. Hence some of the questions such as food chain and photosynthesis were not included in the curriculum for the seventh grade, students had a low understanding of the ecosystem test.

4.3.2.4. Knowledge of Instructional Strategies

Both of the teachers preferred to use teacher centered strategies such as questioning and direct instruction. However, one class students were in charge of presenting their power point slides they prepared. One of the teachers explained the reason for using teacher centered strategies as having lack of time and a thick curriculum. However, the other participant did not use a student-centered activity although she mentioned a field trip activity in pre-interviews. Both teachers actively used board marker and the black board to facilitate students' understanding. Moreover they both used visuals such as drawings, photos or videos in the sites they used or in the presentation they asked students to prepare. However, only one teacher used analogy of factory as an example for ecosystem. None of the teachers used experimentation, drama or creating a model of ecosystem. Both of the teachers used various examples of population and habitat to clarify the terms for students. One of the teachers asked her students to write after she said whereas one of them asked hers to open their text-book and underline the part she said. To conclude both of the teachers used traditional instruction techniques instead of student-centered ones in their lessons.

4.3.2.5. Knowledge of Assessment

Both of the teachers used assessment techniques for assessing only students' conceptual understanding of ecosystem topic which are based on objectives in the curriculum (2013). None of them assessed students' problem-solving skills or science process skills. Moreover both of the teachers used formative assessment during the lesson with their verbal questions and observations. Only one of the teachers used a test after showed a video on a site on the board. However, as a summative assessment both teachers used home works. Two participants preferred to use traditional assessments only. Therefore both of them had a partial understanding of knowledge of assessment.

Table. 4.3. 2. *Teachers' TSPCK in Teaching Ecosystem*

	Orientations towards Science		**Knowledge of Curriculum**	**Knowledge of Students' Understanding and Difficulties**	**Knowledge of Instructional Strategies**	**Knowledge of Assessment**	
	Central goal	**Peripheral goal**				**Formative**	**Summative**
Ezgi	Subject matter goal	Schooling goal	Partially stated the objectives Partial horizontal and vertical connections Textbook, blackboard and online educational platforms were used as materials.	No indication of environment and human relationships, organisms, energy concept and matter as well as phases of matter as prerequisite. Habitat and population concepts were stated as possible difficulty due the everyday language. Only questioning method was mentioned to identify and eliminate the misconceptions of students.	Direct Instruction Questioning No additional strategies or activities were mentioned in pre-interviews.	Verbal Questions Questions presented in textbook and online educational platform	Questions provided at the end of the chapter in the textbook

Table 4.3.2. *Continued*

Nilay	Schooling goal	Affective goal	Partially stated the objectives Partial horizontal and vertical connections Textbook, students' presentation and blackboard were used as materials.	No indication of environment and human relationships, organisms, energy concept and matter as well as phases of matter as prerequisite. Habitat and population concepts were stated as possible difficulty due the everyday language. Questioning method was mentioned to identify misconceptions of students. Repeating the concept and giving more examples were mentioned to eliminate students' misconceptions.	Direct Instruction Questioning Field trip was mentioned in pre-interviews but not used in the class.	Verbal Questions	Questions provided at the end of the chapter in the textbook

CHAPTER 5

DISCUSSIONS AND IMPLICATIONS

In this chapter discussions of the results demonstrated in the previous chapter, the implications and recommendations for further researchers are presented.

5.1. Discussions

The study aimed to identify two experienced science teachers' CK and TSPCK regarding ecosystem based on components of Magnusson et al. (1999) model. In this section, the results found in this study was interpreted and compared and contrasted with other studies in PCK literature. Since syntactic content knowledge (Khalick & BouJaoude, 1997; Schwab, 1964) was not addressed in the study, only the substantive structures (Schwab, 1964) of content knowledge of science teachers were discussed. Science teachers' substantive content knowledge was gathered via pre-interviews and supported with in-class observations. Substantive content knowledge of teachers were investigated under two sub-categories as basic ecological terms and concepts related to the energy flow in an ecosystem

The previous studies mostly investigated students' understandings and conceptions regarding ecosystem (e.g. Adeniyi, 1985; Carlsson, 2002; Eliam (2002); Griffiths, & Grant. 1985, Helldén, 2004; Leach et al. 1995, 1996a, b; Lin &Hu, 2003; Magntorn & Helldén, 2007). However, there is a need for teacher's having a sound understanding of ecological concepts since their limited or naïve understandings have a potential to affect their teaching of these concepts in an effective way (Hungerford &Folk, 1990; Khalid, 2003; Moseley et al., 2003; Mosothwane, 2002).

In the current study, order to examine teachers' conceptual understandings of ecosystem, they were asked to say 12 words that came to their minds with regards to free word association test (WAT), develop a concept map, and draw an ecosystem.

Combined finding revealed that all participants had partial understanding of ecosystem. For example, teachers were asked to define and exemplify concepts related to ecosystem, like species, population, community, habitat, ecological niche and biological diversity. These concepts are seen as important concepts to have a meaningful knowledge on ecosystem in a constructivist perspective. Moreover teachers were asked about energy flow in an ecosystem and related concepts like producers, consumers, decomposers, food chains, food webs and energy pyramids. These concepts provided this study with enough structure to determine understanding of ecosystem without making participants overwhelmed (Kearney & Kaplan, 1997; Leake, Maguitman & Reicheherzer, 2004; McClure et al., 1999; Novak & Gowin, 1984; Yin et al., 2005; Zak & Munson, 2008). Teachers defined and gave examples for species and habitat concepts so they had a sound understanding about species and habitat concept. The findings of some of the earlier studies had shown that generally students have difficulty in conceptualization and elements of habitat (Strommen, 1995; Lock, Kaye & Mason, 1995). Science teachers had misconceptions of decomposers, food chains and food webs since they did not fully explain how decomposers work in nature and did not point out the directions of arrows correctly while showing the energy flow in a food web. The results are consistent with the students' misconceptions in the literature (Adeniyi, 1985; Barman & Mayer, 1994; Griffiths & Grant, 1985; Hogan, 2000; Preston, 2018; Yorek et al., 2010). Adeniyi (1985) found that students held some misconceptions on ecological concepts like; for example, they believed that the top of a food chain has the highest energy because it accumulates up the chain, that traits develop since they are parts of a predetermined plan and that traits passed on by the bigger and stronger organisms replacing the smaller and weaker ones. Similarly, in their studies Griffiths and Grant (1985) stated that students held some misconceptions on food web. For example they believed that a change in one population will only affect another population if these are related as prey and predator, that a population placed higher on a food chain within a food web is predator of all populations, that a change in size of a prey population has no effect on its predator population, that if the size of one population in a food web is altered, all other populations in the web will be altered in the same way and that organisms in a population are important only to those other organisms on which it preys for food sources. In Hogan's study (2000) the misconceptions identified were those the students consider food webs in terms of individual rather than interconnected food chains, and that they concentrate on direct instead of indirect impacts of perturbations. The findings of Preston's study (2018) revealed that students had difficulties of reading the food web diagram as they could not make sense of where to start reading, understanding arrow meaning and biochemical processes happening at the individual organism level and ecological processes at population level. On the other hand science teachers had a partial understanding on concepts regarding biological diversity and producers by explaining biodiversity as species richness and not mentioning ecological or genetic diversity. This study supports the findings of Nuraeni, Rustaman and Hidayat (2017) in which they indicated that the science teachers have difficulty in understanding the concepts of biodiversity. Therefore the findings of this study also consistent with the fact that biodiversity is a challenging educational topic (van Weelie & Wals, 2002; Gaston & Spicer, 2004; see also Dor-Haim, Amir & Dodick (2011) Moreover science teachers thought that there is no limit to food chain and energy can be recycled. Nuareni, Rustaman and Hidayat (2017) claimed that science teachers also have a weakness in understanding the concept of energy conversion and this study showed that the science teachers had a naïve idea on energy conversion with respect to the 2nd law of thermodynamics. According to the research studies some concepts like matter and energy transformations and plant and animal nutrition are especially resistant to change (Anderson et al., 1990; Bell & Brook, 1984; Roth & Anderson, 1987).

Assessing primary teachers' understanding of the ecological issues, Summers, Kruger and Childs (2000) show that most of the teachers indicated as possessing the knowledge of living things exist in communities interacting with each other, were knowledgeable about the biological diversity and extinction and stated the reasons of these issues. Although two teachers indicated the need for biodiversity, they did not give a specific example for its beneficial influence on human. Four of the teachers defined ecosystem without mentioning abiotic factors. Only six of the teachers gave the definition of ecosystem correctly. Teachers confused the terms community with ecosystem and ecosystem with biosphere. In general, primary teachers reported with substantial understanding about ecological concepts. But yet they possessed less comprehension on underlying ecological scientific principles with several misconceptions and missing concepts. Since teachers' content knowledge is an important prerequisite for developing an effective teaching in real classroom contexts (Summer et al., 2000); researchers pointed out the need for addressing teachers' difficulties and lack of understanding of ecological concepts in teacher training programs of professional development.

In brief, science teachers' content knowledge regarding was examined via interview questions and supported with classroom observations in this study. When they were asked to define community and ecological, science teachers pointed that these terms were not included in the science curriculum for seventh grade (MNE, 2013). Therefore Ezgi did not define or give examples for ecological niche and community. Whereas Nilay gave correct definition of ecological niche whilst she had a naïve understanding on community since she perceived and described it as population. In the classroom observations it was seen that science teachers only mentioned producers, consumers and decomposers as biotics and climate and soil conditions as abiotic factors without any energy flow in an ecosystem.

To better understand the teachers' ecosystem knowledge, drawing technique was used (Kurt, 2013; Levin & Bus, 2003; Pridmore & Bendelow, 1995). By using the Draw-an-Ecosystem Test (Flowers et al. 2015) for analysis of the ecosystem drawings of the participants, it was seen that teachers drew ecosystems including some biotic factors such as trees and birds and abiotic factors such as water and soil. However, there were no indication of human or human built which may affect the biotic factors (Meyers, Saunders & Garrett, 2004) in both of the participants' drawings. Drawing an ecosystem which was isolated from human is common in other studies (Bruni & Schultz, 2010; Vining, Merrick & Price, 2008) and many of them are related to students' environmental orientations (Alerby 2000; Barraza 1999; Bowker 2007; Dentzau & Martinez 2014). In classroom observations it was monitored that both of the participants used pictures or videos related to ecosystems instead of drawing an ecosystem on the board. Consequently, they did not mention any interactions or elements of these ecosystem that were visualized on pictures or videos explicitly. Hence science teachers were not aware the fact that drawings are important to determine possible cognitive gaps on children's minds regarding ecosystem components and relationships (Larson, Green & Castleberry, 2011). On the other, Nilay mentioned how human impact nature in a hazardous way by giving examples of destroyed forests and harmed animals like those kept in aquariums instead of being free in their wild nature, although she did not express any human impact on her drawings in interviews. Whereas Ezgi confined herself to show a video on ecosystem form morpa campus [educational information site] and did not mention human and nature relationships. Moreover it is crucial for science teachers to indicate human impact or human built on ecosystem in addition to the abiotic and biotic factors since it facilitates students to connect to nature and to understand human and nature relationship (Bruni & Shultz, 2010; Vining, Merrick & Price, 2008).

