

COMPARATIVE STUDY ON NOVICE AND EXPERT SCIENCE TEACHERS'
PEDAGOGICAL CONTENT KNOWLEDGE REGARDING TEACHING
ECOLOGY

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TEACHING ECOLOGY**

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ABSTRACT

COMPARATIVE STUDY ON NOVICE AND EXPERT SCIENCE TEACHERS' PEDAGOGICAL CONTENT KNOWLEDGE REGARDING TEACHING ECOLOGY

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The present study aims to compare novice and expert science teachers' PCK concerning teaching ecology. To understand science teachers' PCK in ecology were analyzed by taking four components (i.e., knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, knowledge of assessment) of Magnusson, Krajcik, and Borko (1999) PCK model took into consideration.

Qualitative research methodologies were used to investigate science teachers' PCK and multiple sources of data collection procedures were followed in order to gain sound and deep information about novice and expert science teachers. Semi-structured interviews, concept map construction, lesson plan preparation, and classroom observations were the sources utilized to gain in-depth information about

participant science teachers. There were two novice and two expert science teachers in the study practicing teaching in public schools.

The results of the study indicated that both novice and expert science teachers have misconceptions and a lack of comprehension of some basic ecological concepts. Novice science teachers were found to have a conflict between actual PCK or enacted PCK and reported PCK. Expert science teachers were able to provide concrete examples of their teaching practices. The findings have important implications, especially for the improvement of science teacher education in terms of enhancing science teachers' professional development in teaching ecological concepts and principles.

Keywords: Pedagogical Content Knowledge, Ecology, Novice Science Teachers, Expert Science Teachers

ÖZ

GÖREVE YENİ BAŞLAMIS VE DENEYİMLİ FEN BİLİMLERİ ÖĞRETMENLERİNİN EKOLOJİ ÖĞRETİMİ KONUSUNDA PEDAGOJİK ALAN BİLGİLERİNİN KIYASLANMASI

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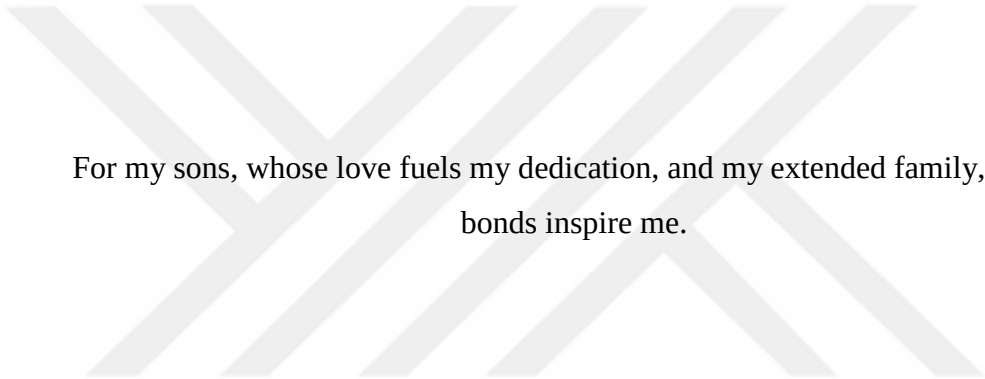
Pedagojik Alan Bilgisi (PAB), öğretmenlerin konu alan bilgilerini derslerinde iletişim ve uygulama yoluyla öğrencilerin anlayabileceği bir forma dönüştürme sürecini anlamak için temel bir yapıdır (Shulman, 1986). Bu bağlamda, bu çalışma, göreve yeni başlayan ve deneyimli fen bilimleri öğretmenlerinin, ekoloji öğretimiyle ilgili olarak PAB'lerini karşılaştırmayı amaçlamaktadır. Fen bilimleri öğretmenlerinin ekoloji öğretimi hakkında PAB bileşenlerini karşılaştırmak amacıyla, Magnusson, Krajcik ve Borko (1999) tarafından geliştirilen PAB modelinin “fen öğretimi amaçları ve hedefleri bilgileri” dışındaki tüm bileşenleri kullanılmıştır.

Nitel araştırma yöntemleri, fen bilimleri öğretmenlerinin PAB'lerini araştırmak için kullanılmış ve katılımcı fen bilimleri öğretmenleri hakkında doğru ve derin bilgi elde

etmek için çeşitli veri toplama yöntemleri (örneğin; yarı yapılandırılmış görüşmeler, kavram haritası oluşturma, ders planı hazırlama ve sınıf gözlemleri) kullanılmıştır. Çalışmada, devlet okullarında öğretmenlik yapan iki göreve yeni başlayan ve iki deneyimli fen bilimleri öğretmeni bulunmaktadır.

Araştırmanın sonuçları hem göreve yeni başlayan hem de deneyimli fen bilimleri öğretmenlerinin bazı temel ekoloji kavramları hakkında kavram yanlışlarının ve eksik bilgilerinin olduğunu göstermiştir. Göreve yeni başlayan fen bilimleri öğretmenlerinin gerçek öğretim uygulamaları ile inançlarının uyuşmadığı görülmüştür. Deneyimli fen bilimleri öğretmenleri, öğretim uygulamaları hakkında somut örnekler sunabilmiştir. Bulgular, özellikle fen bilimleri öğretmenlerinin ekoloji öğretiminde profesyonel gelişimini artırmak açısından önemli sonuçlar ortaya koymaktadır.

Anahtar Kelimeler: Pedagogik Alan Bilgisi, Ekoloji, Göreve Yeni Başlamış Fen Bilimleri Öğretmenleri, Deneyimli Fen Bilimleri Öğretmenleri



For my sons, whose love fuels my dedication, and my extended family, whose
bonds inspire me.

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LIST OF ABBREVIATIONS

ABBREVIATIONS

PCK	Pedagogical Content Knowledge
TSPCK	Topic-specific Pedagogical Content Knowledge
TSPK	Topic-specific Pedagogical Knowledge
CK	Content Knowledge
PK	Pedagogical Knowledge
SMK	Subject Matter Knowledge
KoL	Knowledge of Students’ Understanding
KoIS	Knowledge of Instructional Strategies
KoC	Knowledge of Curriculum
KoA	Knowledge of Assessment
CoRe	Content Representations
MoNE	Ministry of National Education
SBS	National central examination for transition to secondary education in Türkiye

CHAPTER 1

INTRODUCTION

Science teachers are considered to be one of the most influential factors for effective science learning because of their essential roles in learning through facilitating students' learning processes. Early studies characterized science teachers' essential knowledge for effective science learning with the subject matter they possess (e.g., Arzi & White, 2007; Hashweh, 1987; Childs & McNicholl, 2007; Großschedl et al., 2014; Kapyla et al. 2008; Mahler et al., 2017; Shulman, 1986; Summer et al., 2000; Veal & MaKinster, 1999). Carré (1998, p. 103) pointed out the importance of subject matter knowledge in terms of efficient science teaching as follows "The more you know about science, the more you will be able to provide a framework to help children think in scientific ways; in so doing you will also represent the subject with integrity." However, Shulman's attempt to find the "missing paradigm" changed the perception of teachers' knowledge (Shulman, 1986). In line with this perception, science teachers are expected to transform content knowledge into forms accessible to the students being taught by serving the content with proper instructional strategies and methods, being aware of students' prior knowledge and alternative conceptions, and treating their misconceptions properly, providing a learning environment in accordance with the determined curricula, encouraging students' responsibility for their own learning and designing appropriate assessment methods (Geddis, 1993). All of these essential aspects of effective science teaching gain more significance when they are combined with subject matter knowledge in coherence. This transformation of content knowledge and pedagogy was introduced by Shulman (1986) as pedagogical content knowledge (PCK). In fact, Shulman (1987, p. 8) defined pedagogical content knowledge as a "special amalgam of content and

pedagogy that is uniquely the province of teachers, their own special form of professional understanding”. Science educators, however, have not yet agreed on Shulman’s definition of pedagogical content knowledge and its constituting aspects (Gess-Newsome, 2015; Kind, 2009b; Krepf, Plöger, Scholl, & Seifert, 2017; Nilsson & Loughran, 2012; Park & Chen, 2012). Although definitions and models proposed by educators differ in the field of pedagogical content knowledge, the knowledge of instructional strategies including representations of subject matter and understanding of specific learning difficulties and student conceptions are the components of pedagogical content knowledge most of the educators agree on (Van Driel, Verloop & De Vos, 1998). Moreover, most research has consensus on the content knowledge that is seen as the undoubtful part of the PCK and prerequisite for effective science teaching as well (Carlsen, 1991; De Jong & Van Driel, 2004; Gess-Newsome, 2015; Kind, 2009b; Krepf et al., 2017; Lucero, Petrosino, & Delgado, 2017; Nilsson & Loughran, 2012; Park & Oliver, 2008; Van Driel & Berry, 2012).

As researchers interpreted Shulman’s proposed model differently, they introduced different models or added new constructs to existing models. For example, Cochran, DeRuiter, and King’s (1993) PCKg model, Gess-Newsome’s (1999) Integrative and Transformative PCK models, Grossman’s (1990) PCK model, Veal and MaKinster’s (1999) Hierarchical Taxonomy of PCK model, Magnusson, Krajcik and Borko’s (1999) PCK model, Park and Oliver’s (2008) Hexagon PCK model, Gess-Newsome’s (2015) consensus model and Carlson and Daehler’s (2019) refined consensus model of PCK.

Briefly, PCK studies continue to evolve and progress over time. Yet, with the scope of the study, Magnusson et al. (1999) PCK model was used as the theoretical framework to elicit novice and expert science teachers’ subject matter and pedagogical content knowledge regarding ecology. Magnusson et al. (1999, p.98), in line with Shulman’s view, explained science teachers’ knowledge is formed by

four knowledge domains, namely subject matter knowledge (SMK), pedagogical knowledge (PK), knowledge of the context (KofC) and pedagogical content knowledge (PCK) (Figure 1.1). In line with the teachers' knowledge model, they proposed the PCK model (Figure 1.2). Magnusson et al. (1999) proposed a teachers' knowledge model regarding relationships among the domains and components of the PCK model for science teaching (Magnusson et al., 1999, p. 99) presented in Figure 1.1.



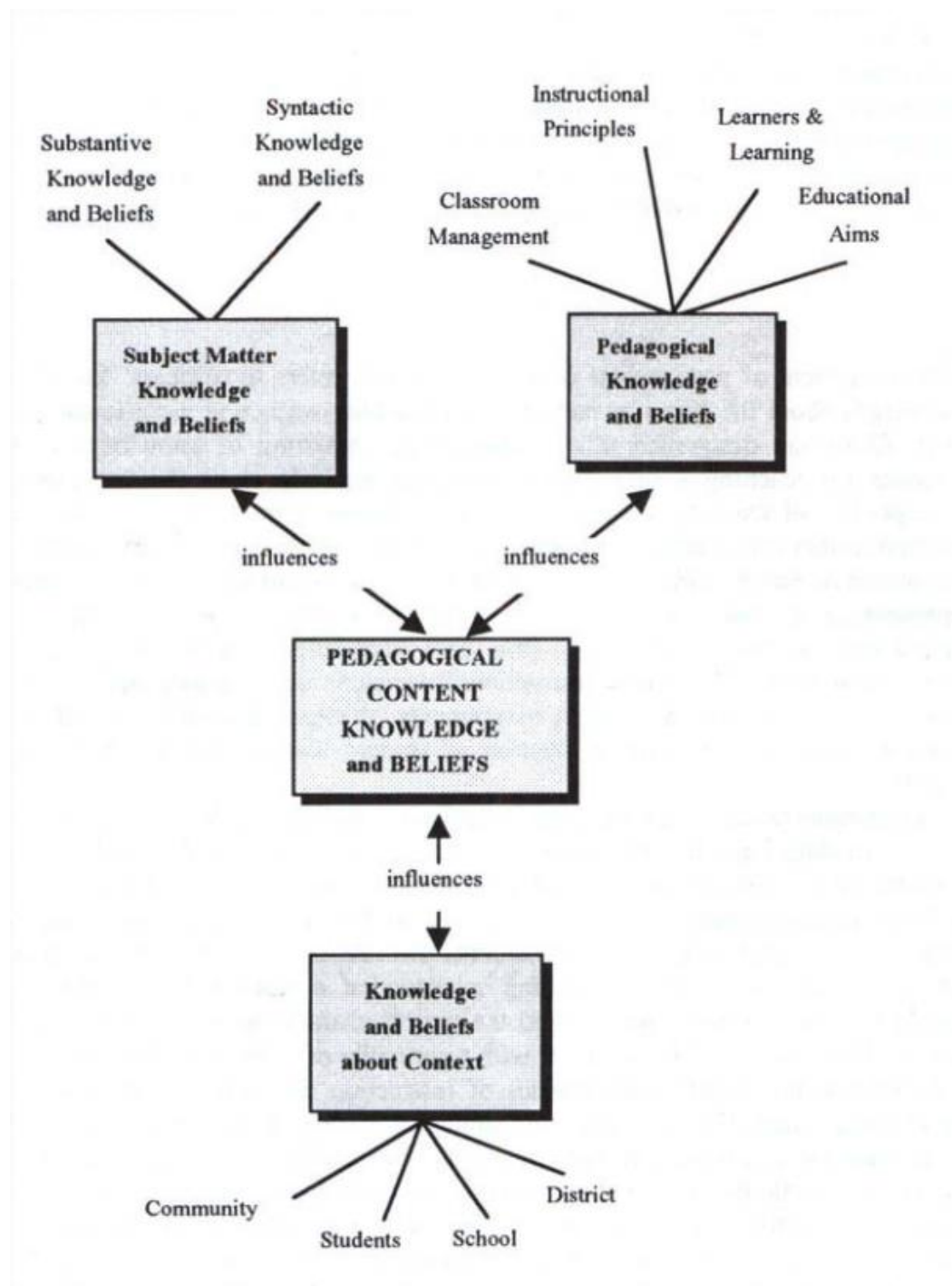


Figure 1.1 Magnusson et al. (1999, p.98) Model Regarding Relationships Among the Domains of Teachers' Knowledge