Science teachers' concept maps on Ecosystem, on the other hand, showed participants' difficulties in making connection among the concepts of ecosystem. Ezgi, for example, only named abiotic and biotic factors with no connections among them. She also did not include energy concepts; food webs, and food chains in her map (Zak & Munson, 2008). She also did not mention producers, consumers and decomposers (Zak & Munson, 2008) in her concept map. When Nilay was asked to construct an ecosystem concept map, she did not use any linking words and linked the concepts in a meaningful order (Zak & Munson, 2008). In fact, both teachers seemed to have enough knowledge on constructing a concept map. In classroom observations it was noted that science teachers did not use any proper concept maps including linking and linked words with arrows. However, Ezgi used her drawing of ecosystem (see Fig. 4.1.3.) in the classroom where she drew one when she was asked to develop an ecosystem concept map in interviews. Although not it was not aimed in this study, it will be helpful for teachers to get more information on how to develop concept maps and use them in the classroom appropriately to help students to develop their learning regarding ecosystem (Mintzes et al, 1997; 424; Brown, 1995; Kinchin, 2000a).

The findings of this study are not consistent with the findings of Zak and Munson's (2008) study regarding some aspects. The study of Zak and Munson (2008) addressed the issue of pre-service elementary science teachers' conceptual understanding of ecology via the use of concept maps. These concept maps were developed by the pre-service elementary science teachers for the sixth-grade students after participants were given a list of 16 ecological concepts. After the participants constructed their concept maps, the concept maps were analyzed based on their structure, content and organization. Analysis of concept maps led to forming two clusters as food web cluster including food web, energy flow, producers, consumers and decomposers concepts and as ecosystem cluster including ecosystem, community, populations and species concepts. The concepts of food web, species, populations and organisms were the most used ones in forming concept maps. However, as oppose to what was found in this current study, Zak and Munson (2008) stated that biotic factors and abiotic factors were not frequently used in constructing concept maps.

5.1.1. Discussions on Teachers' TSPCK

Science teachers' orientations are resistant to change due to the complex and multi-dimensional features of it (Luft & Roehring, 2007). In this study science teachers' orientations were categorized as central and peripheral goals of teachers' goals of teaching science. Findings indicated that science teachers' central goals were schooling and subject matter goals and their peripheral goal was an affective goal as for teaching their students respect nature. However, since science teachers' central goal was to transmit the subject matter knowledge to learner, they focused on only teaching the subject without concerning any affective goals in classroom observations. Therefore this orientation is restricted and problematical for TSPCK for the fact that PCK shaping other components (Şen, 2014). Moreover focusing only on transmitting subject matter knowledge does not respond and concern students' needs as it focused mostly on lecturing and academic rigor. The results arguing that teachers' orientations were not only based on subject matter goals but also the affective and schooling goals support the findings of Friedrichsen and Dana (2005). On the other hand as oppose to what Miranda (2010) suggested in his study in which he studied with teachers who considered astronomy as a difficult object and it requires students to have good cognitive skills; Miranda (2010) discussed that teachers teaching astronomy, believed that students' motivation was important for them to perform well in an astronomy class. Teachers in this study ignored students' interest and motivation as also stated in Drechsler and Van Driel (2008) study where it was observed teacher founded more interesting experiments of acids and bases for students instead of what students found boring. The possible reason for science teachers preferred to focus mostly on schooling goals is the High School Entrance Exam (TEOG) and loaded curriculum. These results are consistent with Aydın's (2012) conclusions that she stated a loaded curriculum also have an impact on teachers' orientations. Therefore presence of nationwide exam together with the loaded curriculum act as a barrier or shape their orientations. The objectives of ecosystem topic are asked in the exam and there are many units in science curriculum to teach (MNE, 2013). Hence teachers had to omit some of the activities which may require more time then the curriculum prescribed. Nargund-Joshi et al., (2011) also stated that Indian teachers also had to alter their way of teaching since the system was exam-based. Similarly in China there is a gap found between how teachers plan to teach and how they teach in in the class due to the presence of nationwide exam and the loaded curriculum. (Zhang et al., 2003).

Regarding knowledge of curriculum, science teachers were aware of both the place of ecosystem unit in the science curriculum and the previous and following unit in this current study. In addition participants mentioned the vertical connections of the curriculum. However, only one of the teachers referred to the spiral curriculum and connect the topic horizontally. Teachers partially stated the objectives in the curriculum and they could not rank them in the order of importance. Both of the teachers used textbook and blackboard while teaching ecosystem in the classroom observations. Moreover visuals and pictures of ecosystems were used by both of the teachers but one of them also used an internet site to show an educational video regarding the topic. In addition only one of the participants exceeded the curriculum by teaching community even though it was not prescribed in the science curriculum as reported in other studies (Graf et al., 2011; Lankford, 2010; Tekkaya & Kılıç, 2012). For example in the findings of Graf et al. (2011) it was argued that pre-service science teachers were not aware of the objectives and the place of evolution topic in the curriculum. The results also supported the previous PCK studies in that science teachers who have been teaching for more than ten years are familiar with the curricular objectives and the place of the unit in the curriculum (Hanuscin et al., 2010; Lankford, 2010; Karakulak & Tekkaya, 2010; Mıhlandız & Timur, 2011; Şen, 2014). For instance, in the context of cell division, Şen (2014) reported that experience science teachers were familiar to the curricular objectives and the place of the topic in the curriculum because they have been teaching since ten years. In other study, Karakulak and Tekkaya (2010) found that novice science teachers whose PCK was examined in the study based on ecology concepts are not aware of the objectives of ecology concept in the curriculum. Similar findings were represented in other studies including pre-service science teachers (Graf et al., 2011; Özcan & Tekkaya, 2011; Tekkaya & Kılıç, 2012). To illustrate in their study Tekkaya and Kılıç (2012) found that pre-service biology teachers had lack of curriculum knowledge on evolution because of the frequent changes in the curriculum. However, science teachers should be capable of modifying textbooks according to their students' needs (Miranda, 2010) because sources suggested in the curriculum address students' needs in general context (Bayer & Davis, 2012).

As findings of this study presented, science teachers pointed out that concept of living and non-living things was prerequisite for students to learn ecosystem topic. However they could address environment and human relationships, organisms, energy, matter and phases of matter concepts as prerequisite knowledge for learning ecosystem. On the other hand according to one of science teachers the terms used in ecosystem like habitat and community can be confusing for students which can be a learning difficulty for them. Whilst the other mentioned the terms population and species for possible confusing terms. Therefore science teachers were not aware of students' misconceptions about ecosystem as none of them mentioned numerous misconceptions such as consumers and decomposers (Munson, 1994; Elliam, 2002, Özkan, 2001). As Finley et al. (1982) indicated, science teachers in this study tended to overestimate their students' capability to understand ecosystem. This means that teachers tend to perceive ecological concepts important yet relatively easy or basic to understand although for students, it might not be case and they would have a hard time in understanding ecological concepts. For example in Tekkaya et al's (2001) study, high school students identified ecology as 2^{nd} easy topic to understand and mentioned that they were introduced with ecology topics across the grade level. Teachers, in their sample, also confirmed their students' response by saying t that '"Students generally learn ecology easi1y.....they transfer concepts of ecology to many contexts of everyday life' (p.146). Authors concluded that both students and teachers do not perceive ecology to be a difficult topic. A recent study by Grotzer and Basca (2003) stated the opposite and claimed that pupils have difficulty in comprehending concepts of ecosystem partly due to their difficulty in understanding *the underlying causality that structures the concepts* by Grotzer and Basca (2003, p.16). They underlined the importance of teaching student how to structure ecosystems concepts besides teaching ecosystems information. Earlier study by Barman and Mayer (1994) which explored high school students' understanding of food chains and food webs reported that participants have basic and unsophisticated understanding of the concepts of food chains and food webs, and also possessed some misconceptions...Nonetheless the reason for this overestimation may be that remaining possible misconceptions were about the topics which students will learn in the eighth grade such as food chain, food web and energy pyramid (Adeniyi, 1985; Munson, 1994; Elliam, 2002, Özkan, 2001). Both of the teachers mentioned daily language use of students for a possible source as reported in studies conducted by Ben, (1985) and Gilbert et al., (1982) for students' misconceptions but none of them indicated textbooks (Yip, 1998) and teachers' (Sanders, 1993; Yip, 1998) or students' preconceptions (Özkan, 2001). Yet since teachers had schooling goals as their central goal and that is a teacher led orientation it can be estimated that teachers might have inadequate knowledge of students' understandings. Based on knowledge of students' learning, research indicated that teaching experience is the most important cause of it (van Driel et al., 2002); but the experienced science teachers in this study was not able to develop a solid knowledge of students' understanding and difficulties regarding ecosystem topic. Therefore the results of this study is consistent with Aydın's study (2012) as it was claimed that teaching experience does not guarantee for developing a rich PCK (Friedrichsen et al., 2009). Furthermore as PCK components might vary depending on the topic (Henze et al., 2008) science teacher' content knowledge quality can be another reason for teachers to form TSPCK through the transformation of SMK (Shulman, 1986; Grossman, 1990; Magnusson et al., 1999). For identifying and eliminating misconceptions science teachers mentioned questioning and repeating the answer None of them pointed out constructivist strategies such as concept maps (Arnaudin & Mintzes, 1985; Mann & Treagust, 1998; Özkan, 2001; Sungur et al. 2001), and two-tier diagnostic tests (Haslam & Treagust, 1987; Peterson et al.,1989; Seymour & Longden, 1991; Odom &Barrow, 1995; Özkan, 2001).

Science teachers preferred to use teacher centered instructional strategies such as questioning and direct instruction. However, one of the teachers asked her students to be prepared and make a presentation on the topic of ecosystem and while her students were presenting their information, they gathered she was asking questions and explaining and verifying students' examples. Thus the results of this study support the previous research (Brown et al., 2013; Käpylä et al., 2009; Karakulak & Tekkaya, 2010; Mıhlandız, 2010; Mıhlandız & Timur, 2011; Tekin, 2006; Aydın; 2012; Şen, 2014). One of the possible reasons for science teachers' using teacher centered strategies can be the deficit in knowledge of teachers' student-centered activities (Brown et al., 2013). Another reason may be science teachers' orientations since their central goal was transmitting curricular objectives which was consistent with the findings of Şen (2014). Moreover, contextual factors might be another reason (Aydın et al., 2010) such as loaded curriculum (Aydın, 2012). Although one of the teachers asked their students to be in charge of presenting an ecosystem topic presentation, other students were not active during the presentation. Therefore, in addition to other possible reasons teachers' lack of knowledge of students' understanding and difficulties might have affected their choice of instructional strategies. Science teachers might have used constructivist strategies such as problem based learning (Lewinsohn et al., 2014), experimentation (Finn et al., 2002), inquiry (Eilam, 2012; Jordan et al., 2009), role play (Bailey & Watson, 1998; Çokadar & Yılmaz, 2010) and field trip (O'Neal & Skelton, 1994; Farmer et al., 2007). As Magnusson et al. (1999) stated, being able to modify activities according to students' needs is a sign of a good science teacher. Therefore, the lack of knowledge on how to implement these strategies into lessons (Settlage, 2000) and on teaching ecosystem in that way (Flick, 1996) might be another reason for the choice of teachers' instructional strategies. In classroom observations it was noted that all participants used pictures or videos related to ecosystems instead of drawing an ecosystem on the board. However, they did not mention any interactions or elements of these ecosystem that were visualized on pictures or videos explicitly. Hence science teachers were not aware the fact that drawings are important to determine possible cognitive gaps on children's minds regarding ecosystem components and relationships (Larson, Green & Castleberry, 2011). Moreover, in classroom observations, it was seen that teachers did not conduct any activities although they mentioned they would go outside for a field trip to teach ecosystem topic so the result is consistent with Drechsler and Van Driel (2008).

Science teachers in this study both used assessment techniques for only assessing students' conceptual understanding as earlier researches indicated (Lankford, 2010; Tekkaya & Kılıç, 2012; Şen, 2014). The most important reason that might affect what teachers assess is their orientation towards science (Şen, 2014). Due to the fact that teachers' orientations were based on transmitting the knowledge to students, they focused on assessing objectives prescribed in the curriculum. None of them assessed students' problem-solving skills or science process skills. Another reason for this might be their lack of knowledge of students' understanding and difficulties because Henze et al. (2008) suggested that teachers should know well about students' misconceptions to better assess their understanding. This result is consistent with Aydın (2010). Moreover, contextual factors may affect science teachers' assessment (Yarden & Cohen, 2009) and High School Entrance Exam is considered as one of the contextual factors (Loughran et al., 2004; Şen, 2014). Since this exam is focused on assessing curricular objectives and students' conceptual understanding, science teachers may concentrate on assessing students' conceptual understanding. Science teachers also used traditional assessment techniques and they used formative assessment during the lesson with their verbal questions and observations. This result is consistent with previous researches (Canbazoğlu et al., 2010; Graf et al., 2011; Taşdere & Özsevgeç, 2012; Yarden & Cohen, 2009; Aydın, 2012; Şen, 2014). Furthermore, science teachers' lack of knowledge about alternative assessment strategies may affect science teachers' choice of assessment techniques. Kaya (2009) claimed the deficit in assessment courses in undergraduate level of education in Turkey. Another reason concerning this component is the time of the assessment. Formative and summative assessments were used by two participants in this study by using questioning and home works. Formative assessment improves science teachers' PCK (Şen, 2014). Their knowledge of students' understanding improves after they develop their knowledge of assessments. Similarly, as assessments are related to curricular objectives, their knowledge of curricular objectives also increase their knowledge of curriculum (Park & Oliver, 2008).

In this section science teachers' content knowledge and TSPCK findings regarding ecosystem topic were discussed. The next section represented the implications for science teachers, researchers and curriculum developers regarding TSPCK and content knowledge of ecosystem.

5.2. Implications and Recommendations

Discussing the results and revealing the findings pointed out some important implications for in-service teacher education, researchers and curriculum developers. This study revealed that science teachers to some extent have lack of knowledge in substantive knowledge and their orientation towards science, knowledge of instructional strategies, knowledge of students' understanding and knowledge of assessment regarding ecosystem.

First, science teachers need to improve their substantive knowledge so there should be professional development programs for increasing their content knowledge of ecosystem. These programs should focus on the ecosystem concepts like community, biodiversity and energy flow in an ecosystem. Furthermore, in these programs there should be an emphasis on the human and nature interactions. Since improving science teachers' content knowledge is not sufficient itself because there is a curricular limitation for teaching ecosystem such as energy concept is not included in the seventh grade while describing ecosystem, the curriculum developers should focus on integration of energy and matter concept in ecosystems in seventh grade.

Secondly, how many years a teacher spent for teaching is an important indicator for teachers' TSPCK (Grossman, 1990; van Driel et al., 2002). Yet it is not guarantee that an experienced teacher will have a rich and integrated PCK (Friedrichsen et al., 2009). Thus, teachers need to be supported with a professional development seminars and workshops where they could learn instructional and assessment strategies and how to integrate them into their teaching. Moreover, there should be additional educative activities for identifying and eliminating students' misconceptions and learning difficulties (Aydın, 2012).

Thirdly, in order to prepare pre-service science teacher for their future career, pre-service teacher education should focus more in training programs. For increasing pre-service teachers' content knowledge of ecosystem, biology courses should include ecosystem topic. In these courses, student centered instructional strategies, variety of assessment techniques in addition to traditional ones and curriculum and material knowledge on ecosystem should be covered. Moreover, in method courses, educators should concentrate on how to incorporate complex topics like ecosystem. These activities can be also applicable for in-service teachers because with the help of such educational activities, teachers can develop their TSPCK further.

This study has some recommendations for further studies will be conducted. Firstly, it is recommended that science educators to study on topics that are added newly to the science curriculum such as sustainable development in order to see how teachers develop their TSPCK regarding current issue. Furthermore, researchers might focus on the other topic which has provided with less hours and objectives in the curriculum to see whether teachers can enhance the topic which is not seen that important or difficult rather than focusing on more complex topics like ecosystem and meiosis and mitosis.

Secondly, this study used Magnusson et al. (1999) model for determining participants' PCK. With respect to that model, there are five components and all components interact with each other. Even though there are some visions of how these components interact or more independent from the others, there should be more studies focusing on these relationships. Moreover Magnusson et al. (1999) model is a transformative model and there are some integrative models for components of PCK as well. Therefore, using these models for investigating teachers TSPCK can be more helpful to analyze each component in detail. Especially for further researches it is recommended to investigate knowledge of students' understanding and students' achievement itself to see how well teachers know their students.

Finally, further studies should use qualitative, quantitative and mixed methods for a generalization and to see an integration of learning and teaching with each other. Moreover, this study could be replicated with pre-service science teachers to demonstrate how experience change the results. Similarly, since this study is conducted in public schools, future studies could be conducted in private schools in order to see how context of the study affect the findings. Moreover cross cultural PCK studies can be done to determine how a variety of cultures would have an impact on teachers' TSPCK.

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APPENDICES

A. HUMAN SUBJECTS ETHICS COMMETTEE APPROVAL

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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27 ŞUBAT 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Ceren ÖZTEKİN ;

Danışmanlığını yaptığınız yüksek lisans öğrencisi İlknur TIRAŞ' ın ***"Fen Bilimleri Öğretmenlerinin Ekosistem Konusuna İlişkin Alan Bilgisi, Pedagojik Alan Bilgisi ve Öğrenci Başarısı Arasındaki İlişki"*** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-EGT-023** protokol numarası ile **15.03.2018 - 30.09.2019** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Yrd. Doç. Dr. Pınar KAYGAN
Üye

Yrd. Doç. Dr. Emre SELÇUK
Üye

B. PCK INSTRUMENTS USED IN THE STUDY (IN TURKISH)

EK 1. İÇERİK GÖSTERİMİ MÜLAKAT SORULARI

Mülakat aracı Aydın (2012) tarafından izin alınarak ekosistem konusuna adapte edilerek hazırlanmıştır.

Merhaba, ben İlknur TIRAŞ. Orta Doğu Teknik Üniversitesi, Eğitim Fakültesi İlköğretim Fen ve Matematik Eğitimi Bölümü yüksek lisans öğrencisiyim. Ortaokul fen bilimleri öğretmenlerinin ekosistem konusunda konu alan bilgileri ve pedagojik alan bilgileri üzerine bir araştırma yapmaktayım. Bu nedenle konu ile ilgili içten ve samimi cevaplarınız benim için oldukça değerlidir.

Bu çalışmaya katılmak tamamen gönüllülük esasına dayalıdır. Çalışmayı istediğiniz zaman bırakabilirsiniz ve cevap vermek istemediğiniz sorular olursa boş bırakabilirsiniz. Görüşme esnasında toplanan veriler tamamen gizli tutulacak, kimlik bilgileriniz kesinlikle gizli kalacak, veriler ve kimlik bilgileri herhangi bir şekilde Görüşmeyi kaydetmek için izninizi istiyorum. Bu hem görüşmenin akışı hem de cevaplarınızın analizi açısından önemlidir. Görüşme yaklaşık 60 dakika sürecektir. Bana sormak istediğiniz herhangi bir soru varsa yanıtlayabilirim. Teşekkür ederim.

KİŞİSEL BİLGİLER

Adınız, Soyadınız:

Doğum tarihi: Cinsiyet:

Mezun olduğunuz üniversite/Bölüm:

Ne kadar süredir öğretmenlik yapıyorsunuz?:

Görev yapmakta olduğunuz okul:

Kaç yıldır bu okulda görev yapıyorsunuz? Kaçıncı sınıflara giriyorsunuz?

Okulun demografik yapısını nasıl tanımlarsınız?

Sınıflarınızın ortalama öğrenci sayısı:

:

Daha önce çevre ve ekosistem ile ilgili hizmet içi eğitim/etkinlik/seminer/konferans vs. katıldınız mı?

Katıldıysanız, içeriği:

Üyesi olduğunuz çevreye yönelik sivil toplum/dernek/kurum/kuruluşlar:

Ekosistem konusuyla ilgili okul dışı bir deneyiminiz oldu mu? (Günlük hayatta ilginiz var mı?)

YARI YAPILANDIRILMIŞ PEDAGOJİK ALAN BİLGİSİ GÖRÜŞME FORMU

Pedagojik Alan Bilgisi Ön Görüşme Soruları

Ana soru: Fen bilimleri öğretiminin amaçları

Sizce ortaokulda neden fen bilimleri öğretiyoruz? Sizin fen bilimleri öğretmede amaçlarınız nelerdir? Öğrencilere fen bilimleri öğreterek onların hangi bilgi ve becerilere sahip olmasını bekliyorsunuz?

1. Bahsettiğiniz bu amaçları hedefleri nasıl belirlediniz? Amaçları belirlemenize neler yardımcı oldu?
2. Fen öğretiminde öğretmenin rolü nedir öğrencinin rolü nedir?