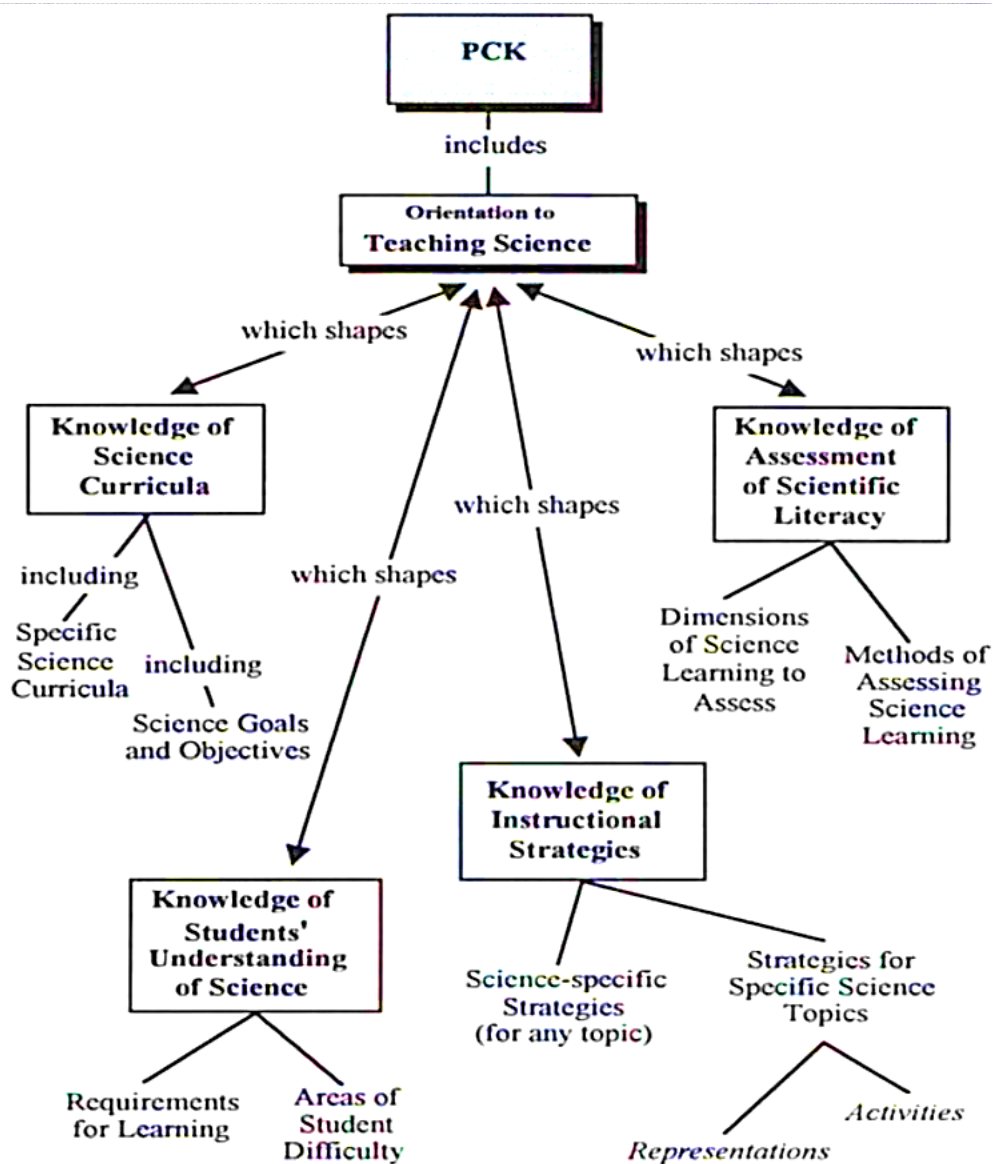


Figure 1.2 Components of Pedagogical Content Knowledge for Science Teaching (Magnusson, Krajcik & Borko, 1999, p. 99)

Magnusson, Krajcik, and Borko (1999) proposed that the PCK model for science teachers included five components which are orientations toward teaching science, knowledge of science learners, knowledge of science curriculum, knowledge of science instructional strategies, and knowledge of science assessment. Different

from other previously proposed models, Magnusson et al. (1999) added the knowledge of assessment because of the importance of finding out what students have learned through the instruction based on the view of Tamir (1988). Pointing out that with this knowledge domain, teachers also gain significant knowledge about their instructional strategies. Moreover, Magnusson et al.'s model included the component of "purposes" which they called "orientations". Moreover, Magnusson et al. (1999) suggested that science teachers select appropriate orientations which are discovery, conceptual change, process, and inquiry aiming at making students experience their own learning and didactic based only on the transmission of the content knowledge. The component of "curricular knowledge" mentioned in the proposed model of Magnusson et al. (1999, p. 103) with claiming curricular knowledge "distinguishes the content specialist from the pedagogue" which based their thought on Grossman's curricular knowledge definition. The components represented in the PCK model of Magnusson et al. (1999) were explained later in the definitions of important terms part. However, being the base for the current study, the PCK components' definitions according to Magnusson et al. (1999), are provided in Table 1.2.

Table 1.1 Pedagogical Content Knowledge (PCK) Components (Magnusson et al., 1999)

PCK Components	Definitions
Orientations toward science teaching	Teachers' knowledge of goals and general approaches to science teaching in a particular grade level. There are several orientations teachers may show more than one. However, the characteristics of the instruction and the goals of teaching shaped differs according to the orientations of the teachers.
Knowledge of science learners	Science teachers' recognition of students' prior ideas, misconceptions, learning difficulties, learning styles, abilities, interest, developmental level and motivations toward science
Knowledge of science curriculum	Knowledge on documents of national, state and district about obligatory goals and objectives as well as about both the horizontal and vertical curricula for a subject (Grossman, 1990). Also, teachers' knowledge about activities and materials utilized for achieving the objectives and goals

Table 1.1 Cont'd

PCK Components	Definitions
Knowledge of science instructional strategies	Knowledge of subject-specific strategies and topic-specific strategies (Magnusson et al. 1999). "Subject-specific strategies" are general approaches to instruction that are consistent with the goals of science teaching in teachers' knowledge such as learning cycles, conceptual change strategies, and inquiry-oriented instruction. "Topic-specific strategies" refers to specific strategies that apply to teaching particular topics within a domain of science.
Knowledge of science assessment	The knowledge of science teachers on what aspects of scientific literacy should be assessed in a particular unit and what methods are useable to assess those specific aspects of student learning (Magnusson et al. 1999). Magnusson et al. added into the model by accepting views of Tamir (1988) on importance of assessment of science learning and the methods utilized for the assessment.

Although Magnusson et al. (1999) PCK model offered five integrated components, in this study, four components of the model were investigated in the light of the model. The underlined reason for the underestimation of "orientations toward science teaching" in the current study is that there is no precise definition of what the teachers' orientations are and how the teachers' orientations can be understood (Friedrichsen & Dana, 2000; 2005). Friedrichsen, Van Driel, and Abell (2010) argued that researchers misinterpreted and even misused the orientations in their studies regarding PCK. Studies also highlighted that even PCK components are

interrelated in some contexts; they emerged individually and developed separately. Highly preferred PCK model, in the Magnusson et al. (1999) PCK model, the components seemed to connect each other with two-way arrows (Figure 1.2) to the "orientations to teaching science" with the linking words "which shapes". The meaning of "which shapes" was not explained clearly, making the "orientations to teaching science" component relation implicit (Friedrichsen, Van Driel & Abell, 2010). Even studies revealed that science teachers might hold more than one orientation changing according to the teaching context (Friedrichsen & Dana, 2005; Sağbilge, 2022; Supprakob et al., 2016). Therefore, teachers' orientation needs to be analyzed in different contexts carefully. The current study's scope is to uncover science teachers' PCK in the context of teaching ecology. Therefore, in line with the purpose and the explained circumstances above, teachers' "knowledge of science learners," "knowledge of science curriculum", "knowledge of science instructional strategies," and "knowledge of assessment" components are studied based on the Magnusson et al. (1999) PCK model.

Studies indicate effective teaching highly depends on experience in teaching. In fact, Hashweh (2005) stated that pedagogical content knowledge develops and accumulates when a science teacher practices teaching a specific science topic repeatedly over time. Hashweh also mentioned that experienced teachers developed their pedagogical content knowledge because of repeated planning and teaching of most regularly taught topics and reflection on their teaching. In fact, experienced science teachers are more confident in selecting appropriate strategies and representations for a specific topic because of having a plentiful repertoire (Angell et al., 2005; Clermont, Borko & Krajcik, 1994; Kind, 2009b) and also better able to detect students' misconceptions (Gomez & Zwiep, 2008; Halim & Meerah, 2002). There were also studies pointed out the importance of supporting teachers with intensive interventions in teaching specific science content which teachers found to improve their PCK (Clermont et al., 1993; Çoruhlu & Çepni, 2010; Park & Oliver,

2008; Pitjeng-Mosabala & Rollnick, 2018; Van Driel, Verloop & De Vos, 1998). On the other hand, novice science teachers indicate internal conflicts between their personal science teaching views and their actual classroom practice (Brickhouse & Bodner, 1992). Even expert teachers, either having weak content knowledge or pedagogical content knowledge in a particular topic, behaved like novice teachers (Rollnick et al., 2008; Sanders et al., 1993). Novice teachers were found to focus on the subject matter they teach rather than facilitating students' understanding of the content (Angell et al., 2005; Supprakob, Faikhamta & Suwanruji, 2016). In fact, researchers indicated that teachers with adequate subject matter are more aware of students' learning difficulties which are one of the aspects of pedagogical content knowledge (De Jong, 2000; Van Driel, De Jong & Verloop, 2002). Moreover, teachers having high subject matter select appropriate instructional methods and strategies (Kind, 2009a). The studies relating subject matter knowledge and pedagogical content knowledge indicated significant relationships between these constructs (Gess-Newsome et al., 2017; Halim & Meerah, 2002; Kaya, 2008; Kind & Chan, 2019; Pitjeng-Mosabala & Rollnick, 2017). Certainly, effective science teachers who have a sound subject matter background can be aware of curriculum goals, choose appropriate teaching strategies and methods, and create a proper learning environment for students to accomplish effective science learning. Teachers with low subject matter cause students to possess understanding apart from scientifically accepted definitions of those science concepts (Gess-Newsome & Lederman, 1995; Halim & Meerah, 2002; Hashweh, 1987; Johnson, 1998; Käpylä et al., 2008; Kind & Chan, 2019; Krall, Lott & Wymer, 2008; Nott & Wellington, 1996). Briefly, Shulman (1987) stated the difference between expert and novice teachers as "the capacity of a teacher to transform the content knowledge he or she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background presented by students" (p.15). In line with these

ideas, the present study explored what are the expert and novice science teachers' pedagogical content knowledge on the topic of ecology.

As pedagogical content knowledge develops with respect to specific content knowledge (Shulman, 1986), studies naturally concentrate on examining pedagogical content knowledge of science teachers on specific science concepts (Boz & Boz, 2008; Clermont & Krajcik, Borko, 1993, 1994; Kaya, 2008; Käpylä, Heikkinen & Asunta, 2009; Lucero, Petrosino & Delgado, 2017; Melo, Cañada-Cañada, González-Gómez & Su Jeong, 2020; Parker, 2006; Rollnick, 2017; Şen et al., 2022; Van Driel et al., 1998). In order to gain an understanding of science teachers' pedagogical content knowledge with reference to a specific subject matter, in this study, "ecology" is chosen. Ecology is not only one of the important interdisciplinary subject matters in life science but also an important contemporary global discipline that should be comprehended by students with scientific explanations. However, studies showed that students hold several misconceptions about ecological concepts like energy flow, pyramid of energy, niche, carrying capacity, food web and food chain (Adeniyi, 1985; Asshoff, Düsing, Winkelmann & Hammann, 2020; Aubusson, 2002; Barrutia & Diez, 2021; Butler, Simmie, & O'Grady, 2015; DeBoer et al., 2014; Eilam, 2002; Gallegos et al., 1994; Griffiths & Grant, 1985; Hogan, 2000; Manzanal et al., 1999; Munson, 1994; Musheno & Lawson, 1999; Opitz et al., 2014; Özay & Öztaş, 2003; Özkan et al., 2004; Preston, 2018; Reiner & Eilam, 2001; Soylu, 2006; Webb & Bolt, 1990; Wernecke et al., 2018). Fisher (1985) stated that science-related misconceptions are pervasive, stable, and resistant to change, at least through traditional instruction. If science teachers were aware of these misconceptions that students held, they could take precautions and remedy them with scientifically accepted conceptions by using appropriate teaching strategies and classroom activities. Studies also indicated that science teachers do not criticize students' answers, indicating misconceptions about ecological concepts (Özkan et al., 2004). However, studies revealed that teachers had

difficulties and misconceptions about ecological concepts and issues similar to students (Beals et al., 2012; Krall et al., 2009; Martín-Gámez et al., 2020; Summers et al., 2000). If science teachers become aware of students' misconceptions and possess the necessary knowledge, they could address them through appropriate teaching strategies and classroom activities. Therefore, the PCK study on ecology teaching of novice and expert science teachers increases the attention to students' effective learning practices in ecology in the related literature.

Accordingly, the current study compares expert and novice science teachers' pedagogical content knowledge regarding ecology in order to investigate and compare essential knowledge domains of novice and expert science teachers resulting in effective science teaching and learning, how these knowledge domains interact during ecology teaching practices and how expert and novice science teachers implement their knowledge components during ecology instructions.

1.1 Significance of the Study

Pedagogical content knowledge is a substantial knowledge base for understanding how science teachers practice teaching a specific topic. In order to represent this knowledge, science teachers' awareness of specific science curricula, their usage of representations, activities, and analogies, their perception of students' understanding, and learning difficulties, and how and when they assess students should be determined with respect to a specific science concept.

There were numerous kinds of research explores preservice science teachers' PCK (Abell, 2008; Aydın, 2012; Brown et al., 2017; Faikhamta, 2009; Kind, 2009), experienced science teachers' PCK (Gess-Newsome et al., 2017; Kınık, 2022; Sağbilge, 2022; Şen et al., 2022; Tıraş, 2019) and novice science teachers' PCK (Amador et al., 2022; Hume, 2010; Kind, 2009a; Nathan & Petrosino, 2003; Pitjeng-

Mosabala & Rollnick, 2017). This study aimed to compare two novice and two expert science teachers' PCK regarding teaching ecology.

The current study aimed to compare inservice science teachers' PCK and SMK. Therefore, this study had significant importance in unveiling inservice expert and novice science teachers PCK and SMK in the context of ecology. Inservice science teachers served learning opportunities for students. Hence, it is robust importance to understand inservice science teachers' SMK in ecology and PCK in teaching ecology. In fact, inservice science teachers are expected to convert their subject matter in a particular area into forms that can be easily understood by the students they are instructing. This meant that inservice science teachers have roles to provide effective teaching approaches and techniques, acknowledge the students' prior knowledge, address any misconceptions they may have, establish a learning atmosphere that aligns with established curricula, motivate students to take charge of their own learning, and creating suitable assessment methods (Geddis, 1993).

In order to elicit expert and novice science teachers' PCK components for comparison, multiple data sources were collected, which is the strength of the current study. In fact, teachers in the study were observed in their real classroom settings to understand their teaching experiences in the actual teaching environment when they practiced ecology teaching in 8th grade. They were also asked to prepare lesson plans for their ecology lessons to compare and contrast with their planning and practicing of teaching ecology. Therefore, this study highlighted the tools to investigate teachers' PCK in ecology that may guide professional development programs for prospective and inservice training.