Fen Öğretimine karşı Yönelimler

1. Size göre "fen öğretmek" ne anlama gelmektedir? Düşüncelerinizi açıklar mısınız?

2. Sizce genel anlamda fen öğretiminin amacı/amaçları nedir? Cevabınızı açıklar mısınız?

3. Özel olarak "ekosistem" konusunu ele alırsak bir fen bilgisi öğretmeni olarak bu konuyu öğretmek sizin için ne anlama geliyor? Cevabınızı açıklar mısınız?

a) Ekosistem konusunu siz, neden öğretiyorsunuz?

Konu Alanı 1. Öğrencilerin Öğrenmesi Gereken Konular

Müfredat Bilgisi

Ana Soru: İnsan ve Çevre İlişkileri / Canlılar ve Hayat ünitesinde öğrencilerin neleri (hangi temel noktaları) öğrenmesini istiyorsunuz?

1. Sizce ekosistem konularına öğretim programında neden yer verilmiştir?

2. Ekosistem müfredattaki yerini biliyor musunuz?

- Sizce "ekosistem" konusu kaçıncı sınıfta okutulmaktadır?
- Ekosistem konusu (7.sınıf ders programında) kaçıncı ünitedir?
- Bu konulardan önceki ve sonraki üniteler nelerdir? Cevabınızı açıklar mısınız?

3. Öğretim programında ekosistem konuları diğer konularla, ünitelerle veya sınıflarla ilişkilendirilmiş mi?

- Eğer ilişkilendirilmişse önceki yıllarda işlenen hangi fen konuları ile ilişkilidir?
- Eğer ilişkilendirilmişse 7.sınıftaki hangi konularla ilişkilendirilmiştir?
- Eğer ilişkilendirilmemişse, sizce hangi konularla ilişkilendirilse konunun öğretimi ve öğrenilmesi daha iyi olur? Neden böyle düşündüğünüzü açıklayınız.

4. Fen bilimleri öğretim programında ekosistem ile ilgili olarak öğretilmesi amaçlanan temel kazanımlar nelerdir? (Programda bu konu ile ilgili öğrencilerin hangi kavram/becerileri geliştirmeleri bekleniyor?)

6. Sizce öğrencilerin öğrenmesi gereken en önemli kavramlar/noktalar nelerdir? Bu noktaları/ kavramları nasıl belirlediniz?

7.Öğrencilerin hangi kavramları öğrenmesini ve bu bilgilerle neleri yapabilmesini bekliyorsunuz?

8. Bu kazanımlardan farklı olarak sizin ekosistem konuları ile ilgili önemli gördüğünüz noktalar var mıdır?

- Eğer varsa nelerdir? Cevabınızı açıklar mısınız?
- Yoksa neden böyle düşündüğünüzü açıklar mısınız?

1. **1.** Ekosistemi öğrenmeleri öğrencilere ne gibi avantajlar sağlar? Neden?
2. **2.** Öğrencilerin bu kavramları bilmeleri neden önemlidir? Onlara nasıl bir katkısı olabilir?

9. Fen bilimleri öğretim programında ekosistem ile ilgili kavram yanılgılarına ve konunun anlatımı sırasında uyulması gereken sınırlamalara yer verilmiş midir?

- Eğer varsa, belirtilen kavram yanılgıları ve sınırlamalar nelerdir?
- Yoksa neden böyle düşündüğünüzü açıklar mısınız?

10. Öğrencilerinize ekosistem konularını anlatırken hangi kaynakları kullanıyorsunuz?

- Eğer kullanıyorsanız, bu kaynakları hangi amaçla kullanıyorsunuz?
- Eğer kullanmıyorsanız neden kullanmaya ihtiyaç duymadığınızı açıklar mısınız?

<u>*Konu Alanı: 2 Konuyu öğretmek ile İlgili Zorluk ve Sınırlılıklar*</u>

<u>**Ana Soru: Ekosistem Konusunu öğretirken yaşadığınız zorluk var mıdır?**</u>

1. Sizce bu konuyu öğretmek zor mudur? Neden?

2. Bu konuyu öğretmeyi zorlaştıran etkenler nelerdir? Neden?

3. Bu faktörler yaptığınız öğretimi nasıl etkilemektedir?

4. Bu konuyu öğretirken kendinizi ne kadar özgür/bağımsız/seçme hakkına sahip hissediyorsunuz?

5. Bu konuyu öğretmenin zor olduğuna nasıl kanaat getirdiniz?

6. Ekosistem konusunun öğretimine yönelik kaygılarınız var mı?

a. Evet derse: kaygıların nelerdir?
b. Kaygılanma nedenin nedir?
c. Hangi faktörlerin senin ekosistem öğretimini etkileyeceğini düşünüyorsun?

d. Ekosistem öğretimi ile ilgili zorluklar ve seni sınırlayan faktörler olabilir mi?
e. Bu konuyu öğretmenizi etkileyen diğer faktörler nelerdir?
f. Bu konuyu öğretmenin zorlukları nelerdir?
g. Bu konuyu öğretirken yaşadığınız sınırlılıklar nelerdir?

Konu Alanı: 3 Öğrencilerin Düşünceleri

Öğrenci Bilgisi

Ana Soru: Bu aşamada öğrencilerin ekosistem konusundaki düşünceleri/kavramaları hakkında konuşmak istiyorum. Öğrenciler ekosistem konusunu öğrenirken hangi noktalarda zorlanıyorlar?

1. Sizce öğrencilerinizin ekosistem konusunu öğrenebilmeleri için gerekli olan ön bilgiler neler olmalıdır? Neden böyle düşünüyorsunuz? Cevabınızı açıklar mısınız?

2. Öğrencilerinizin ekosistem ile ilgili olarak, hangi konuları anlamakta zorluk çektiklerini düşünüyorsunuz?

3. Sizce öğrencilerinizin bu konuları anlamakta zorlanmalarının sebepleri nelerdir?

4. Öğrencilerinizin ekosistem ile ilgili kavram yanılgıları var mıdır? Varsa bu kavram yanılgıları nelerdir? Cevabınızı açıklar mısınız?

5. Öğrencilerinizin ekosistem ile ilgili sahip oldukları kavram yanılgılarının nedenleri sizce neler olabilir?

6. Öğrencilerinizin ekosistemde sahip olduğu kavram yanılgılarını nasıl saptarsınız? Kavram yanılgılarını saptamak için hangi yöntemleri kullanıyorsunuz?

- Eğer öğrencilerinizin kavram yanılgılarını saptamıyorsanız nedenini belirtiniz.

7. Saptadığınız bu kavram yanılgılarını gidermeye çalışıyor musunuz?

- Cevabınız evet ise, Kavram yanılgılarını gidermek için hangi yöntemleri kullanıyorsunuz?

- Kavram yanılgısını gidermek için neden bu yöntemi seçtiğinizi açıklar mısınız?
- Sizce bu yöntem kavram yanılgısını gidermek için yeterli mi?
- Neden yeterli/ neden yeterli değil?
- Cevabınız hayır ise neden kavram yanılgılarını gidermediğinizi açıklar mısınız?

Konu Alanı: 4 Öğretim Prosedürleri

Ana Soru: Öğrencilerin bahsettiğiniz kavramları anlamasına yardımcı olmak için hangi öğretim stratejilerini (analoji, gösteri deneyi, benzetim/simülasyon, grafik, günlük hayat örnekleri vs.) kullanacaksınız? (Ya da hangi aktiviteler öğrencilerin o kavramları anlamalarında yardımcı olabilir?)

Öğretim stratejileri bilgisi

1. Genel olarak fen konularını öğretirken hangi öğretim strateji, metot ya da öğretim yöntemlerini kullanıyorsunuz? Bu strateji, metot ya da yöntemi kullanma nedenlerinizi belirtiniz.

2. Bu stratejileri kullanmayı nasıl öğrendiniz? Bu stratejileri kendiniz mi geliştirdiniz yoksa başka kaynaklardan mı (kişi, kaynak, vb.) öğrendiniz?

3. Ekosistem ile ilgili sınıfta etkinlik yapıyor musunuz?

- Eğer yapıyorsanız bu etkinlikler nelerdir?
- Eğer ekosistem ile ilgili etkinlik yapmıyorsanız neden etkinlik yapmadığınızı açıklayınız.

4.Ekosistem konusunu öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyorsunuz?

- Neden bu öğretim yöntemlerini diğer öğretim yöntemlerine tercih ettiğinizi açıklar mısınız?

5. Öğrencilerinizin ekosistem konularını öğrenmeleri ve kavramlarını anlamaları için gösterimler, figürler, simülasyonlar, çizimler ya da metaforlar kullanıyor musunuz?

- Eğer gösterimler, figürler, simülasyonlar, çizimler ya da metaforlar vs. kullanıyorsanız bunlar nelerdir? Cevabınızı açıklayınız.
- Eğer gösterimler, figürler, simülasyonlar, çizimler ya da metaforlar kullanıyorsanız kullandığınız bu gösterimlere örnek verir misiniz?

Eğer gösterimler, figürler, simülasyonlar, çizimler ya da metaforlar vs. kullanmıyorsanız, neden bu gösterimleri kullanmadığınızı açıklar mısınız?

6. Konuyu öğretirken öğrencilerin konu ile ilgili yanlış kavramalara sahip olduklarının farkına varsanız ne yaparsanız?

7. Etkili aktivite bulmada ne kadar iyisiniz? Neden iyi/kötü olduğunuzu düşünüyorsunuz? Ya da bu kanıya nasıl vardınız?

8. Yapmayı planladığınız bu aktivite/strateji vs.'nin etkili olduğunu/olacağını nasıl öğrendiniz/anladınız/nereden biliyorsunuz?

9. Amaçlarınızla seçtiğiniz metotlar arasında nasıl bir bağlantı var, seçtiğiniz metotlar amaçlarını ne ölçüde yansıtıyor?

10. Günlük hayatta ekosistem konusunun uygulamasını gördüğünüz alanlar var mı? Bunu yaptığınız öğretimde kullanıyor musunuz?

11. Yaptığınız öğretimin etkili olup olmadığını nasıl anlarsınız?

Konu Alanı: 5 Öğrencilerinin Anladıklarının Ölçülmesi:

Değerlendirme Stratejileri Bilgisi

Ana Soru: Öğrencilerin konuyu anlayıp anlamadıklarını nasıl ölçersiniz?

1. Öğrencilerin ekosistem konusunda ne öğrendiklerini hangi ölçme tekniklerini kullanarak ölçersiniz?

2. Niçin bu ölçme tekniklerini kullanmayı tercih ediyorsunuz?

3. Değerlendirme sonuçlarını nasıl kullanıyorsunuz?

4. Öğretiminizi değerlendirme yolları bulmada ne kadar iyisiniz? Neden iyi/kötü olduğunuzu düşünüyorsunuz? Ya da bu kanıya nasıl vardınız?

5. Öğrencilerinizin ekosistem ile ilgili bilgilerini ölçerken tam olarak neyi ölçmeyi hedefliyorsunuz?

6. Öğrencilerinizin öğrenmelerini ne zaman ölçüyorsunuz? (Ünitenin hangi aşamasında ölçüyorsunuz?)

- Neden bu zaman dilimini seçtiğinizi açıklar mısınız?

C. ECOSYSTEM CONTENT KNOWLEDGE INSTRUMENTS USED IN THE STUDY (IN TURKISH)

EK 2. Öğretmen Ekosistem Alan Bilgisi Mülakat soruları

1. Sistem nedir? Bir sistemi nasıl tanımlarsınız?
2. Bir örnek verebilir misiniz?
3. Örneğinizi bir sistem yapan şey nedir?
4. Sizce Ekosistem bir sistemi midir? Neden?
    - Ekosistemi sistem yapan şey/öğeler nedir?
    - Ekosistemin bileşenleri nelerdir?
    - Ekosistemlerde ne tür olaylar gerçekleşir? Bu olaylar arasında bir ilişki var mıdır?
    - Ekosistemlerdeki enerji akışını çizerek açıklayınız

5. Ekosistem deyince aklınıza gelen 12 kelimeyi söyler misiniz?
6. Ekosistem konusunda bir kavram haritası çiziniz
7. Bir ekosistem çizerek, çiziminizi açıklayınız.
8. Aşağıda verilen terimleri tanımlayınız ve örnek veriniz:
- Habitat:
- Komünite:
- Tür:
- Popülasyon:
- Biyolojik çeşitlilik:
- Ekolojik niş:
- Üretici:
    - Üreticilerin ekosistemdeki önemi nedir?
- Bitkinin besini nedir?
- Tüketici:
    - Tüketicilerin ekosistemdeki önemi nedir?
- Ayrıştırıcı:
    - Ayrıştırıcıların ekosistemdeki önemi nedir?

9. Besin zinciri nedir? Örnekler verebilir misiniz?

- Bir Besin zinciri çizerek açıklar mısınız?

10. "Nektar, bir kelebek, bir kuş, ayrıştırıcılar", verilen sıraya göre, bir besin zinciri oluşturur mu?

11. Neden Besin ağı nedir?

- Örnekler verebilir misiniz?

12. Bir Besin zinciri çizerek açıklar mısınız? Enerji piramidi nedir? Örnekleri nelerdir?

- Bir enerji piramidi çiziniz. Neden piramit şeklinde olduğunu açıklayınız.
- Piramit üstünde Üreticileri Tüketicileri ve Ayrıştırıcıları gösteriniz.
- Ayrıştırıcılar enerji piramidinde hangi basamakta yer alırlar? Açıklayınız

13. Üreticiler, Tüketiciler ve Ayrıştırıcılar arasındaki ilişkiyi açıklayınız.