Previous studies also highlighted that science teachers' possession of content knowledge is critical for effective science teaching and a prerequisite for developing PCK (Pitjeng-Mosabala & Rollnick, 2017). In fact, science teachers' subject matter

influences science learning by several means. For instance, teachers' awareness of students' learning difficulties and misconceptions and finding appropriate ways to overcome these difficulties and misconceptions seemed to be influenced by teachers' possessing subject matter knowledge in particular science topic teachers teach (De Jong, 2000; Halim & Meerah, 2002; Kaya, 2008; Van Driel, De Jong & Verloop, 2002). Since science teachers' PCK is topic-specific, the current study was significant to compare expert and novice science teachers' PCK components of knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment in the light of Magnusson et al.'s (1999) PCK model. In fact, PCK studies focused more on chemistry topics (e.g., Demirdöğen, 2016; Hume & Berry, 2011; Jong, Van Driel & Verloop, 2005; Mavhunga, 2018). There was a need to investigate science teachers' PCK in biological topics.

At the time of data collection in 2010, ecology was in the elementary science curricula from 4th to 8th grades (MoNE, 2009). The name of the learning domain of ecology in the curriculum is 'Living Organism and Life.' Ecology concepts within the curriculum are 4th-grade human health, ecosystems, environmental pollution, protection, and responsibility; at 5th grade, human health, balanced diet, ecosystems, food chain, environmental problems, prey-predator relationship, biodiversity; at 6th grade, organic agriculture, pesticide usage; at 7th grade, ecosystem, environmental protection, abiotic factors, biodiversity, environmental problems; at 8th grade, adaptation, evolutions, biodiversity, energy flow, food chain, material cycles, recycling, energy sources, photosynthesis and respiration (MoNE, 2009).

In fact, covering valuable concepts inside, ecology is multidisciplinary and almost boundless in its concern (Çokadar & Yılmaz, 2009; Martín-Gómez et al., 2020). In fact, ecology is the broadest field within the biological science with explicit links to every other biological discipline, such as botany, zoology, biochemistry,

microbiology, physiology, genetics, evolution photosynthesis, respiration, as well as many other disciplines, including geology, chemistry, and physics, earth science. Ecology has relations with crosscutting concepts such as energy and matter conservation that were crucial to teaching in schools effectively. Indeed, "crosscutting concepts should be learned by every student to achieve scientific literacy" (NGSS, 2013).

However, students find ecology concepts difficult, and they possess several alternative conceptions. Over the past few decades, studies indicating teachers' and students' possession of non-scientific knowledge on concepts such as ecosystem, ecological niche, carrying capacity, food web and food chains, energy flow, and ecology form a predominant aspect of most biology curricula (Adeniyi, 1985; Aubusson, 2002; Eilam, 2002; Gallegos et al., 1994; Griffiths & Grant, 1985; Hogan, 2000; Manzanal et al., 1999; Munson, 1994; Reiner & Eilam, 2001; Webb & Bolt, 1990). As the ecological concepts and principles are interconnected, students experience difficulties in understanding (Mambrey, Timm, Landskron & Schmiemann, 2020; Mambrey, Schreiber & Schmiemann, 2022). For instance, food web and food chain concepts could not be understood correctly without sound comprehension..

1.2 Statement of the Problem

The main goal of the study was to compare the Subject Matter Knowledge and Pedagogical Content Knowledge of expert and novice science teachers in teaching ecology. To achieve this, the researcher examined the Subject Matter Knowledge of both groups of teachers in ecology to see how they use and interpret this knowledge to help their students learn about ecology. The investigation of PCK looked at the teachers' knowledge of their students' understanding of science, their knowledge of the science curriculum, their knowledge of instructional strategies, and their

knowledge of assessment. The study focused on the following research questions to address its scope.

1.2.1 Research Questions

1. What are expert and novice science teachers' subject matter knowledge about ecology?
 - 1.1. What are novice science teachers' subject matter knowledge about ecology?
 - 1.2. What are expert science teachers' subject matter knowledge about ecology?
2. What are expert and novice science teachers' pedagogical content knowledge about ecology?
 - 2.1. What are expert and novice science teachers' knowledge about students' understanding of ecology?
 - 2.2. What are expert and novice science teachers' knowledge of science curriculum related with ecology?
 - 2.3. What are expert and novice science teachers' knowledge of science instructional strategies related with ecology?
 - 2.4. What are expert and novice science teachers' knowledge of assessment related with ecology?
3. To what extent do novice and expert science teachers' SMK and PCK similar?

1.3 Definition of Important Terms

This part presented and provided the definitions of the terms most frequently used in the context of the study.

Ecology: "Ecology is the scientific study of the relationship between organisms and their environment" (Smith & Smith, 2003). In the study of the environment, the part of "eco" and "system" part refers to the ecosystem as a system function as a whole

(Smith & Smith, 2003). “The systematic study of how organisms interact with the physical and chemical environment.” (Starr, 2006). Interactions commence within and among populations, then ripple through communities, ecosystems, and ultimately, the biosphere (Starr, 2006).

Expert science teacher: The science teachers who have more than 5 years of teaching experience in ecology were referred to as expert science teachers in the current study (Berliner, 2004; Turner, 1995).

Novice science teacher: In this study, it referred to novice science teachers when science teachers have few than 5 years of teaching experience in the domain-specific task that is ecology (Berliner, 2004; Turner, 1995).

Subject Matter Knowledge: Shulman (1986, p. 9) defined the teachers’ content knowledge refers to knowledge of teachers in a specific subject matter which is similar to a content expert. Schwab (1964) defined substantive knowledge structures as basic concepts and principles in a specific discipline. In this study, substantive knowledge regarding ecology was explored and it referred to the subject matter knowledge of participants in ecology.

Pedagogical Content Knowledge (PCK): “subject matter knowledge for teaching” (Shulman, 1986, p. 9). Pedagogical content knowledge constituted the most powerful and utilized analogies, representations, and examples for making students comprehend the content. In this study, PCK referred to teachers’ knowledge of curriculum regarding ecology, knowledge of students’ understanding of science, knowledge of instructional strategies regarding ecology, and knowledge of assessment regarding ecology.

Knowledge of Science Curriculum: Knowledge of documents of national, state, and district about obligatory goals and objectives as well as about both the horizontal and

vertical curricula for a subject (Grossman, 1990). In this study, it refers to knowledge of curriculum regarding ecology and, additionally, teachers' knowledge about activities and materials utilized for achieving the objectives and goals regarding ecology.

Knowledge of Students' Understanding of Science: Science teachers' recognition of students' prior ideas, misconceptions, learning difficulties, learning styles, abilities, interests, developmental levels and motivations toward science (Magnusson et al., 1999). In the context of this study, it meant that teachers' understanding of students' prerequisite knowledge, misconceptions, learning difficulties, learning styles, abilities, interests, developmental levels and motivations toward ecology.

Knowledge of Instructional Strategies: Knowledge of subject-specific strategies and topic-specific strategies (Magnusson et al., 1999). "Subject-specific strategies" are general approaches to instruction that are consistent with the goals of science teaching in teachers' knowledge such as learning cycles, conceptual change strategies, and inquiry-oriented instruction. "Topic-specific strategies" refers to specific strategies that apply to teaching particular topics within a domain of science. In the current study, knowledge of instructional strategies was defined as teachers' knowledge of subject-specific and topic-specific strategies in teaching ecology.

Knowledge of Assessment in Science: The knowledge of science teachers on what aspects of scientific literacy should be assessed in a particular unit and what methods are useable to assess those specific aspects of student learning (Magnusson, 1999). Magnusson et al. added to the model by accepting the views of Tamir (1988) on the importance of assessment of science learning and the methods utilized for the assessment. In the context of the current study, knowledge of assessment meant teachers' knowledge of what to assess and the methods of assessment in ecology..

CHAPTER 2

LITERTURE REVIEW

One of the prominent knowledge domains of teachers is pedagogical content knowledge, introduced by Shulman (1986, 1987). Pedagogical content knowledge with its constituent aspects is defined in numerous studies as a blending of content and pedagogical knowledge of teachers, commonly including teachers' knowledge of representations, teaching methods, analogies and activities, and understanding of learners. As pedagogical content knowledge is tacit knowledge in the minds of teachers, it is difficult to find out what exactly it is (Kind, 2009b). The question of "what knowledge domains are essential for teaching" brings educators to investigate teachers' PCK to understand teachers' knowledge components and their relationships during teaching. As teachers must transform their subject matter knowledge into appropriate forms of representations, activities, and analogies for students, teachers' possession of specific subject matter knowledge is essential (Shulman, 1986). Therefore, studies examined teachers' SMK interaction with PCK in several science concepts (Chan & Yung, 2017; Kaya, 2008; Käpylä et al., 2008; Kind, 2009a; Long et al., 2023; Sanders et al., 1993; Van Driel, Verloop & De Vos, 1998).

The following parts initially review the models proposed for teachers' knowledge. Then the studies regarding pedagogical content knowledge of science teachers with its constituent aspects, subject matter knowledge science teachers possess, and the interactions of SMK and PCK in teachers' teaching practices were presented. As the scope of the study is to compare expert and novice teachers' PCK regarding teaching ecology, the science literacy about ecology with respect to students and teachers is

reviewed and documented in the following sections. In line with the related studies, the first section aims to review the literature on PCK of pre-service science teachers; the second section aims to review the literature about Pedagogical Content Knowledge of inservice science teachers; and the third section aims to review the ecology literature.

2.1 Teachers' Knowledge

Teachers' knowledge has assumed several meanings in educational research in the past fifty years (Abell, 2007). Besides the possession of related SMK, being able to interpret the subject matter knowledge in the form of making students knowledgeable, pedagogical knowledge is indispensable. These characteristics discriminate teachers from content specialists (Shulman, 1986, 1987). Thus, to understand teachers' distinguishing characteristics, Shulman (1986, p. 9) introduced "pedagogical content knowledge" to investigate what is defined as the special knowledge of teachers.

Early studies on teachers' knowledge emphasized more on teachers' subject matter knowledge (Mallinson & Sturm, 1955; Raina, 1967; Swann, 1969; Uselton et al., 1963). Shulman (1986, p. 6) pointed out the importance of teachers' content knowledge as a prerequisite for teaching; he called content knowledge for teaching a "missing paradigm" and tried to answer the necessary questions related to teachers' content knowledge. Some of these questions were; "what are the domains and categories of the content knowledge in the minds of teachers?", "how, for example, are content knowledge and general pedagogical knowledge related?", "in which forms are the domains and categories of knowledge represented in the minds of teachers?" In fact, to answer the questions, Shulman and his colleagues designed a study. The study was conducted with English, biology, mathematics, and social studies secondary novice teachers with one- or two years of teaching practice. The

initial attempt of the study was to determine secondary novice teachers' understanding, conception, and orientations on sources for the subject matter they teach. Novice teachers were interviewed, asked for their responses for the materials about the subject they teach, and observed during their instructions. Depending on the collected data from teachers, they categorized teachers' content knowledge as "subject matter content knowledge, pedagogical content knowledge, and curricular knowledge" (Shulman, 1986, p. 9). Content knowledge is defined as teachers' amount and organization of subject matter knowledge. He argued that in different content areas, teachers' knowledge structures differed. Building on the notion of Schwab's substantive and syntactic knowledge structures, teachers should possess both substantive and syntactic subject matter structures in order to facilitate students' comprehension. Substantive structures were basic concepts and principles in a specific discipline; syntactic knowledge was the establishment of evidence and proof in the discipline. Pedagogical content knowledge was referred to as a second kind of content knowledge defined as "subject matter knowledge for teaching" (Shulman, 1986, p. 9). Pedagogical content knowledge constituted the most powerful and utilized analogies, representations, and examples for making students comprehend the content. Moreover, teachers' understanding of easy and difficult content for students, their prior knowledge, developmental level and needs, misconceptions, and how to address these misconceptions to overcome were all included in the pedagogical content knowledge category of teachers' knowledge. Another knowledge category was curricular knowledge stands for a series of designed teaching programs on a specific grade level and instructional materials. Also, curriculum knowledge refers to alternative materials for instruction, like alternative texts, visual aids, software programs, and laboratory demonstrations.

One year later, Shulman (1987) examined experienced and novice secondary teachers' content and pedagogical knowledge in order to find out the relationships of the knowledge domains in teachers' minds for effective teaching. Through

interviews, observations, structured tasks, and materials, Shulman understood that teaching was more than an improvement of understanding; it was a process starting with understanding the issue to be taught and continuing with decision-making for appropriate teaching strategies and activities for learning. That is, teaching was from reasoning to performing and elaborating knowledge. Teachers need to select appropriate activities and representations by using their knowledge and transforming their knowledge into forms that could be grasped by students. In fact, the pedagogical reasoning of teachers was mentioned as cyclic actions of teachers determining what a teacher knows and how to make it comprehensible to others. The cyclic aspects of pedagogical reasoning are explained as comprehension of a specific area and educational purposes; transformation of the ideas into representations and teaching methods according to students' characteristics and demands; instruction referring to the enactment of various teaching performances; and evaluation of understanding after instruction leading to the reflection setting the stage for teachers to the development of their teaching practices from their experiences; new comprehension of teachers turn the action at the beginning with new forms of comprehension and process of pedagogy. In addition, Shulman determined major sources of teachers' knowledge bases. One of these sources was content knowledge which is characterized as knowledge of substantive and syntactic structures, as Schwab (1964) defined it. Teachers were defined as the primary source for students' learning of a specific subject matter. Therefore, teachers need to possess in-depth understanding of subject matter knowledge on a specific content. The other source was knowledge of curriculum with its purposes, including materials, districts and states' rules, and governance and finance. Teachers had the role of using these elements, and they were used by them. Hence, teachers should be aware of how to manage these elements properly. Moreover, Shulman determined teachers' understanding of the processes of learning and teaching as the other sources of knowledge domains. As the last source, teaching practice was indicated by pointing

out the expert teachers' being capable of performing good teaching. According to his work on teachers' knowledge, in 1987, Shulman extended his initial proposed model to the seven components made up of a teacher knowledge base in which pedagogical content knowledge lay as a separate subcategory. He mentioned pedagogical content knowledge as a "special amalgam of content and pedagogy that is uniquely the province of teachers, their own special form of professional understanding." (Shulman, 1987, p.8). According to Shulman, pedagogical content knowledge included two components which were knowledge of representations and instructional strategies and knowledge of students' learning difficulties. Other subcategories of the model were; (i) Content knowledge, according to Shulman (1986, p. 9), is teachers' content knowledge refers to knowledge of teachers in a specific subject matter which is similar to a content expert's, (ii) General pedagogical knowledge is teachers' knowledge of classroom management, organization strategies, and instructional principals, (iii) Curriculum knowledge, is knowledge of materials and programs appropriate for effective teaching practices, (iv) Knowledge of learners, is awareness of teachers about characteristics of learners, (v) Knowledge of educational context, including classroom environment that teachers' practicing teaching, groups of people teachers collaborated with, schools' governance and financial positions and cultural issues and characteristics, (vi) Knowledge of educational purposes, ends and values is teachers' philosophical and historical notions to the teaching.