14. Ekosistemlerde enerji akışını çizerek açıklayabilir misiniz?

15. Madde döngüleri ve besin zinciri arasında bir ilişki var mıdır? Açıklayınız.

D. ORIGINAL DRAWINGS OF EZGI

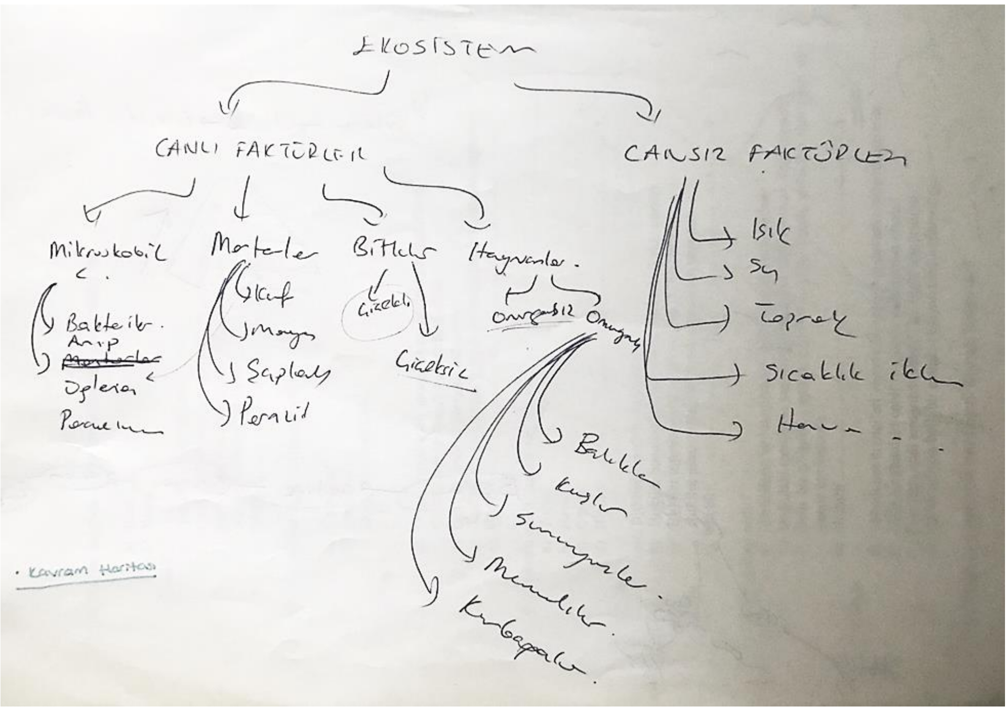

Figure 4.1. 1. Ezgi's concept map about an ecosystem

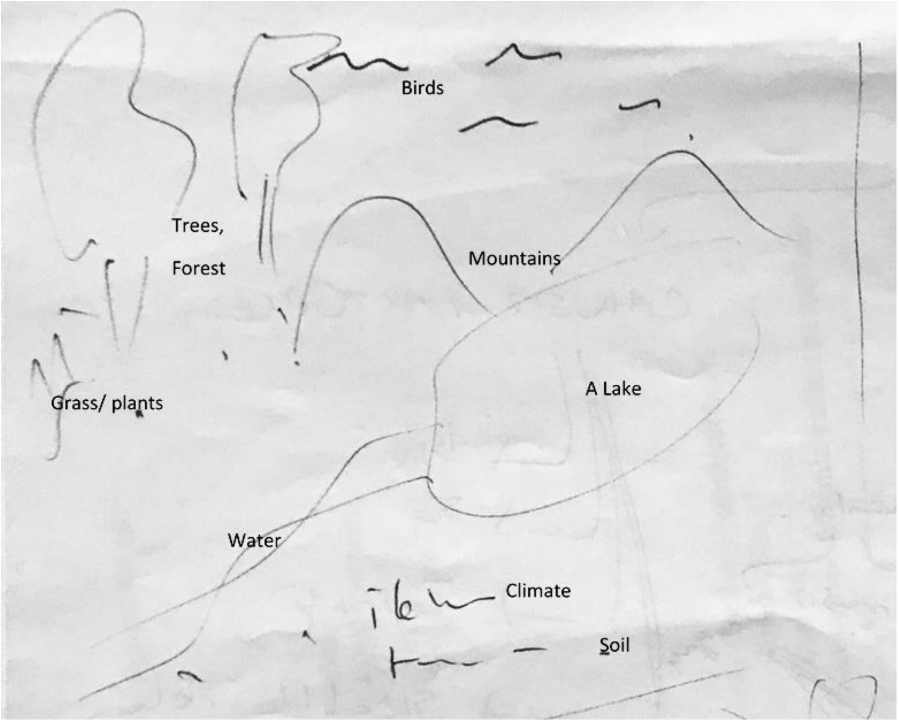

Figure 4.1. 2. Ezgi's drawing of an ecosystem

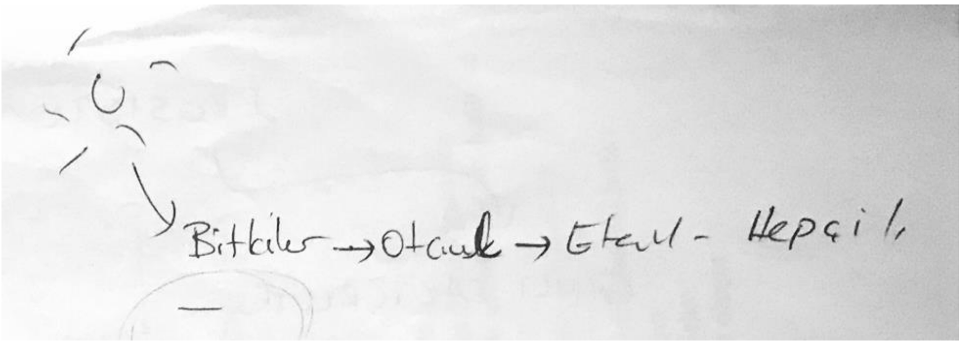

Figure 4.1. 3. Ezgi's drawing of a food chain example

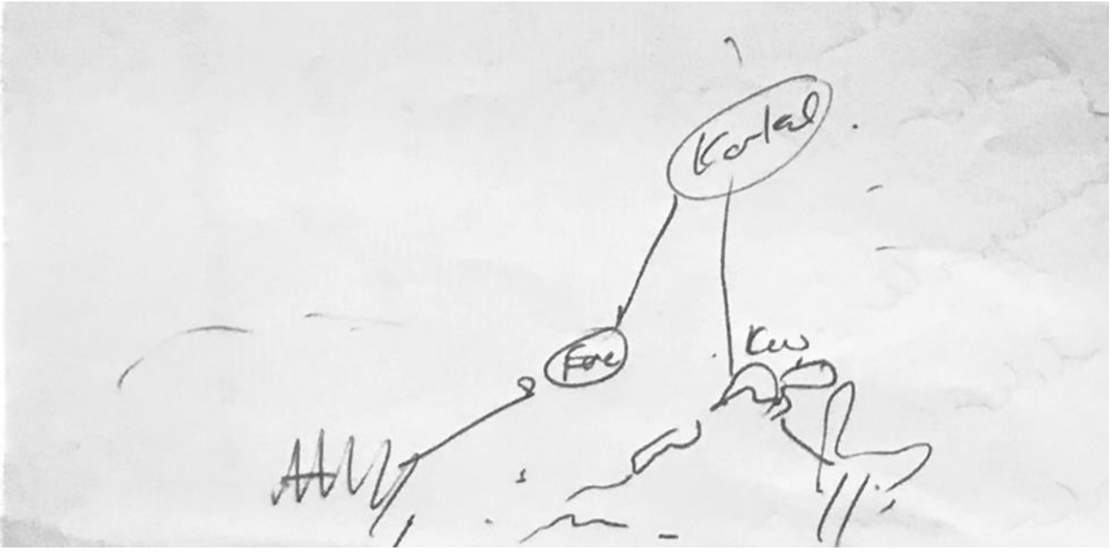

Figure 4.1. 4. Ezgi's drawing of a food web example

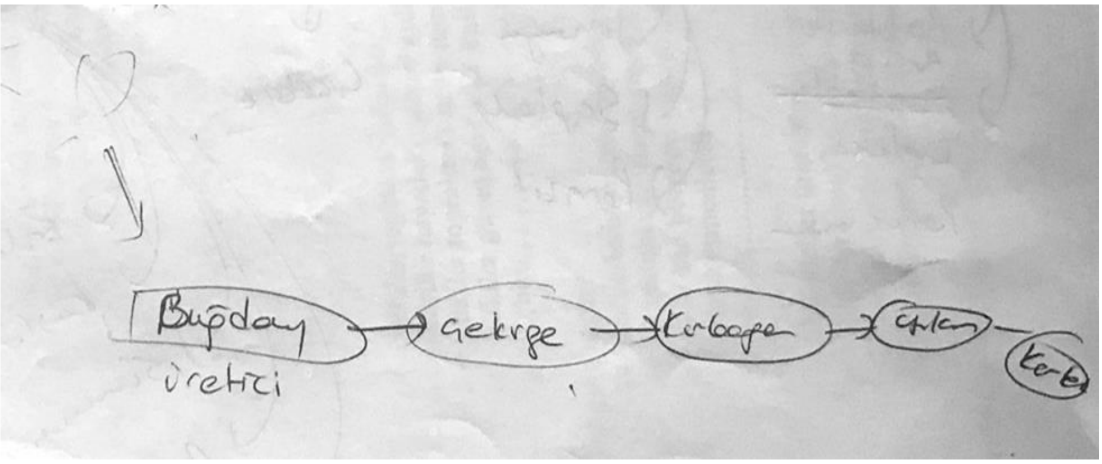

Figure 4.1. 8.Ezgi's drawing of energy flow in an ecosystem

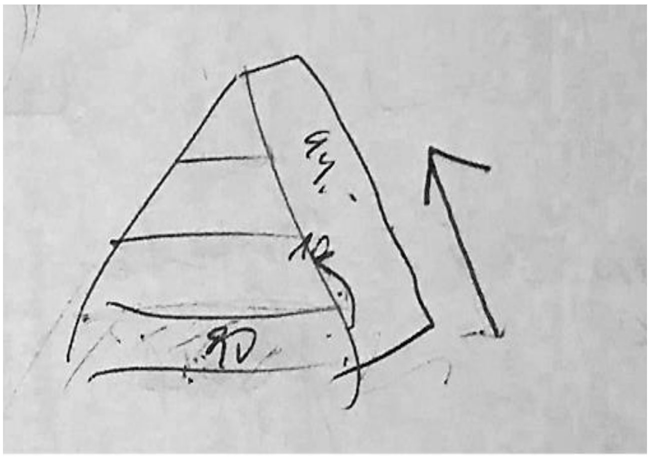

Figure 4.1. 6. Ezgi's drawing of energy pyramid

E. ORIGINAL DRAWINGS OF NILAY

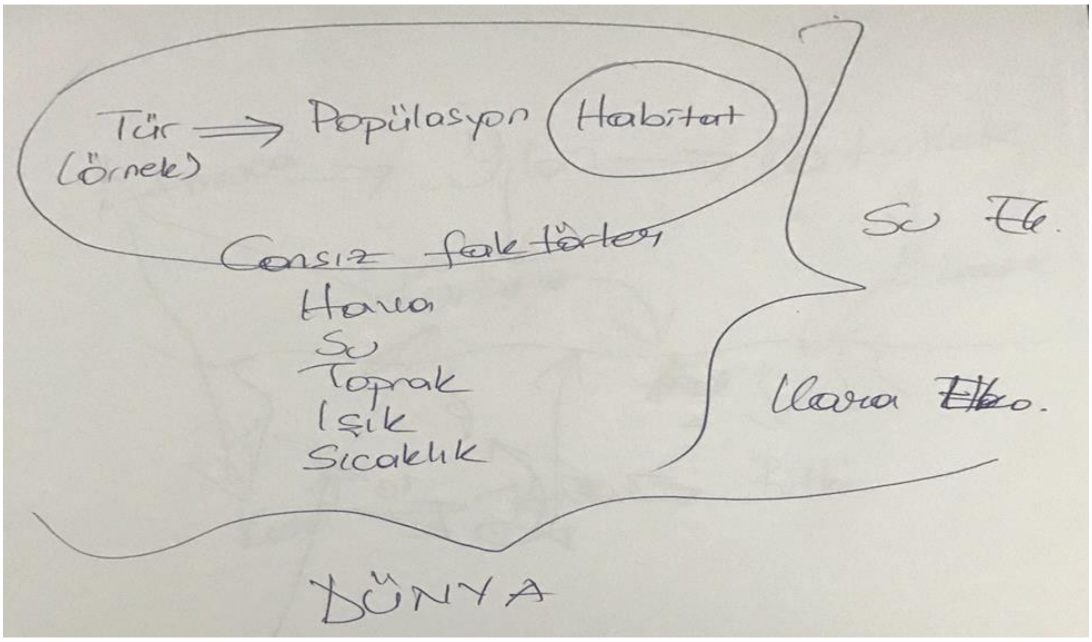

Figure 4.2. 1. Nilay's drawing of ecosystem concept map

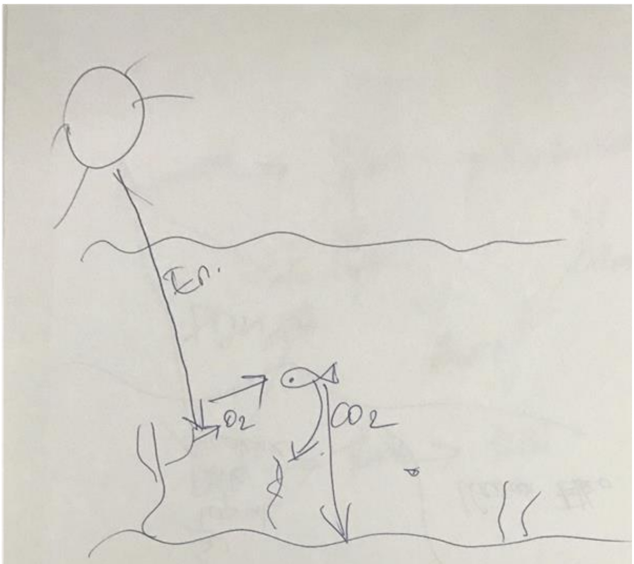

Figure 4.2. 2. Nilay's drawing of an ecosystem example

Figure 4.2. 3. Nilay's drawing of a food chain example

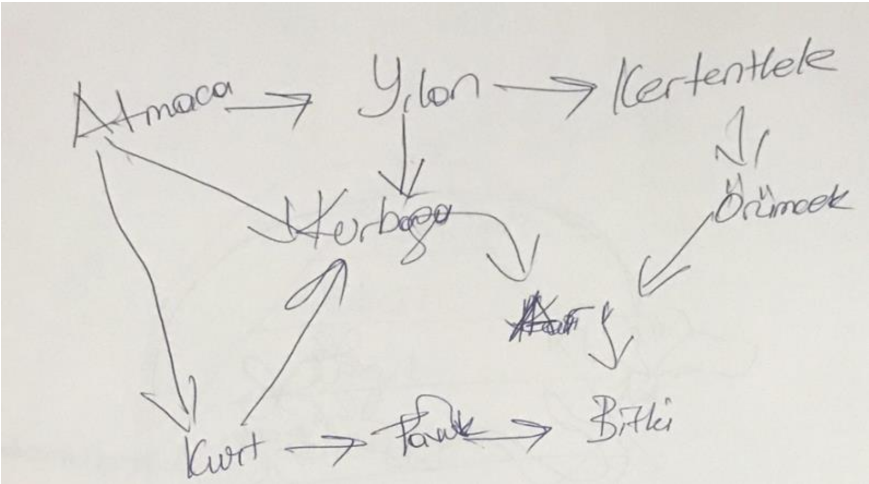

Figure 4.2. 4. Nilay's drawing of a food web example

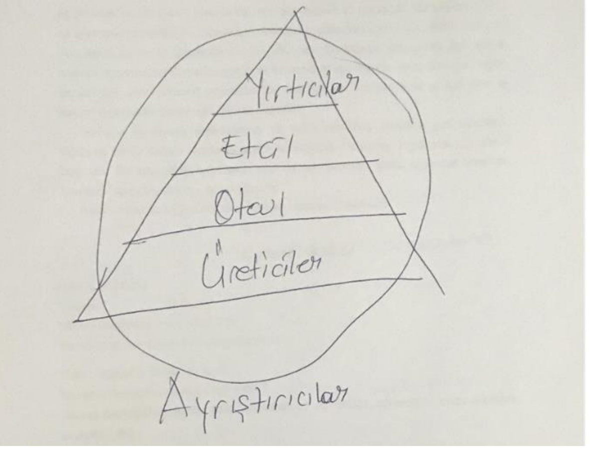

Figure 4.2. 6. Nilay's drawing of an energy pyramid

F. APPROVAL FOR USING QUESTIONS

01.04.2019 Ynt_ veri toplama aracı.html

Merhaba İlknur; tabi ki kullanabilirsin. Çalışmalarında kolaylıklar ve başarılar dilerim. Ceren Hoca'ma selamlar ve sevgiler.

İyi günler.

Doç. Dr. Sevgi AYDIN GÜNBATAR
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Bilgi: ceren@metu.edu.tr
Konu: veri toplama aracı

Sayın Doç. Dr. Sevgi Aydın,

Ben ODTÜ Fen ve Matematik Eğitimi programında, Prof. Dr. Ceren Öztekin danışmanlığında, yüksek lisans eğitimi almaktayım. Önümüzdeki dönem tez dönemine geçeceğim ve verilerimi toplarken sizin doktora tezinizde kullandığınız bazı soruları (İÇERİK GÖSTERİMİ MATERYALİNİ DOLDURURKEN SORULACAK MÜLAKAT SORULARI-p.249) kullanmak için izninizi almak istiyorum.
Şimdiden çok teşekkür ederim.

Saygılarımla,
İlknur Tıraş

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G. MINISTRY OF NATIONAL EDUCATION RESEACRH APPROVAL

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.5999404 22.03.2019
Konu : Araştırma izni

ORTA DOĞU TEKNİK ÜNİVERSİTESİNE
(Öğrenci İşleri Daire Başkanlığı)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) 06.03.2019 tarihli ve 102 sayılı yazınız.