The proposed models for teachers' knowledge served theoretical framework for several kinds of research (Banks et al., 2005; Fernández-Balboa & Stiehl, 1995; Grossman, 1990; Magnusson et al., 1999; Marks, 1990; Park & Oliver, 2008; Turner-Bisset; 1999, 2001; Veal & MaKinnester, 1999). However, as teachers' knowledge is complex and what influences them during instructional decisions is hard to determine, researchers and science educators have interpreted pedagogical content knowledge from different perspectives. Therefore, they introduced new terms for

teachers' knowledge and revised Shulman's proposed model later. For example, Grossman (1990) explained pedagogical content knowledge by using Shulman's two key aspects, namely knowledge of strategies and representations; and knowledge of students' understanding, learning difficulties, and alternative conceptions. The pedagogical content knowledge definition of Grossman also emphasized the transformation of subject matter knowledge, pedagogical knowledge, and knowledge of context. Grossman (1990, p. 8) also defined teaching purposes and goals as "teachers' goals for teaching particular subject matter." and curricular knowledge as teachers' awareness of appropriate instructional materials and obligatory goals and objectives that should be achieved. Grossman's model represents that pedagogical content knowledge serves as the center knowledge domain surrounded by the knowledge of subject matter, general pedagogical knowledge, and contextual knowledge (Figure 2.1). Among the four knowledge bases, pedagogical content knowledge is mentioned with the greatest influence on teaching practices.

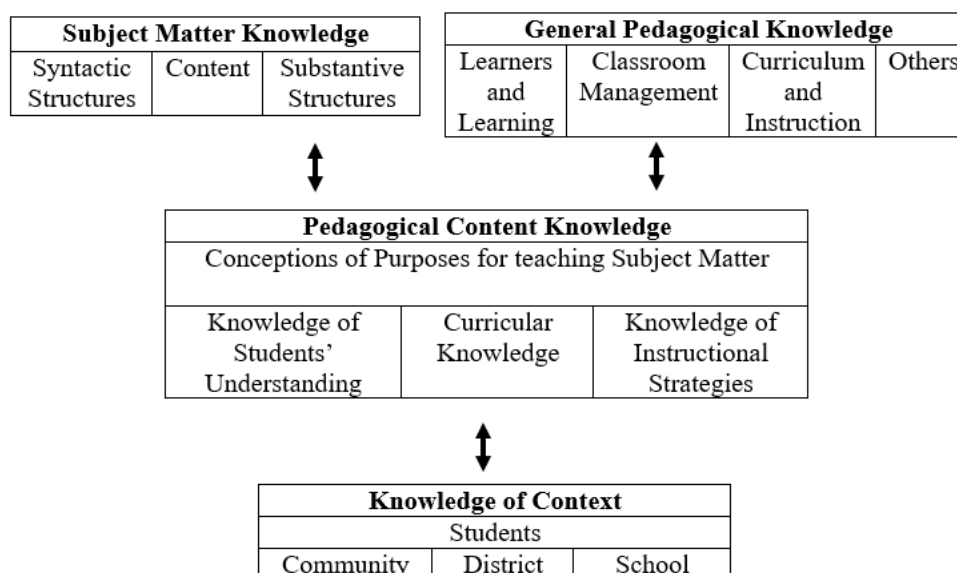


Figure 2.1 Grossman's PCK Model (1990, p.5)

As demonstrated by previous studies, researchers have varying perceptions and definitions of pedagogical content knowledge, leading to the introduction of new terms and models. Consequently, there is no consensus among researchers about its constituents. For instance, Cochran, DeRuiter, and King (1993) renamed pedagogical content knowledge as pedagogical content knowing (PCKg) to reflect a constructivist view of teaching (Figure 2.2). They defined pedagogical content as "a teacher's integrated understanding of four components of pedagogy: subject matter content, student characteristics, and the environmental context of learning" (p. 266). The authors emphasized that knowledge of instructional strategies is distinct from pedagogical content knowledge, which can be gained before teaching practices, as implied by Shulman. They saw subject matter knowledge combined with pedagogical content knowledge, not as separate parts of teacher knowledge, and emphasized that the four components of their model form pedagogical content knowing. The PCKg model of Cochran et al. (1993, p.268) is presented in Figure 2.2.

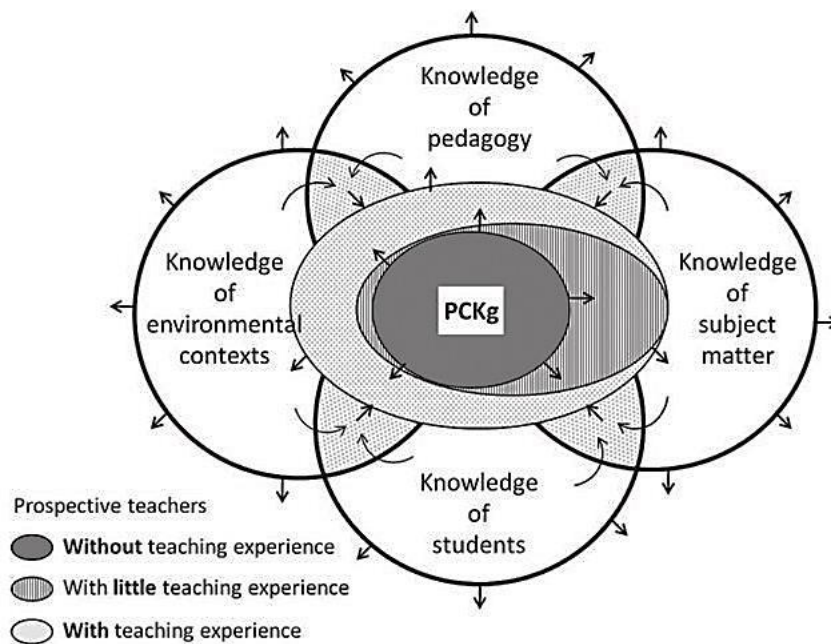


Figure 2.2 Cochran et al.'s PCKg Model (1993, p.268)

The PCKg model explains teachers improve their PCKg over time through experience and incorporate the aspects of knowledge of environmental contexts, knowledge of pedagogy, knowledge of subject matter, and knowledge of students in order to initiate comprehensive PCKg.

In another study, pedagogical content knowledge was perceived as the hierarchical structure of knowledge which was composed of ten components (Veal & MaKinster, 1999). These components are content knowledge, knowledge of students, knowledge of context, pedagogy, classroom management, assessment, curriculum, environment, nature of science, and socio-cultures (Figure 2.3). Veal and MaKinnester (1999) defined pedagogical content knowledge as the translation of subject matter knowledge within suitable forms of students' understanding and with interactions of other knowledge types of teachers; knowledge of context, pedagogy, classroom management, assessment, curriculum, environment, nature of science, socio-cultures.

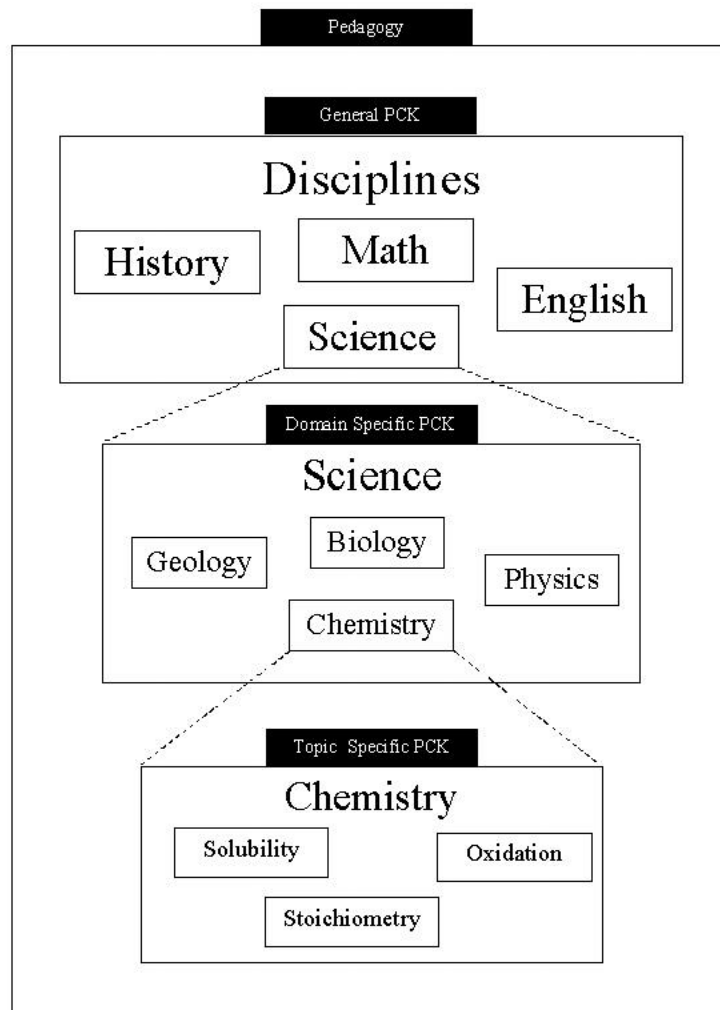


Figure 2.3 Veal and MaKinster's Hierarchical Taxonomy of PCK Model (1998, p.7)

In Veal and MaKinster's MaKinster's Hierarchical Taxonomy model (Figure 2.3), which they called "the general taxonomy of PCK" (p. 7), pedagogical content knowledge is the lowest level of the hierarchy among four levels and the top two levels are new terms as "domain specific" and "topic specific" pedagogical content knowledge. Domain-specific PCK means teachers' preferences for teaching a specific area within a subject. Conversely, topic-specific PCK explains how teachers

possessing different subject matter knowledge teach a specific concept. These definitions are appropriate for understanding how teachers with different subject matter knowledge possess similar pedagogical content knowledge and gain similar domain-specific pedagogical content knowledge.

The second proposed hierarchical model, which was Taxonomy of PCK Attributes, Veal and MaKinster (1999) stressed the importance of knowledge of students, including students' difficulties and misconceptions, rather than pedagogical knowledge. The second side of the model illustrated that if teachers have sound content knowledge, they could easily capture students' learning difficulties and misconceptions. Therefore, teachers' content knowledge and the knowledge of students are presented as integrated in their model (Figure 2.4; 2.5).

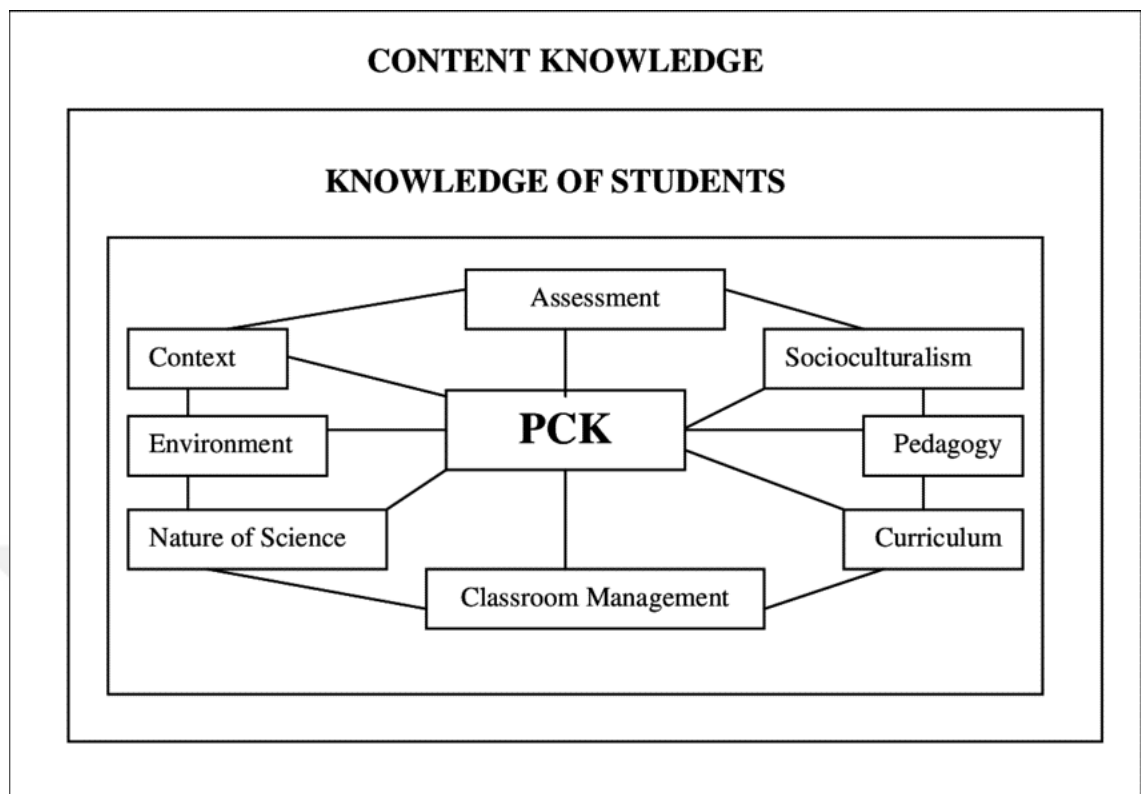


Figure 2.4 Veal and MaKinster's (1999) The Taxonomy of PCK Attributes Model from Bird's Eye View (p.10)

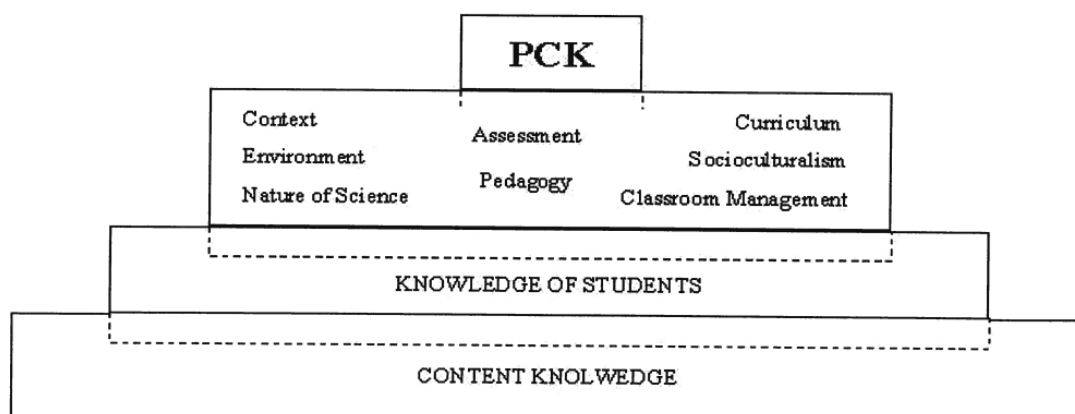


Figure 2.5 Side View of Veal and MaKinster's Taxonomy of PCK Attributes (1999, p11)

Gess-Newsome (1999) in line with Shulman (1986, 1987), Grossman (1990), Magnusson et al. (1999), and Cochran et al. (1993) defined integrative and transformative views of the pedagogical content knowledge. In fact, Gess-Newsome's views are an adoption of Shulman (1986, 1987), Grossman (1990), Magnusson et al. (1999), and Cochran et al. (1993) definitions of pedagogical content knowledge. Whether subject matter knowledge and pedagogical content knowledge are separate knowledge domains or combined is controversial as seen from the studies about pedagogical content knowledge. In this respect, Gess-Newsome (1999) described two different pedagogical content knowledge views which are an integrative view and a transformative view highlighting these two different controversies. Figure 2.6 reveals the Gess-Newsome's PCK models.

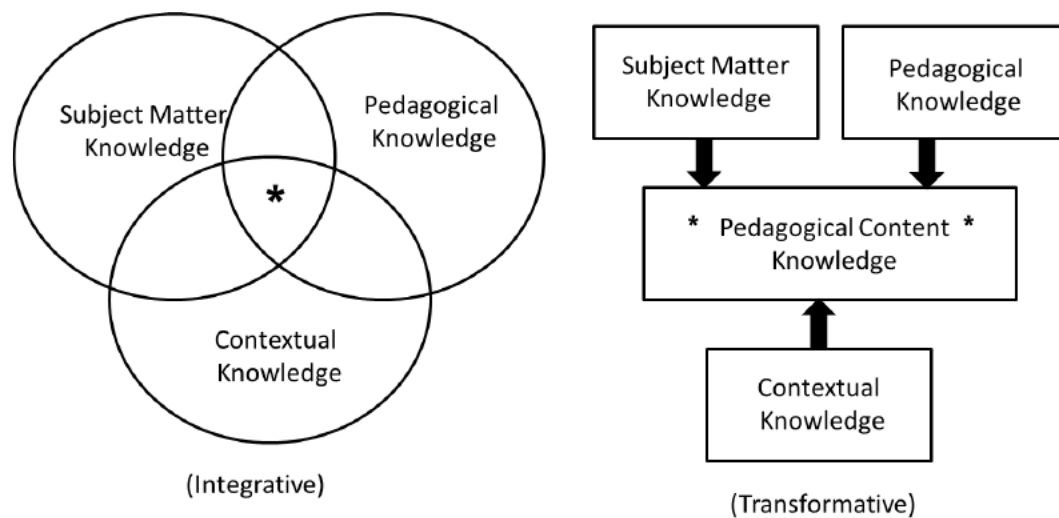


Figure 2.6 Gess-Newsome's Integrative and Transformative PCK models (1999, p.12)

The integrative view is interpreted as pedagogical content knowledge that does not separate from subject matter knowledge, knowledge of context, and pedagogical knowledge. Rather they are integrated, especially during teaching practice. In this model, subject matter knowledge is integrated into pedagogical content knowledge, and pedagogical content knowledge is not a separate knowledge type. Therefore, the integrative model differs from Shulman's proposed pedagogical content knowledge model as he described it as the transformation of subject matter knowledge, pedagogy, and contextual knowledge. The proposed PCK models of Banks et al. (2005), Cochran et al. (1993), Fernández-Balboa and Stiehl, Marks (1990), and Veal and Makinster (1999) conform integrative view in which teachers naturally combine their subject matter knowledge, pedagogical knowledge, and contextual knowledge during instruction ending up with pedagogical content knowledge. However, in the transformative view, teachers' pedagogical content knowledge is seen as the transformation of subject matter knowledge, general pedagogical knowledge, and knowledge of context. These knowledge bases are combined through teaching practice into the form of pedagogical content knowledge. In that model, subject

matter knowledge is a separate knowledge component from pedagogical content knowledge. PCK models of Shulman (1986, 1987), Grossman (1990), and Magnusson et al. (1999) are types of transformative PCK models. In these models, teachers possess the necessary subject matter knowledge and transform it appropriately in order to make students knowledgeable. The components of the pedagogical content knowledge, like orientations and instructional strategies, depend on specific subject matter. That is, teachers generate different pedagogical content knowledge towards different subject matters.

Park and Oliver (2008) suggested a heuristic model of pedagogical content knowledge through an empirical study to examine experienced science teachers' knowledge bases in light of the PCK model of Grossman (1990) (Figure 2.1). The results of their study revealed that as a new influential aspect of pedagogical content knowledge, teachers' context and domain-specific self-efficacy beliefs are included in the heuristic pedagogical content knowledge model. That is a heuristic pedagogical content knowledge model with new knowledge domains composed of six aspects within the relation. According to this model, "pedagogical content knowledge represents not only teachers' understanding of how to teach subject matter effectively but also the enactment of their understanding" (Park & Oliver, 2008, p. 280). The hexagon PCK model proposed for science teaching by Park and Oliver (2008, p.279) is presented in Figure 2.7.

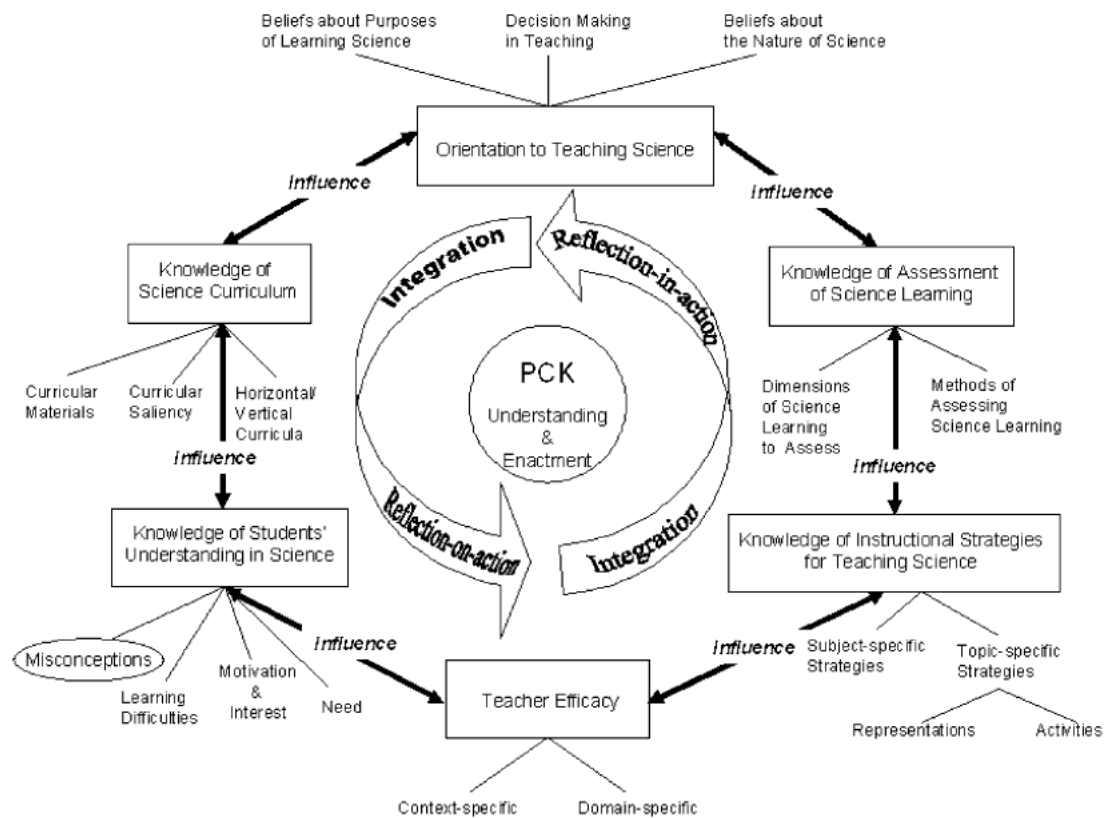


Figure 2.7 Park and Oliver's (2008a) Hexagon PCK Model (p.279)

As a result of their empirical research, Park and Oliver (2008) put forward an evolved PCK model, which they called a heuristic model of PCK (Figure 2.7). Adopting Grossman's model (1990), they investigated teachers' knowledge bases and concluded the study with new characteristics of pedagogical content knowledge through recognition of the influences of knowledge-in-action and knowledge-on-action. They referred to knowledge-in-action as teachers' decisions that occurred in an unexpected situation during instruction. That is the teachers' active and dynamic process. Knowledge-on-action is also known as the expansion or development of planning or teaching after a specific instruction. That is the teachers' stable and static process. Although these two new characteristics emerged as separate domains, they were highly interrelated with each other forming teachers' characteristics of

knowledge production. By examining science teachers' explicit pedagogical content knowledge in-depth, Park and Oliver perceived that teachers' efficacy beliefs emerged as a separate, influential aspect of pedagogical content knowledge, which also influenced students' learning outcomes. In fact, the efficacy beliefs of teachers depended on the specific domain and topic and were affected by specific classroom contexts. The other aspect that emerged from this empirical study was that students' questions, thoughts, responses, and especially their misconceptions were factors influencing teachers' pedagogical content knowledge. Moreover, it was found that each individual teacher's teaching decisions are influenced by teachers' characteristics, the context in which teachers practice teaching, and students' characteristics. The authors concluded that the emergence of teachers' efficacy beliefs as a separate domain, the idiosyncratic nature of teachers' knowledge, and the influence of reflections teachers make activated them to modify the pedagogical content knowledge model and to form a heuristic model. The six proposed components are 'orientation to teaching science', 'knowledge of assessment of science learning', 'knowledge of instructional strategies for teaching science,' 'teacher efficacy', 'knowledge of students' understanding of science,' and 'knowledge of science curriculum' integrated by teachers and enacted in a specific context for effective teaching.

Although it is not PCK-specific, the consensus model of teacher professional knowledge and skills models proposed by Gess-Newsome (2015) includes PCK (Figure 2.8). Therefore, the model is also called the PCK consensus model. The PCK consensus model is presented in Figure 2.8.

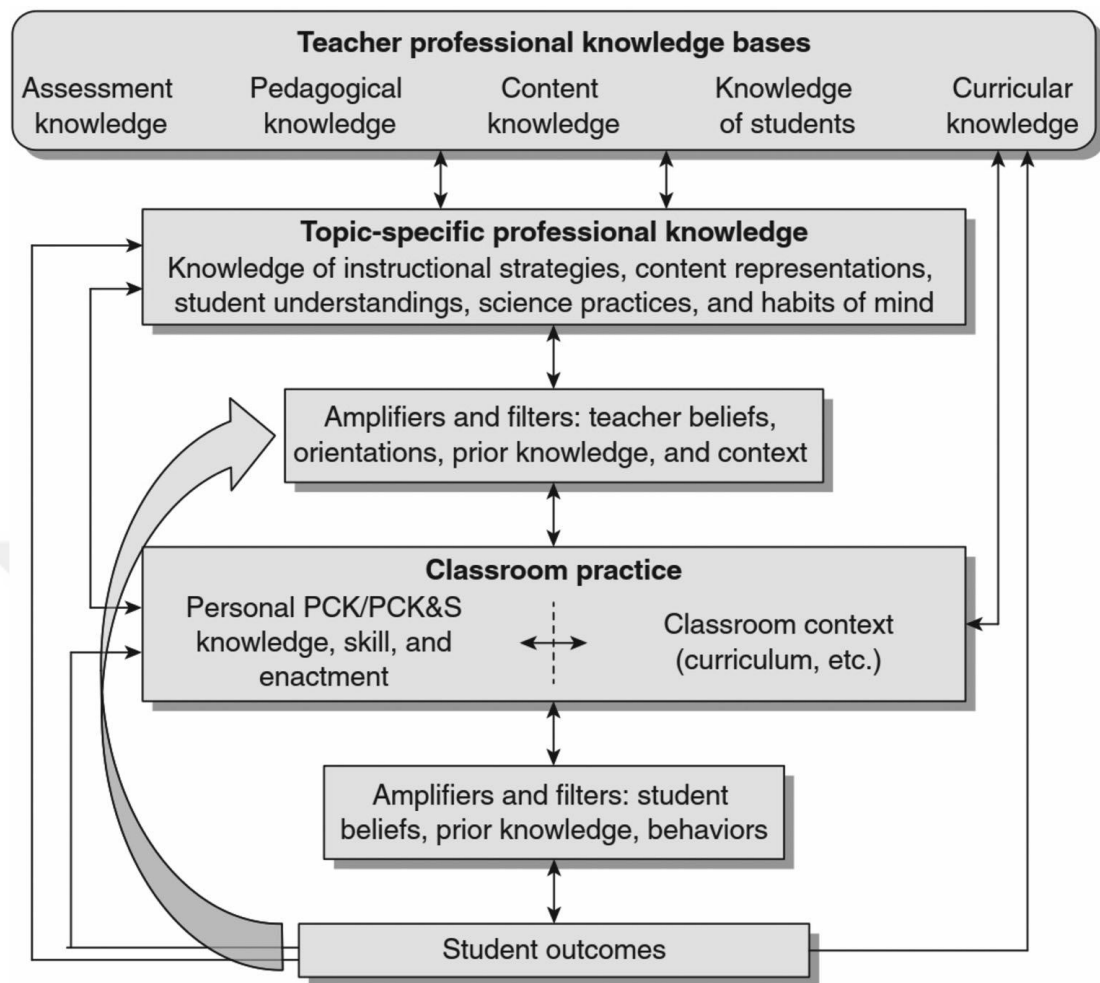


Figure 2.8 Gess-Newsome's (2015, p. 31) the PCK consensus model

The PCK consensus model identifies the complexity of knowledge necessitated for teaching. In that respect, the model associates and highlights teachers' professional knowledge bases, topic-specific professional knowledge (TSPK), teacher amplifiers and filters, classroom practice, and students' outcomes. The former, which are related to teachers' generic and normative knowledge bases, elaborated on assessment knowledge, pedagogical knowledge, content knowledge, knowledge of students, and curricular knowledge that are connected to classroom practice and student outcomes. The second is more related to teachers' knowledge of a certain

topic. The teacher amplifiers and filters explained in the model form teachers' beliefs, orientation, prior knowledge, and context influence teachers' teaching choices of strategies consistent with Magnusson et al. (1999) PCK model. The classroom practice integrates personal PCK and Pedagogical Content Knowledge and Skill (PCK&S). Personal PCK is explained as teachers' knowledge of students learning in a specific topic. PCK&S represents teaching a specific topic in a certain way to students. The difference between personal PCK and PCK&S is that personal PCK is more related to reflection-on-action, which can be explicitly identified and assessed, whereas PCK&S is about knowledge-in-action hardly identified, tacit, and more difficult to capture. Before students' outcomes, there is a base that is amplifiers and filters referring to students' beliefs, prior knowledge, and behaviors linked to the students' outcomes. In the teaching and learning process, students' outcomes are pointed out as the important bases that are associated with the other bases in the model.