Üniversiteniz Sosyal Bilimler Enstitüsü Yüksek Lisans Öğrencisi İlknur TIRAŞ' ın **"Fen Bilimleri Öğretmenlerinin Ekosistem Konusuna İlişkin Alan Bilgisi, Pedagojik Alan Bilgisi ve Öğrenci Başarısı arasındaki ilişki"** konulu araştırması kapsamında uygulama yapma talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Uygulama formunun (15 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme Şubesine gönderilmesini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdürü

Güvenli Elektr
Aslı İle A
22/03/2019

Mahmut ÖZDEMİR

Adres: Emniyet Mah. Alparslan Türkeş Cad. 4/A Yenimahalle
Elektronik Ağ: ankara.meb.gov.tr
e-posta: istatistik06@meb.gov.tr

Bilgi için: Emine KONUK
Tel: 0 (312) 212 36 00
Faks: 0 (___) ___ __ __

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H. TURKISH SUMMARY/TÜRKÇE ÖZET

DENEYİMLİ FEN BİLİMLERİ ÖĞRETMENLERİNİN EKOSİSTEMLERİN ÖĞRETİMİNE İLİŞKİN KONUYA ÖZEL PEDAGOJİK ALAN BİLGİSİNİN İNCELENMESİ

GİRİŞ

Öğretmenin fen öğretimi üzerinde etkisi, öğrenciden sonra gelen en önemli etmendir (Kind, 2009). Öğretmenin bilgisi üzerinde çeşitli çalışmalar yapılmıştır. Shulman (1986; 1987) öğretmenlerin konu alan bilgisine sahip olmadan sınıfta etkili öğretim yapamayacağını savunmuştur. Pedagoji alan bilgisi ve konu alan bilgisinin bir arada kullanılması pedagojik alan bilgisi (PAB) olarak adlandırılmıştır (Shulman, 1986;1987). PAB, Ülkemizde de öğretmen yetiştirme programlarında yerini almıştır. (Nakiboğlu ve Karakoç, 2005).

PAB üzerinde yapılan çalışmalara göre; PAB diğer bilgi alanlarının (fene karşı yönelimler, müfredat bilgisi, öğrenci bilgisi, öğretim yöntemleri bilgisi ve değerlendirme bilgisi) birleşimi (Cochran vd., 1993; Veal & MaKinster, 1998) ya da diğer bilgi alanlarının PAB'a dönüştürülmüş halidir (Grossman, 1990; Magnusson vd., 1999). PAB ayrıca, konuya özgü, alana özgü ve genel olarak üç kategoride sınıflandırılır (Veal & MaKinster, 1998). Bir öğretmenin PAB'ını etkileyen tek etmen konu olmamakladır; zaman, mekan ve öğrenci de öğretmenin PAB'ını etkileyen diğer etmenlerdir (Park & Oliver, 2008; Van Driel vd., 2012).

Yapılan bu çalışmada, PAB konuya özgü olarak ele alınıp, çalışmanın teorik çerçevesi BU DOĞRULTUDA şekillendirilmiştir. Çalışmasında incelenen konu ekosistemlerdir. Çünkü ekosistemler konusu, enerji ve madde dönüşümleri gibi karmaşık ve birbirleriyle ilgili olan konuları içermektedir (Çokadar & Yılmaz, 2009; Martín-Gámez, Acebal & Prieto, 2018). Bu doğrultuda, oğrencilerin sistemsel düşünme becerilerinin geliştirilmesi açısından önemlidir. Bunun yanında, ekosistem konusunun fen, teknoloji, toplum ve çevreyle ilgili bağlantısı olduğundan (MEB, 2013, p.29), öğretmenlerin ekosistemleri etkili bir şekilde öğretmeleri gelecek nesillerin enerji ve madde konularını iyi kavrayarak, ekosistemleri korumak adına önlemler almalarına önayak olacaktır (NGSS, 2013).

Çalışmada, Magnusson ve arkadaşlarının (1999) geliştirdikleri beş farklı boyuttan oluşan model kullanılmıştır. Bu boyutlar fene karşı yönelimler, müfredat bilgisi, öğrenci bilgisi, öğretim yöntemleri bilgisi ve değerlendirme bilgisidir. Bu modele göre öğretmenin fene karşı yönelimleri onun fen öğretimine karşı tutumunu ve fen öğretimiyle ilgili inançlarını temsil eder ve diğer dört boyut için bir filtre görevi görür (Magnusson vd., 1999). Müfredat bilgisinin dâhilinde hedef ve kazanımlar bilgisi ve özel programlar ve materyal bilgisi de yer almaktadır. Bunun yanında öğrenci bilgisi; feni öğretmek için gerekli olan ön bilgileri ve öğrencilerin zorlandıkları konuları içermektedir. Öğretim yöntemleri bilgisi; genel öğretim yöntemlerine ek olarak konuya özgü öğretim yöntemlerini de ele alır. Değerlendirme bilgisinin alt boyutlarını ise fen öğrenimi değerlendirme boyutları ve değerlendirme yöntemleri oluşturmaktadır.

Önceki PAB çalışmaları incelendiğinde çoğunlukla öğretmen adaylarıyla yapılmış olduğu ve sadece birkaç boyutunun ele alındığı (Abell, 2008; Aydın & Boz, 2012), genellikle kimya konularına değinildiği (De Jong & van Driel, 2004; Mavhunga, 2016) görülmüştür. Bu bağlamda, biyoloji ve çevre konuları üzerinde daha çok araştırma yapılmasına ihtiyaç duyulduğu düşünülmektedir (Aydın & Boz, 2012; Şen, 2014).. Özetle, bu çalışmada, deneyimli fen bilimleri öğretmenleriyle çalışılarak PAB'ın bütün boyutları ele alınmış, ve öğretmenlerin hem ekosistem alan bilgisi, hem de ekosisteme özgü pedagojik alan bilgisi ortaya çıkarılmaya çalışılmışır.

Araştırma Soruları

Bu çalışmada iki ana araştırma sorusu ve bu soruların alt soruları bulunmaktadır. Çalışmanın araştırma soruları şu şekilde sıralanmaktadır:

1. Deneyimli fen bilimleri öğretmenlerinin ekosistem ile ilgili konu alan bilgisi nedir?
   1.1. Deneyimli fen bilimleri öğretmenlerinin içeriğe yönelik alan bilgisi nedir?

2. Deneyimli fen bilimleri öğretmenlerinin ekosisteme özgü pedagojik alan bilgisi nedir?
   2.1. Deneyimli fen bilimleri öğretmenlerinin fene yönelik yönelimleri nedir?
   2.2. Deneyimli fen bilimleri öğretmenlerinin ekosistemle ilgili müfredat bilgisi nedir?
   2.3. Deneyimli fen bilimleri öğretmenlerinin ekosistemle ilgili öğrenci bilgisi nedir?
   2.4. Deneyimli fen bilimleri öğretmenlerinin ekosistemle ilgili öğretim strateji ve yöntemleri bilgisi nedir?
   2.5. Deneyimli fen bilimleri öğretmenlerinin ekosistemle ilgili değerlendirme bilgisi nedir?

YÖNTEM

Çalışma Deseni

PAB örtük ve saklı olduğundan (Abell, 2008), bu bilgiyi anlayabilmek ve yorumlayabilmek için birden fazla veriye ihtiyaç duyulmaktadır. Bu nedenle bu çalışmada nitel yöntemler tercih edilmiştir. Çalışma deseni olarak çoklu durum çalışmalarında her bir durum araştırma sorularına detaylı bilgi verdiği için (Creswell, 2007; Merriam, 2009) çoklu durum çalışması seçilmiştir.

Katılımcılar

Bu çalışmada iki deneyimli fen bilimleri öğretmeniyle çalışılmıştır. Öğretmenlerin ikisi de devlet okulu çalışanlarıdır ve örneklem seçimi amaçlı örneklem yöntemiyle yapılmıştır. Öğretmenlerin gerçek isimleri yerine Ezgi veNilay rumuz isimleri kullanıştır. Çalışmada yer alan öğretmenler hakkındaki bilgiler Tablo 1'de gösterilmiştir.

Tablo 1. *Öğretmenler hakkındaki bilgiler*

Öğretmenler	Tecrübe (yıl)	Fen öğretimi tecrübesi (yıl)	Diğer tecrübeler	Şimdiki okulda geçirilen süre	Dersine girilen sınıf düzeyi	Lisans eğitimi
Ezgi	15	9	Lise fizik	1	5, 7, 8	Fizik Öğretmenliği
Nilay	24	15	Lise kimya	6	5, 6, 7	Kimya Öğretmenliği

Veri Toplama Araçları

Mevcut çalışmada veriler 7. Sınıflarda görev yapan ve devlet okullarında çalışan iki deneyimli fen bilimleri öğretmenlerinden toplanmıştır. Çalışma kapsamında öğretmenlerin konu alan bilgilerini ve pedagojik alan bilgilerini saptamak adına içerik alan bilgisi ön görüşmesi (çizimler, kavram haritası vb), PAB ön görüşmesi ve sınıf içi gözlemler kullanılmıştır. Yaklaşık 50 dakika süren ön görüşmeler, ses kaydına alınarak analizi yapılmıştır.

Veri Analizi

Çalışmada katılımcılardan toplanan veriler, hedeflenen ilgi türleri göz önüne alınarak ayrı ayrı kodlanıp kategorilere ayrılmıştır. Öğretmenlerin ekosistem konusuna yönelik içerik alan bilgilerini ölçmeye yönelik olan sorular ilgili literatür doğrultusunda araştırmacı tarafından hazırlanmış (Özkan vd., 2004) ve öğretmenlerin verdikleri yanıtlar tam anlama, kısmi anlama ve kavram yanılgıları olarak gruplandırılmıştır. Katılımcıların vermediği yanıtlarda cevapsız kategorisine alınmıştır.

PAB ile ilgili olarak ise sorular Magnusson vd., (1999) PAB modeline bağlı, Aydın (2012) tezinden uyarlanmıştır. Bu modele göre öğretmenlerin verdiği cevaplar, modelin beş boyutu ve onların ilgili alt boyutlarınca incelenmiştir.

BULGULAR VE TARTIŞMA

Mevcut araştırmada fen bilimleri öğretmenlerinin konu içerik alan bilgisi ve ekosisteme özgü pedagojik alan bilgisi ele alınmıştır.