A recent study proposed the refined consensus model (RCM) by Carlson and Daehler (2019) following Gess-Newsome's (2015, p. 31) PCK consensus model. RCM suggested three distinct domains of PCK that are collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK) (Figure 1.11). Collected PCK (cPCK) represents a collection of content knowledge, pedagogical knowledge, and teaching experience. According to Carlson and Daehler (2019), cPCK identifies the scales of discipline-specific PCK, topic-specific PCK, and concrete concept-specific PCK. Personal PCK (pPCK) is explained as the knowledge construct teachers form on their own. When teachers' sources for pPCK are published, articulated, or empirically evaluated results in the transformation of pPCK into cPCK. If pPCK becomes observable teaching outcomes like teaching strategies, models used in the classroom, or methods for tackling students' learning difficulties, it refers to enacted PCK (ePCK).

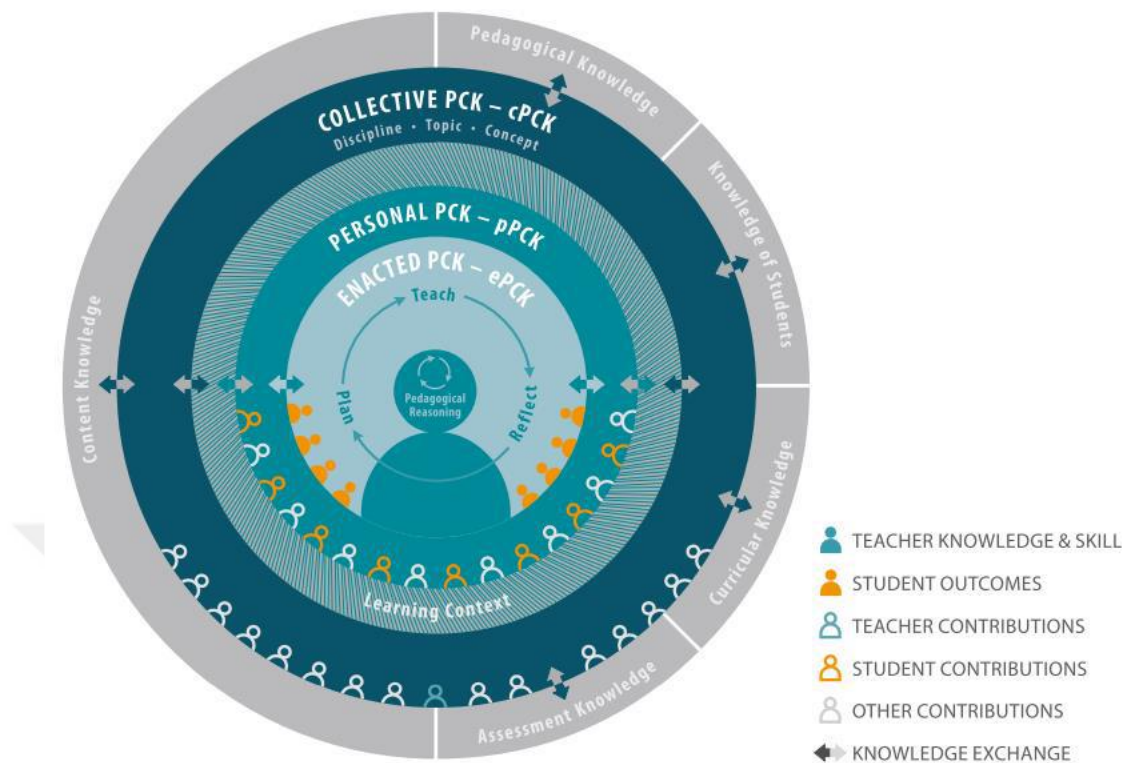


Figure 2.9 Carlson & Daehler's (2019) Refined Consensus Model of PCK (p.83)

In the refined consensus model, the relations of PCK domains are explained with their interactions of teaching and learning processes. It was implied in the model that PCK settles from a broader view that is discipline-specific to a narrow point of view that is content-specific horizontally. Knowledge levels of PCK are interpreted to be changeable from basic to advanced vertically.

The proposed models for teachers' knowledge and pedagogical content knowledge seem to be endless. However, in light of these proposed models mostly built on Shulman's proposed models (1986, 1987), several studies were conducted in order to discover teachers' knowledge domains essential for stimulating students' science learning. Studies on teachers' knowledge have concentrated on finding out teachers' pedagogical content knowledge and its components, the relationships of the

components, and the interaction of pedagogical content knowledge with the other knowledge domains, such as subject matter knowledge, pedagogical knowledge, and context knowledge. Hence, the following part of the chapter is devoted to the review of related literature on pre- and inservice science teachers' PCK with components, their interactions, and influences on teachers' teaching practices, students' and teachers' ecology understanding, respectively.

2.2 Studies Regarding PCK and SMK of Science Teachers

Considering the possible contribution of this study to science teacher education programs, the next section summarizes the studies regarding preservice teachers' PCK and SMK on biology/life sciences.

2.2.1 Studies regarding Preservice Science Teachers' PCK and SMK on Biology/Life Sciences

Some of the reviewed studies investigated the relationships between teachers' subject matter knowledge and their pedagogical content knowledge and general pedagogical knowledge (Kaya, 2008; Käpylä, Heikkinen & Asunta, 2009; Kind, 2009a). For instance, with the purpose of examining the influence of the amount and quality of content knowledge on pedagogical content knowledge, Käpylä, Heikkinen and Asunta (2009) conducted a study on ten primary student teachers and ten secondary biology student teachers regarding photosynthesis and plant growth. Primary student teachers were called content novices because of their less structured knowledge with more mistakes and inaccuracies. Secondary biology student teachers were referred to as content experts that their possession of structured knowledge and comprehension of concepts in coherency. They used a lesson preparation method accompanied by interviews to investigate the effect of subject matter knowledge of

student teachers on their pedagogical content knowledge. After student teachers prepared their lesson plans, two questionnaires were administered to them. Results revealed that because of the poor content knowledge, primary students were reported to be less conscious of students' learning difficulties. On the other hand, as biology student teachers' solid knowledge of the content, they were more aware of the students' learning difficulties and their alternative conceptions. Related to curriculum knowledge, primary student teachers in general gave the answer as basic ecological understanding in primary biology. Biology student teachers, however, emphasized the most important topic more often than primary student teachers did. Primary student teachers recorded their selection of student-centered instructional strategies like drama, and making animations; biology teachers with their selection of direct activities like observing, and experimenting. In fact, primary student teachers' orientation to teaching was determined mostly as constructivist, biology student teachers as between conceptual and constructivist teaching orientation. The problems primary student teachers faced when they prepared their lesson plans were found to be their poor content knowledge, and then come knowledge of students' learning. Biology student teachers' difficulties were reported to be related to students' learning difficulties, prior knowledge, and understanding. Therefore, educational needs implied by content novices were necessary for content knowledge, and content-relevant instructional strategies. Content experts, however, pointed out teaching strategies, teaching practice at the primary level, knowledge of curriculum, and knowledge about students' understanding of their educational needs. The study implied that there is a need for primary and secondary science teachers to develop domain-specific and topic-specific teaching methods. In fact, the authors suggested that although some content knowledge is required for effective teaching, pedagogical content knowledge is an essential domain to be enhanced.

Kind (2009a) explored science trainee teachers' teaching practices when they teach within and outside their specialism. The study was conducted in a university in

Northern England in which trainees enrolled in an initial teacher education course. The course was to enhance the trainee's subject matter knowledge to teach science topics properly. Topics were electricity, forces, chemical reactions, energy, waves, ecosystems, the genome, Earth and space, substances, and investigations. The design of the study was a traditional interpretive and descriptive qualitative study. Data was collected through interviews and questionnaires. Trainee science teachers reported preferring the internet, textbooks, prior knowledge, and formal documentation mostly for the preparation of science lessons within their subject matter knowledge. For outside specialism, trainee teachers preferred mostly school colleagues, textbooks, the internet, and formal documentation. The findings showed that some trainee teachers indicated that they have difficulties to achieve learning objectives when teaching within subject specialism topics. However, more than half of the trainee teachers indicated that they are less confident teaching outside specialism, 21% of them indicated they can teach both outside and within specialism contents, not affecting their confidence. Moreover, slightly less than half of the teachers (48%) were confident about handling of difficult questions. The majority of the teachers (83%) welcomed learning new subject matter knowledge. The result of the study showed that transforming subject matter knowledge to the forms that students comprehend could be achieved when trainee science teachers teach outside their specialism. Therefore, it was suggested in the study that teacher educators and mentors should encourage trainee science teachers to gain advice from experienced colleagues for teaching both within and outside their specialism.

In order to understand prospective science teachers' knowledge development in a specific subject Brown, Friedrichsen, and Abell (2013) designed a longitudinal multiple case study with four prospective secondary biology teachers. The scope of the research was to understand prospective teachers' science teaching orientations, knowledge of students' understanding of science, and knowledge of sequencing of science instructions using Magnusson et al.'s (1999) PCK model as the theoretical

framework. The data from prospective teachers were collected in a science teacher certification program. Teachers were asked to prepare a lesson plan according to predetermined standards that they used to teach 8th-grade level students. After the lesson plan, teachers conducted semi-structured interviews and they were interviewed following the end of the training program. Interview transcripts, field notes, lesson plans, and classroom documents were the data sources for teachers' PCK components. The findings from qualitative analysis of the collected data showed that PCK components of Magnusson et al. (1999) connected to each other enhanced simultaneously. In fact, researchers found a strong influence of knowledge of orientations on the knowledge of learners and knowledge of instructional sequence. Therefore, the findings further imply that prospective science teachers need support in constructing a more sophisticated science teaching orientation to be better capable of knowledge of learners and knowledge of instructional sequence.

Preservice science teachers' PCK studies mainly focused on the teacher education program to improve teachers' PCK with its constituent components. Großschedl, Harms, Kleickmann, and Glowinski (2015) conducted a cross-sectional study with 274 German preservice biology teachers to investigate content knowledge (CK) and pedagogical content knowledge (PCK) of teachers with two tests. Preservice biology teachers' CK test included 78 items consisting of evolution, genetics, microbiology, and morphology. PCK tests included 66 items with open-ended, short-answered, and multiple-choice questions related to preservice biology teachers' knowledge of students' understanding, knowledge of instructional strategies, knowledge of biology curriculum, and knowledge of assessment. A confirmatory factor analysis (CFA) was done to ensure the construct validity of the tests. The conducted comparative fit index (CFI) valued the offered model for the professional knowledge of teachers consisting of PK, CK, and PCK was 0.98 and the value of the Tucker–Lewis fit index (TLI) was 0.96. These values confirmed the model. Moreover, the results showed that CK and PCK of the preservice teachers were highly correlated.

PCK and PK relation was indicated moderate relation. The findings related to learning opportunities for professional development revealed that teacher education program type was not correlated to PK and teachers having a second science subject had lower scores in PK. The relationship between teaching experience and PCK was also analyzed and it was found to have a positive correlation between teaching experience and PCK rather it was found to have no correlation between PK and CK. The overall inferences of the research were PK, PCK, and CK were distinguishable correlated domains except PK and CK were found to have no significant relations in the study. Teachers with academic-track participants who were defined according to their certification type of A seemed to have high rescores compared to non-academic track teachers who were identified as having certification type B in terms of not only CK but also PCK.

Nugraha (2017) explored preservice science teachers' PCK in relation to the digestive system using CoRe. The study gathered data from 20 pre-service teachers enrolled in a teacher education program, using CoRes, interviews, reflective journals, and field notes. The participating pre-service teachers emphasized that students should comprehend (1) the organs of the digestive system and accessory digestive system, (2) the food processing stages involving ingestion, digestion, absorption, and elimination, and (3) issues related to digestive deficiency. These teachers aimed to effectively convey the curriculum content, believing that teaching the digestive system was vital for promoting overall health. They acknowledged potential challenges students might face in understanding the topic; for instance, students might lack awareness of accessory digestive organs and the four stages of food processing. The pre-service teachers suggested that students' preconceptions could stem from everyday experiences. They further advocated for a student-centered teaching approach encompassing role-playing, experiments, and interactive games to facilitate digestive system understanding. Finally, the teachers intended to assess student learning through testing exclusively. The researcher concluded that

CoRe proved to be a valuable tool for enhancing pre-service teachers' development of PCK.

In a longitudinal study, Sickel and Friedrichsen (2018) studied with three preservice biology teachers PCK to explore their topic-specific PCK for teaching natural selection. Interviews and classroom observations were conducted to elicit teachers' PCK aspects and Magnusson et al. (1999) PCK model was used as the theoretical framework. Qualitatively analyzed data of the study revealed that teachers hold varied orientations towards natural selection such as some of the teachers were found to hold constructivist, student-centered beliefs, the other one didactic beliefs. In fact, teachers revealed constructivist orientations showed notable enhancement in PCK components. In fact, teachers were especially found to improve their knowledge of assessment over time in the study. The participants reported to differ in their knowledge bases' enhancement. For example, some of the participants noted to improve their knowledge of instructional strategies, the other knowledge of learners, and another participant found to improve knowledge of assessment. One of the important findings of the study was that enhanced subject knowledge, possibly acquired through coursework on evolution, could serve as a foundation to assist teachers in integrated Pedagogical Content Knowledge (PCK) that corresponds with fundamental concepts within evolutionary subjects. The study implied that clearly articulating the objectives of fostering Pedagogical Content Knowledge (PCK) within teacher training programs had proven effective in aiding preservice science teachers to cultivate advanced teaching expertise in science.

As reported by related literature, teachers' SMK is in relation to their PCK to promote students' comprehension of ecological concepts and principles, teachers' possession of necessary subject matter knowledge on ecology is a crucial asset. In fact, early studies demonstrated that in order to facilitate students better understanding, teachers' possession of subject matter knowledge is a prerequisite

(Abell, 2007; Gess-Newsome, 1999; Gilbert et al., 2004; Shulman, 1986b, 1987; Van Driel, Verloop, & De Vos, 1998). Van Driel, Verloop & De Vos (1998) claimed that pedagogical content knowledge is concerned with teaching a certain topic and it has value for its relation with pedagogical knowledge and subject matter knowledge. They also stated that subject matter knowledge is a prerequisite for pedagogical content knowledge which they defined as “teachers’ interpretations and transformations of subject-matter knowledge in the context of facilitating students learning”. Therefore, in order to achieve this subject matter transformation, teachers should possess sound subject matter knowledge on a specific content area. For these reasons, the studies presented below covered the previous studies of understanding ecological concepts and principles of preservice science teachers.