1. Deneyimli Fen Bilimleri Öğretmenlerinin Ekosistem İçerik Alan Bilgisi

Çalışma bulgularına göre fen bilimleri öğretmenleri sistem, tür ve habitat kavramları hakkında tam bilgiye sahiptir. Ancak öğretmenlerin habitat kavramını anlatırken barınak ve beslenme/yiyecek gibi canlının temel ihtiyaçlarına değinmedikleri not edilmiştir. Bunun yanı sıra, çalışma bulguları öğretmenlerin ekosistem, biyolojik çeşitlilik ve ayrıştırıcılar hakkında kısmen bilgili olduklarını göstermiştir. Öğretmenlerin ekosistem çizimlerinde insan etkilerinden uzak, enerji terimi kullanılmadan ve canlı-cansız ilişkilerine değinilmediği tespit edilmiştir. Ayrıca kelime ilişkilendirme testine göre öğretmenlerin yalnızca canlı ve cansız kategorisine bağlı kalarak kelime ürettikleri görülmüştür. Biyolojik çeşitlilik konusunda sadece tür çeşitliliğine değinen öğretmenlerin, genetik çeşitlilik ve ekolojik çeşitliliğinden bahsetmediği görülmüştür. Bununla beraber ayrıştırıcıların görev tanımını yaparken öğretmenlerin, ayrıştırıcıların neyi neye dönüştürdüğü konusunda eksikleri tespit edilmiştir. Diğer taraftan çalışmaya katılan öğretmenlerin besin zinciri ve besin ağı hakkında kavram yanılgılarına sahip olduğu gözlemlenmiştir. Örneğin, öğretmenlerin besin zincirini oluştururken ayrıştırıcılara yer vermediği ve besin ağında yer alan okların yönlerini yanlış çizdikleri saptanmıştır. Ek olarak, kimya öğretmenliği programından mezun olan katılımcının popülasyon ve komünite kavramlarını birbirine karıştırdığı, fizik öğretmenliği programından mezun olan ve 9 yıldır fen bilimleri öğretmenliği yapan katılımcının ise bir süredir fen bilimleri müfredatında ekolojik niş ve komünite kavramlarının yer almamasından dolayı, bu terimleri öğretmediğini ve hatırlayamadığını belirterek ekolojik niş ve komünite sorularını yanıtsız bıraktığı görülmüştür.

2. Deneyimli Fen Bilimleri Öğretmenlerinin Ekosisteme Özgü Pedagojik Alan Bilgisi

Bu çalışmada öğretmenlerin fene karşı yönelimleri ön görüşme sorularıyla elde edilmiştir. Öğretmenlere ekosistem konusunun neden önemli olduğu sorulduğunda, Ezgi'nin yönelimi öğrenciyi hayata hazırlamak ve bilgiyi aktarmakken, Nilay'ınki öğrenciyi hayata hazırlamak ve doğaya karşı sorumluluk kazandırmaktır. Katılımcıların ikisi de ekosistem öğretimiyle ilgili herhangi bir endişe duymadıklarını ve ekosistemler konusunun öğretmesi kolay bir konu olduğunu belirtmişlerdir.

Katılımcıların ekosistemle ilgili müfredat bilgilerine bakıldığında, fen bilimleri öğretmenlerinin ekosistemin müfredattaki yerini bildikleri ancak müfredatta belirlenen hedef ve kazanımların tamamını sayamadıkları gözlemlenmiştir. Bu durum deneyimli öğretmenlerle yapılan diğer çalışmalar tarafında da desteklenmektedir (Hanuscin et al., 2010; Lankford, 2010; Karakulak & Tekkaya, 2010; Mıhlandız & Timur, 2011; Şen, 2014). Sadece 15 yıllık fen öğretimi deneyimi olan fen bilimleri öğretmeni, sınıfta Komünite kavramını öğreterek müfredat sınırlarını aştığı gözlenmiştir. Deneyimli öğretmenler daha önceki yıllardaki bilgilerini de kullanarak zaman zaman müfredat dışına çıkma eğiliminde oldukları bazı çalışmalarda da rapor edilmiştir (Graf et al., 2011; Lankford, 2010; Tekkaya & Kılıç, 2012). Bunun yanı sıra, fen bilimleri öğretmenlerinin ekosistemler konusunun müfredattaki yatay ve dikey bağlantıları kurmakta zorlandıkları görülmüştür. Sadece dikey bağlantıyı söyleyen öğretmenler, yatay olarak 7. sınıf düzeyinde bağlantılı bir ünite olmadığını dile getirmişlerdir. Öğretmenler, mevcut fen bilimleri müfredatında (2013) ekosistemler konusuyla bağlantılı olan enerji ve besin zinciri ilişkilerine 8. sınıfta yer verildiğine değinirken, 3. sınıf düzeyinde öğretilmeye başlanan canlı ve cansızlar ünitesine değinmemiştir. Bundan dolayı katılımcıların müfredat bilgilerinin sınırlı olduğu gözlemlenmiştir.

PAB'ın bir diğer boyutu olan öğrenci bilgisi düzeyinde, fen bilimleri öğretmenleri, ekosistem öğrenimi için gerekli olan ön bilgileri için canlı ve cansızların sınıflandırılmasını ve beslenme şekillerini dile getirmişler, insan ve çevre ilişkileri, organizmalar, enerji kavramı, ve madde döngülerinden bahsetmemişlerdir. Öğrencilerin sahip olabilecekleri ekosistemle ilgili kavram yanılgıları ya da öğrenme zorlukları sorulduğunda ise, iki deneyimli fen bilimleri öğretmeni de öğrencilerin habitat ve popülasyon terimlerini karıştırdığını belirtmiş ve neden olarak da öğrencilerin günlük yaşamda kullandıkları dili öne sürülmüştür. Yapılan çalışmalar öğrencilerin ekosistem konusunda yer alan tüketiciler, ayrıştırıcılar, eneji akışı gibi diğer konularla ilgili birden fazla kavram yanılgısına sahip olabileceklerini rapor etmiştir. (Munson, 1994; Elliam, 2002, Özkan, 2001). Öğretmenlere mevcut kavram yanılgılarını nasıl saptadıkları ve bunları gidermek için neler yaptıkları sorulduğunda ise iki öğretmen de soru-cevap ve daha çok açıklama yapmak cevabını vermişlerdir. Ders gözlemlerinde öğretmenlerin sadece doğrudan anlatım ve soru-cevap yöntemlerini kullandıkları görülmüştür. Öğretmenlerden hiçbiri görüşmeler sırasında yapılandırmacı yöntemlerden bahsetmemiş ve bu yöntemleri kullanmamışlardır.

Öğretmenlerin ekosistemle ilgili öğretim yöntem ve stratejileri incelendiğinde ön görüşmelerde lisans eğitimi kimya eğitimi olan fen bilimleri öğretmeni alan gezisi gibi farklı bir etkinlik önerse de ders gözleminde her iki öğretmenin de doğrudan anlatım ve soru cevap yöntemine sıklıkla başvurduğu görülüştür. Ayrıca 15 yıllık deneyimi olan fen bilimleri öğretmeni alan gezisi önermesine rağmen sınıfta bir grup öğrenciyi görevlendirerek ekosistemle ilgili bir sunum hazırlamalarını istemiş ve sunum esnasında bir takım sorular sorarak dersi işlemiştir. Bu nedenle bu çalışmada da her iki öğretmen de öğretmeni temel alan klasik öğretim yöntemlerini seçmişlerdir (Brown et al., 2013; Käpylä et al., 2009; Karakulak & Tekkaya, 2010; Mıhlandız, 2010; Mıhlandız & Timur, 2011; Tekin, 2006; Aydın; 2012; Şen, 2014). Öğretmenlerin yeni ve öğrenciyi aktif kılan öğretim tekniklerine hakim olmamaları (Brown et al., 2013) ya da fene karşı belirledikleri tutumları (Şen, 2014) muhtemel nedenler olarak gösterilebilir.. Diğer taraftan, her iki öğretmen de sınıfta video, resim ve çizimlerden yararlanmıştır. Öğrencilerin akıllarında herhangi bir kavramsal boşluk kalmamsı için çizimlerin kullanımı önemli olmasına karşın (Larson, Green & Castleberry, 2011), öğretmenlerin çizimlerinde ekosistemin bileşenlerinden ve bu bileşenler arasındaki ilişkilerden bahsetmemişlerdir.

Bu çalışma sonuçlarına göre fen bilimleri öğretmenlerinin ikisi de değerlendirmeyi sadece öğrencilerin konuyu anlayıp anlamadıklarını ölçmek için kullanmıştır. Bu sonucu önceki çalışmalar da desteklemektedir (Lankford, 2010; Tekkaya & Kılıç, 2012; Şen, 2014). Şen’ e göre, (2014)buuna gösterilebilecek en önemli sebeplerden biri öğretmenlerin sahip oldukları fene karşı tutumlarıdır. Bağlamsal faktörlerin de öğretmenin değerlendirmesini etkilediği görülmüştür (Yarden & Cohen, 2009; Şen & Öztekin, 2019). Örneğin TEOG sınavının olması da öğretmenleri klasik yöntemler kullanarak değerlendirme yapmaya yönlendiriyor olabilir (Loughran et al., 2004; Şen, 2014). Öğretmenlerin biçimlendirici ve özetleyici değerlendirme yöntemlerinde sözlü soru ya da gözlem gibi klasik metotları kullanmaları önceki çalışmalarla tutarılık göstermektedir (Canbazoğlu et al., 2010; Graf et al., 2011; Taşdere & Özsevgeç, 2012; Yarden & Cohen, 2009; Aydın, 2012; Şen, 2014).

ÖNERİLER

Bu çalışmanın sonuçlarına bağlı olarak fen bilimleri öğretmenlerine ekosistem konularında bir profesyonel gelişim ya da hizmet içi eğitim programı önerilmektedir. Ayrıca ekosistemler konusunun, enerji ve madde dönüşümleri gibi karmaşık ve birbirleriyle ilgili olan konuları içermesi ve karmaşık bir sistem olması dolayısı ile öğretim programı hazırlayıcılarının ekosistem konusunu sistemsel düşünme yaklaşımı doğrultusunda hazırlamaları ve öğretmenlerin bu konunun öğretimde sistemsel düşünme yaklaşımını benimsemeleri önerilmektedir. Konuları birbirinden ayrı bölümler halinde vermek öğretmenlerin ve öğrencilerin aynı konuyu farklı konularmış gibi düşünüp konuyu anlamlı bir şeklide öğrenilmesini zorlaştırmaktadır. (Assaraf & Orion, 2005; Cho vd., 1985; Eilam, 2012).

Bu çalışmada öğrenci boyutuna değinilememiştir. Bu yüzden bir sonraki yapılacak olan çalışmalarda öğretmen PAB'ı ve öğrenci başarısı arasındaki ilişkinin araştırılması önerilmektedir. Çalışmada, sadece ön görüşme yapılmış ama son görüşme yapılamamıştır. Bir sonraki yapılacak olan çalışmalarda son görüşmenin eklenmesi önerilmektedir.

Bunun yanı sıra öğretmen PAB ve PAB'ın alt boyutları arasındaki ilişkilerin incelenerek bir PAB haritası hazırlanması PAB literatürü için önemli bir kazanım olacaktır.

Son olarak ise bu çalışmada ortaya konan öğrenci bilgileri, kavram yanılgıları, öğretim yöntem ve teknikleri, öğretmen etkinlikleri, öğretmenlerin kullandıkları benzetimler, öğretmenlerin konular arası yaptıkları ilişkilendirmeler ekosistem öğretiminde tecrübesi olmayan öğretmen adayları için yararlı olabilir. Bu yüzden bu araştırmanın sonuçları öğretmen eğitimi veren kurumlarda kullanılabilir. Böylece öğretmen adayları ilerisi için ekosistem konularında bir ön hazırlık yapmış olabilirler.

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