One of these studies investigated preservice elementary teachers’ conceptual understanding of ecology by analyzing teachers’ prepared concept maps in terms of organization, association, and description of relationships (Zak & Munson, 2008). Fifty-six preservice elementary teachers in the final semester from four teacher preparation universities in Minnesota participated in the study. Forty-one of the students were female, fifteen were male, twenty-two of the teachers were from liberal arts colleges, and thirty-four of them were from public universities. Preservice elementary teachers were given a list of sixteen ecological concepts asking them to prepare a concept map on the ecology unit for sixth-grade students. Their concept maps were analyzed in terms of structure, content, and organization identified according to patterns. Then, each concept map was broken into its individual propositions in a spreadsheet which in turn categorized according to both the originating concept and linked concept. Later, the frequencies and patterns of the propositions were identified. Visual analysis of the concept maps resulted in the emergence of two main clusters. One of the clusters was the food web cluster including generally the concepts of food web, energy flow, producers, consumers, and decomposers. The second cluster was the ecosystem cluster including

ecosystem, community, populations, and species. 'Food web', 'species', 'populations', and 'organisms' were found to be mostly used concepts in concept maps. This showed that participants had a better understanding of these ecological concepts. Conversely, 'biotic factors' and 'abiotic factors' were the concepts that nearly half of the teachers used in their concept maps. The most critical ecological concept of 'energy flow' was used by less than half of the preservice teachers. This lack of associations of the concepts indicated teachers' lack of understanding or their misconceptions. Other concept pairs associated most commonly with each other such as community and populations; food web and prey-predator; and food web and producers indicated that these concepts were conceptualized by teachers meaningfully. On the other hand, 'prey-predator can lead to extinction' propositions of teachers indicated preservice teachers' misunderstanding of the process of extinction. Similarly, the 'species make adaptations' proposition might indicate teachers' common misunderstanding of the evolutionary process. In the study, Zak and Munson suggested educators help preservice teachers understand basic concepts in ecology and their common essential relationships.

Pre-service primary teachers' progression in their understanding ecosystem in an inquiry-based learning experience was explored (Martín-Gámez, Carmen Acebal & Prieto, 2020). 73 pre-service primary teachers involved in three-step processes. First, teachers detect their conceptions of students; second, enabling pre-service teachers to recognize students' conceptions; comparing and contrasting teachers' initial conceptions with gained inquiry-based learning. Data collected through observations and teachers' posters analyzed qualitatively indicated that pre-service teachers gained remarkable improvement in their posters regarding the ecosystem. In fact, teachers prepared posters in groups initially found to include only either biotic or landscapes without identifying components of the ecosystem. Conversely, the final posters of the groups represented a landscape with biotic and abiotic components, even one group's poster identified different components either biotic or abiotic.

Although pre-service participant teachers indicated progress in their conceptual understanding of the ecosystem in general, there were still groups of teachers found to reveal few improvements. Therefore, the study's findings stress the importance of inquiry-based learning opportunities in promoting teachers' knowledge bases and pre-service teachers' need to enhance their understanding of components of the ecosystem, the relationships of these components, and the human role in this system.

In Türkiye, researchers focused on preservice science teachers' PCK about ozone layer depletion (Kaya, 2009); acid rain and photosynthesis and cellular respiration (Kaya, Kaya, Aydemir & Ebenezer, 2022); evolution (Tekkaya & Kılıç, 2012; Tekkaya, Kılıç & Özcan, 2011). For instance, Kaya (2009) explored Turkish preservice science teachers' PCK in relation to knowledge of curriculum, knowledge of students' learning difficulties, knowledge of instructional strategies and activities, and the knowledge of assessment. He also investigated the association between the SMK and PCK with its constituents. There were two hundred sixteen senior preservice science teachers in the study. Specifically, the study focused on the conceptualization of ozone layer depletion which is one of the important environmental science topics. Preservice science teachers' conceptual understanding of ozone layer depletion was determined by using a five-item open-ended survey. Preservice science teachers' PCK and its components regarding ozone layer depletion were determined according to semi-structured interviews. Multivariate analysis of variance (MANOVA) was used to investigate preservice teachers' SMK interaction with their PCK and its components. The inter-relationships and intra-relationships of PCK components were explored by computing the Pearson product-moment correlation coefficient. Analysis of both qualitative and quantitative data showed that about half of the preservice science teachers held a naïve understanding of ozone layer depletion. Most of the preservice science teachers had a conception about the nature of the ozone layer and the consequences of ozone layer depletion; half of the preservice science teachers had difficulties with the functions of the ozone

layer and held misconceptions about the relation of its depletion with global warming. When their PCK was analyzed with its components, participants were found to have inadequate PCK to teach ozone layer depletion. The intra-relationship of PCK was found to have also significant relation on the topic of ozone layer depletion which means that if teachers develop one of the components of pedagogical content knowledge, it influences other components in the same direction except knowledge of assessment. The interviews related to the relationship between SMK and PCK mostly supported the quantitative data found. In general, preservice teachers were aware of the curriculum, and students' difficulties and had knowledge about instructional strategies mostly between traditional and contemporary approaches regarding ozone layer depletion. The results of the study pointed out that the preservice teachers with high knowledge of the subject matter possessed high competency in knowledge of curriculum, instructional strategies, students' learning and addressing their learning difficulties, and pedagogy. The results of the study imply that preservice education programs need to focus on the preparation of teachers' pedagogical content knowledge with necessary courses. Preservice teachers should take courses in subject matter and pedagogy at the same time to achieve the growth of subject-specific pedagogical content knowledge from starting from their first-year education.

Tekkaya, Kılıç, and Özcan (2011) conducted a case study with two German and two Turkish preservice science teachers to investigate their PCK in evolution. The several data to understand the preservice teachers' CK regarding evolution, knowledge of teaching strategies and methods, knowledge of students' understanding of evolution, orientation towards teaching evolution, knowledge of assessment through semi-structured interviews, concept maps, and lesson plans. Preservice science teachers in German and Türkiye appeared to have weak CK regarding evolution. In fact, the findings of the study revealed that participant preservice science teachers had misconceptions about evolution. Moreover,

preservice science teachers indicated their difficulties with the evolution curriculum, teaching strategies methods, and assessment techniques related to evolution. In addition, as they were likely to have weak CK, they seemed to have hardness in detecting students' learning difficulties and remedying their misconceptions regarding evolution. There were remarkable findings related to the difference between Turkish and German preservice science teachers. For example, German preservice science teachers appeared to use centered teaching methods and strategies rather Turkish preservice science teachers were identified to use teacher-centered methods and strategies. Similarly, German preservice science teachers mentioned formative assessment techniques; however, Turkish preservice science teachers were found to indicate traditional assessment techniques. The findings of the study were valued in terms of highlighting the preservice teachers' PCK development in evolution by providing a comparison between participant preservice science teachers from different countries.

Like the previous research, Tekkaya and Kılıç (2012) designed a case study with seven senior preservice biology teachers on the topic of evolution. The study was targeted to uncover preservice biology teachers' PCK with the gathered data from semi-structured interviews, concept maps, and lesson plans. The PCK findings analyzed in the light of Magnusson et. al (1999) PCK model revealed preservice science teachers had knowledge of students' learning difficulties and instructional strategies to teach science. The preservice biology teachers seemed to have difficulties identifying appropriate teaching strategies to teach evolution rather they identified teaching strategies to teach science in general. Related to the knowledge of assessment, preservice science teachers were likely to prefer summative assessment apart from diagnostic and formative assessment. Moreover, teachers appeared to have difficulties with the curriculum of evolution. The researchers concluded that preservice biology teachers are necessitated to develop their CK and PCK components regarding the evolution topic.

Kaya, Kaya, Aydemir & Ebenezer (2022) conducted causal-comparative research to understand whether there was a relationship between CK and knowledge of students' understanding of science in the context of acid rain and photosynthesis and cellular respiration concepts. There were 73 preservice teachers in the study as participants. Participants collected data from open-ended surveys for CK, and semi-structured interviews for preservice science teachers' knowledge of students' understanding of science. The results of open-ended surveys revealed that most of the preservice science teachers possess a partial or naïve understanding of both acid rain and photosynthesis and cellular respiration concepts. Similar results were obtained from teachers' knowledge of students' understanding of science. In fact, they indicated either a partial or naïve understanding of students understanding of science. In terms of the relationship between CK and knowledge of students' understanding of science, researchers found noticeable relationships. The findings of the study suggested improving preservice science teachers' CK in particular science topics. In fact, the researchers implied the positive influence of teachers CK on the quality of teaching.

As previously mentioned, the studies reviewed above aimed to compare topic-specific and domain-specific aspects of PCK or investigate individual components of PCK. Some studies explored the interrelationships between these components or the influence of SMK on PCK, while others concentrated on the progression of PCK. The following section shifts the focus to earlier research concerning inservice science teachers' PCK and SMK regarding biology and life science.

2.2.2 Studies regarding Inservice Science Teachers' PCK and SMK on Biology/Life Sciences

In order to investigate secondary science teachers' planning, teaching, and reflecting on teaching their area of certification and teaching content area out of their certification from the perspectives of teachers' content knowledge, pedagogical

knowledge, and pedagogical content knowledge, a very earlier study from Sanders, Borko and Lockard (1993) designed a qualitative study. With three-experienced high school science teachers in an Eastern suburban/rural area were the participants. Teachers interviewed both before and after each class about their planning and reflection on their teaching. Class observations were fulfilled following interviews. All interviews were audiotaped and transcribed. In addition, several tools such as a collection of teachers' lesson plans, notes, copies of transparencies, worksheets, and handouts used for data analysis. According to data, when teachers practiced teaching in their area of certification, they acted as experts; however, when they taught different subject matter from their area of certification, they sometimes behaved like novice teachers. Their planning showed differences between their practice especially teaching subject matter out of their specialism. They were reported to possess fewer materials and also indicated as being more time-consuming and less efficient in lesson preparation of different subject matters. In the area of certification, teaching practice was mostly based on student-centered teaching and teachers easily adapted to new teaching settings when necessary and they were aware of the most important points in the curriculum. However, when teachers practiced outside of their area of certification the teaching mostly focused on teacher-centered strategies that students were passive listeners; teachers talked more about explanations of concepts and avoided riskier teaching strategies. Reflections about teaching experience in their area of certifications were more on the students' conceptions and participation. On the other hand, teachers reflected on teaching experience outside of their area of certification were mostly about their teaching. They were unsure about the effectiveness of their teaching. In fact, teachers enhanced especially pedagogical knowledge and pedagogical content knowledge for science topics influencing their teaching practice in a better way to handle whatever subject matter they teach. Therefore, researchers emphasized the importance of teaching preparation programs to emphasize more on teaching a variety of methods and strategies applicable to

many science contents. They also advised education administration to appoint teachers according to their area of certification and select teachers from experts with improved pedagogical knowledge when assigning to teach out of certification.

To investigate experienced biology teachers' topic-specific PCK in osmosis and diffusion, Lankford (2010) conducted a case study in a longitudinal inservice alternative certification program, which was "Alternative Science Teacher Education Program (ASTEP)". Six experienced high school biology teachers were the participants; semi-structured interviews lesson plans, videotaped field observations, and field notes. The collected data was analysed in reference to Magnusson et al. (1999) PCK model and revealed most of the participant biology teachers held a constructivist orientation in teaching biology. The participants indicated their beliefs on enabling their students to construct their knowledge and explore the issues by themselves by engaging them with 5E instructions. In addition to the 5E instructional approach related to knowledge of representations and instructional strategies, the participant biology teachers found to enable students to explore through investigations and used illustration to represent osmosis and diffusion. They stated experimentations and demonstrations as well. Teachers' findings related to students' prior knowledge, requirements, understanding and their difficulties in osmosis and diffusion showed participants teachers aware of the students' difficulties, and prior knowledge, addressing their learning requirements and difficulties through necessary instructional approaches. Teachers were found to use formative assessment techniques to assess students' understanding of osmosis and diffusion. Teachers also seemed to be knowledgeable in vertical and horizontal curriculum relations. The study implied that teachers' orientations influence their decisions of instructional strategies and knowledge of students. Moreover, experienced teachers in the study are better able to use representations to encourage students to learn a particular topic. In fact, the study's findings are valuable in terms of contributions to the research

regarding experienced biology teachers' sound content and representations of knowledge turn into better learning opportunities for students.

Similar to Lankford (2010), to investigate high school biology teachers' integration of PCK components, Park and Chen (2012) conducted a qualitative study by using the Pentagon Model of PCK (Park & Oliver, 2008) as the theoretical framework. The main purpose of the research was to explore experienced teachers' relatedness of PCK components. The four-participant high school biology teachers collected multiple sources of data which were semi-structured interviews, classroom observations, lesson plans, materials used in the lessons in the context of photosynthesis and heredity teaching. In-depth analysis of explicit PCK (Park & Oliver, 2008), enumerative approach (LeCompte & Preissle, 1993) and the constant comparative methods (Strauss & Corbin, 1990) were the approaches to analyze highly intensive qualitative data to gain in-depth insight into the experienced biology teachers' PCK components and also ensured the triangulation. Although the findings of the research confirmed the connectedness of the PCK components, the relatedness of the components differed. For instance, they found high relations between the components of knowledge of students' understanding and knowledge of instructional strategies and representations compared to other relations. Researchers implied that when teachers had strong knowledge of students' prior knowledge, difficulties and learning corresponded effective teaching strategies and representations. Teachers' knowledge of curriculum was also found to have a high correlation with knowledge of instructional strategies and representations besides low correlation with other components. In addition, knowledge of assessment was another component highly related to knowledge of instructional strategies and representations and also related to knowledge of students as well.

A case study was conducted with a single case of experienced biology teachers by Chapoo, Thathong, and Halim (2014a). With the purpose of investigating

experienced teachers' PCK understanding and practices, content representation (CoRe) designing, teaching practice, and semi-structured interviews were used to collect data to gain insight into secondary-level biology teacher's PCK. Magnusson et al. (1999) PCK model was the theoretical framework for understanding the teacher's PCK and the collected data was analyzed accordingly. The biology teacher indicated a constructivist approach to teaching science that she had the knowledge to enable her students to understand the nature of science. In fact, she seemed to have knowledge of students' understanding of science. The participant was found to have a variety of instructional methods and activities to engage students with effective learning facilities. She reported using inquiry-based instructions, experimentations, and active learning strategies based on the constructivist approach to teaching. Regarding curriculum, she followed the of the school and implemented the standard curriculum. Formative assessment was detected as the knowledge of the assessment of the participant. She used several assessment techniques during the CoRe creation. For example, she used multiple-choice tests, concept mapping, classroom observation, peer evaluation, written journals, drawings of the students, and homework assignments to assess students' understanding of science. As teachers have a sound content knowledge base for the sophisticated PCK of teachers, the study suggested science teachers have strong and integrated science content knowledge to implement inquiry-based instructions to motivate students' science learning. Besides, another implication of the study was that teachers need to hold teaching approaches focusing on students' learning science effectively.

The same researchers, Chapoo, Thathong, and Halim (2014b), conducted another case study with three biology teachers to explore their understanding and practice of PCK. The questionnaire, interviews, classroom observations, CoRe plans, and documents were the data collection tools to explicate secondary biology teachers' PCK components in the light of Magnusson et al. (1999) PCK model. According to collected data from teachers, participants differed in terms of understanding and

practice in their PCK. Teachers are found to have conflicts between their beliefs and practices in teaching science. Although they started to teach science in an innovative way triggering educational reform, they used to teach science in traditional ways. They found it to ignore students' understanding and focused on paper-pencil tests to assess students' understanding. The implication of the study was related to the importance of development in biology teachers' PCK with supporting improvement in their beliefs to teach science, knowledge of instructional methods, science curriculum, and content knowledge.

Dealing with inservice biology teachers' PCK development in a professional development program (PDP), Bravo and Cofré (2016) designed a study to investigate the biology teachers' PCK improvement in the context of evolution. Magnusson et al. (1999) PCK model was utilized as the theoretical framework to capture the PCK components of two biology teachers in teaching evolution. Content Representations, CoRe and Pedagogical and Professional-experience Repertoire, and Pa-Pers were the methods to in-depth analysis of teachers' PCK. An interpretive approach to analyzing qualitative data was selected. The purpose of the PDP was explained as to support teachers with plenty of training opportunities in evolution and NOS and improve their teaching in these contents. Teachers enrolled in the process of knowledge construction, teaching practice, and reflection in evolution and NOS in the program. The multiple data collected in the study showed that teachers' NOS knowledge highly influences their teaching practice in evolution. Teachers experienced difficulties in overcoming students' misconceptions of evolution. The possible reasons for these difficulties are explained by students' religious beliefs and corresponding anti-evolutionary ideas; rather teachers' difficulties in the knowledge of students' understanding, difficulties, and misconceptions in evolution. In fact, participant teachers were found to change their teaching practice in line with the PCK components Magnusson et al. (1999) PCK model suggested. The findings of the study approved that PCK components integrated and connected which participants

in the study found to improve new elements in their PCK components correspond to change in the other PCK components as well. They could make new pedagogical decisions for students' difficulties. Therefore, the influence of the PDP on biology teachers' PCK development in evolution was valuable to reinforce teachers to think about their instructional decisions, beliefs, and knowledge in evolution and provide an opportunity to revise these aspects to provide better learning opportunities for students. Reflecting on their knowledge and practice, the professional development programs were recommended for science teachers to improve their PCK components in particular content areas. The researchers did not focus on students' misconceptions of evolution and the methods to remedy these misconceptions, they suggested further studies to investigate knowledge of students' conceptions of evolution.

Supporting the findings and the implications of the previous study, Lucero, Petrosino and Delgado (2017) explored the relationship between subject matter knowledge (SMK) and knowledge of students' conceptions (KOSC) in teaching evolution by natural selection. Magnusson et al. (1999) PCK model was the theoretical framework for the study. Four high school science teachers collected data through the Conceptual Inventory of Natural Selection (CINS), interviews, and video-recorded classroom observations. According to CINS results, participant teachers' correct answers ranged between %76 and %87. Teachers also asked their predictions regarding students' answers to CINS questions revealed that they indicated rationales for the items they did not provide correct answers. In addition, related to 'change in a population', teachers seemed to have clear predictions and rationales. Implying from the findings, teachers appeared to improve their SMK in evolution, on the other hand, they seemed to have misconceptions about their students. Moreover, teachers' SMK had an impact on the teachers' KOSC leading to proper lesson planning and implementation. The participants of the study indicated strong KOSC according to the measured prediction accuracy measure. On the contrary, teachers found to have difficulties in modifying their instructions according to

students' misconceptions. In fact, teachers tended to underestimate students' misconceptions either correcting or refusing. For this reason, teachers need to be aware of students' requirements to solve their alternative conceptions.

Highly related concepts with ecology, photosynthesis, and respiration conceptualization of inservice elementary and middle school teachers were investigated by Krall, Lott and Wymer (2009). The study was conducted with seventy-six inservice elementary and middle school teachers from rural school districts in the central Appalachian region. These teachers attended the Appalachian Math and Science Partnership project in 2005. A twenty-five-item instrument with four forced-choice tasks was designed to investigate teachers' understanding of general life science topics of photosynthesis and respiration, energy flow in an ecosystem, heredity and natural selection, and experimental design. Responses of teachers are divided into three sub-groups the high, middle, and low performance groups. Results of the teachers' responses showed that about half of the teachers had conflicting understanding between essential nutrients for seeds to germinate and the growth of plants. When teachers were asked about the source of food for the germination of a seed, although %64.5 of the teachers gave the correct answer, low-performance group teachers' responses indicated their poor understanding of the function of the cotyledon. About half of the inservice teachers (%50) indicated that carbon dioxide, nutrients from the soil, and sunlight were essentials for plant growth, and less than half of the teachers believed it was nutrients from the soil. Only 5.3% of the teachers gave the correct answer to this question. The results of the study revealed that about %75 of the teachers did not understand plants even respire in the absence of light. Overall findings of the study revealed that inservice elementary and middle school teachers did not possess an accurate understanding of the basics of photosynthesis and respiration. That is, teachers held naive conceptions that may cause their students to construct an inaccurate understanding of these concepts. In

order to promote the conceptual understanding of the students, teachers were expected to gain a sound conceptual understanding of these concepts.

With the aim of assessing primary teachers' understanding of the ecological issues, Summers, Kruger and Childs (2000) performed a study with twelve practicing primary school teachers. They tried to discover primary teachers' comprehension and their misconceptions through interviews. Primary teachers possessed one to twenty years of teaching experience and had studied science as the main subject during their teaching training. After analysis of responses, most of the teachers indicated that possessing the knowledge of living things exists in communities interacting with each other (12 of the teachers). Also, most of the teachers were knowledgeable about biological diversity and extinction and they stated the reasons for these issues. Although two teachers indicated the need for biodiversity, they did not give a specific example of its beneficial influence on humans. Four teachers have the non-scientific view that "different species can breed each other". In addition, one of the teachers held the naïve idea of a Lamarckist view of species' development of resistance to disease as it passes on to the next generation. Four of the teachers defined the 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 the biosphere. Several teachers indicated a partial understanding of sources of carbon dioxide and its portion in the atmosphere. Most of the teachers were aware of the ozone layer's place in the atmosphere and its depletion, although only four teachers mentioned the recent enhancement of ground-level ozone. The most reported misconceptions about global warming by teachers were that the holes cause global warming and ozone-destroying chemicals come from car exhaust. However many of the teachers were aware of the climatic consequences of global warming. Only one teacher mentioned the enhancement of the existing greenhouse effect can be the reason for global warming. In general, primary teachers reported with substantial understanding of ecological concepts. But

yet they possessed less comprehension of underlying ecological scientific principles with several misconceptions and missing concepts. Summer et al. stated that teacher subject matter knowledge is a prerequisite for effective teaching practice. Therefore, researchers suggested that teacher training programs for professional development should address teachers' difficulties and poor conception of ecological understanding.

Inservice elementary and middle school teachers' understanding of basic ecological concepts in energy flow through ecosystems was investigated by Beals, Krall, and Wymer (2012). The participants were 53 inservice elementary and middle school teachers in rural schools of the Southeastern region of the US. The data was collected with the 5 forced-choice instruments including 20 items related to photosynthesis and respiration, energy flow in ecosystems, heredity and natural selection, and experimental design. The instrument consisted of tasks regarding the ecosystem that focused on the primary energy source, the roles of decomposers, trophic levels in food chains and their energy relations, and the organisms feeding relations in the food web. The results of the answers to the instrument's asks revealed that %90.6 teachers knew the energy source for all of the food webs in the forest as sunlight; however, still %7.5 answered as green plants. Related to the task regarding decomposers' role in ecosystems, %52.8 of the participant teachers provided correct answers as breaking down organic matter into inorganic compounds. On the other hand, %43.4 of the teachers answered that decomposers recycle energy from dead matter back into the ecosystem for use by green plants. A high portion of participants was found to have difficulties in discriminating decomposers' role in matter recycling and unidirectional flow of energy in an ecosystem. The next task in the instrument was related to plants as producers of chemical energy in the food chain. For this item, teachers were found to answer correctly to a high degree (%60.4). But %20.8 of the teachers answered the "energy for the food chain comes from the soil" option. The task item related to identifying the trophic levels in a sample food chain

showed %58.5 teachers provided correct answers; however, a high proportion of the teachers seemed to have difficulties in identifying the roles of the trophic levels. Relationships between organisms in a food web was the other task in the instrument %71.7 of the participants answered correctly. In total, teachers in the study revealed their insufficient understanding of the concepts and issues regarding energy flow in ecosystems. The most striking result was teachers' insufficient knowledge was found to be parallel to the findings in previous research conducted with elementary and middle school students. The common implication of this study was teachers' inadequate content knowledge and their misconceptions about energy flow through ecosystems resulted in students' poor understanding correspondingly. Therefore, researchers recommended sufficient professional development programs to support teachers in improving their content knowledge.

Strong content knowledge on ecological principles with pedagogy may encourage science teachers to implement more ecology-based instructions. The research concentrated on secondary science teachers' perceived pedagogical knowledge, current and preferred level of teaching environmental issues, and perceived obstacles to teaching environmental issues with their attitudes towards teaching ecology investigated by Kim and Fortner (2006). The sample was thirteen men and twenty-eight women. Researchers constructed a questionnaire to examine science teachers' attitudes, level of their pedagogical knowledge, level of teaching environmental issues, and barriers to teaching environmental issues. Results showed that teachers believed that environmental concepts and issues are important to teach in lessons and they had the necessary pedagogical knowledge to teach them. In addition, their attitudes toward environmental teaching were positive on average. However, their actual abilities to teach were lower than their preferred abilities. Mostly taught environmental issues reported as air pollution, energy consumption, and acid rain. The least taught issues were nuclear waste disposal, marine pollution, and biodiversity reduction. The obstacles hindering teaching environmental concepts and

issues were indicated as internal and personal barriers; external and logistic barriers. The external and logistic barriers were found to be more influential than internal and personal barriers. Internal and personal barriers were reported mostly as lack of content knowledge about environmental issues, and lack of pedagogical knowledge to teach. The external and logistic barriers were lack of time and following curriculum standards. The findings of the study revealed that in order to support science teachers in the teaching of environmental issues, science teachers needed to be provided with relevant content knowledge and pedagogical knowledge through necessary courses. Teachers indicated as required to be knowledgeable in how to teach environmental issues. Moreover, secondary science teachers indicated issue specific barriers to teaching ecological concepts should be addressed.

There were also PCK studies conducted in Türkiye regarding biology (Kınık, 2022; Şen, 2014; Şen, Öztekin & Demirdöğren, 2018; Tıraş, 2019) and environmental issues (Aydın, Şen & Öztekin, 2017; Sağbilge, 2022) in Türkiye. One of these studies conducted to investigate the science teachers' CK and PCK in cell division. Şen (2014) carried out a case study with three inservice science teachers. Multiple sources of data were collected to understand science teachers' PCK components referenced from the Magnusson et al. (1999) model. For example, semi-structured interviews, classroom observations, documents, and V-NOS C questionnaire for gaining teachers' syntactic knowledge. The content knowledge of the teachers analyzed both their substantive knowledge of cell division and syntactic knowledge of NOS. Participant science teachers were found to have deficiencies in NOS beliefs. Regarding their substantive knowledge, teachers seemed to either have sounds such as chromosome and centrosome, or lack of knowledge such as homolog chromosomes and sister chromatids in cell division concepts. Related to the orientations of science teachers, they seemed to have differences in their beliefs and practices. Their beliefs influenced their teaching practices, choice of instructional goals and methods. Participant science teachers were found to have curricular

objectives and vertical and horizontal goals. They were found to violate the curriculum of the cell division. The one possible reason for this violation was explained because of teachers' pedagogical concerns and beliefs such as making connections between students' daily lives. In fact, teachers could address students' conceptions and misconceptions. In that respect, they could determine appropriate teaching and assessment methods. However, teachers seemed to use traditional assessment methods rather than alternative methods of assessment and teacher-centered direct teaching to teach cell division. The prominent implications of the study were teachers' lack of syntactic knowledge and their deficiency in orientation, instructional strategies, and assessment in science teaching.

Kınık (2022) studied science teachers' TSPCK regarding the human body system. Two experienced science teachers' PCK and SMK were investigated with the help of multiple sources of collected data through semi-structured interviews, Content Representations (CoRe), VNOS-C questionnaire, Human Body System (HBS) questions, and classroom observations. PCK components were collected and analyzed in reference to Magnusson et al. (1999) PCK model. The findings revealed that teachers have SMK regarding human body systems. They seemed to associate systems and settle relations between processes. Having sufficient subject matter knowledge in the human body system, participant science teachers were found to reflect their knowledge to TSPCK. For example, teachers seemed to address students' learning prior knowledge, misconceptions, and difficulties. However, teachers did not use approaches to remedy students' misconceptions although they were aware of the common misconceptions students held in human body systems. Teachers' orientation towards teaching the human body system was also found to be consistent with interviews and classroom observation findings. That is, teachers believed and enacted PCK seemed to be compatible. In line with their orientations, teachers' findings related to TSPCK components revealed that teachers seemed to be aware of how and what to teach regarding the human body system. Although they

revealed some deficiencies in syntactic knowledge and overcoming students' misconceptions, teachers adopted their instructional strategies accordingly and found better ways to teach the human body system effectively. Indeed, the study recommended addressing experienced science teachers' needs to improve their NOS understanding and practice and their knowledge of instructional strategies and methods and assessment techniques accordingly.

Regarding environmental education, Tıraş (2019) studied with inservice middle school science teachers to understand their topic-specific PCK (TSPCK) components in the ecosystem. Several data collection tools were used, such as interviews, and classroom observations, and the documents were analyzed through inductive and deductive approaches. As teachers' content knowledge has a positive effect on their pedagogical decisions, participant science teachers' substantive knowledge including teachers' content knowledge in basic concepts related to ecosystems and the flow of energy in ecosystems was explored. Participant teachers were found to have sound knowledge of some concepts like system, species, and habitat; partial understanding of biological diversity and producer; naïve understanding of decomposer, food chain, and food web. Teachers' drawings and concept maps related to the ecosystem revealed that teachers hardly connect the concepts to each other indicating their deficiencies in content knowledge regarding the ecosystem. In fact, teachers were found to have misconceptions regarding decomposers that were common misconceptions of the students recorded in the related literature. The findings related to TSPCK showed that science teachers' common goals and beliefs in the teaching ecosystem were the transmission of content knowledge to the learners because of the teachers' concerns in nationwide exams. In fact, teachers had the knowledge of curriculum in the ecosystem in which they were aware of the place of the ecosystem, and vertical and horizontal relations. On the contrary, teachers were found to neither have awareness of students' misconceptions about the ecosystem nor find better strategies to overcome these misconceptions and learning difficulties.

Teachers were found to use teacher-centered teaching methods and strategies to teach the ecosystem in general. The implication of teachers' TSPCK was teachers' orientations towards a particular content influenced their components of PCK and their practice in teaching. The findings of the study imply teachers' PCK components are connected to each other and topic-specific in nature. Therefore, teachers need to have sound content knowledge, instructional and assessment techniques in a particular topic and have opportunities to practice teaching. In the study, teachers also reported using traditional assessment methods to assess students' understanding. The content expert teacher was found to have an abundant repertoire of knowledge of representations such as visuals, examples, and analogies although all teachers reported to use traditional instructional approaches for subject-specific strategies for science. The findings of the study highlight the importance of science teachers' CK in a particular topic to provide students with better learning opportunities with teachers' integrated PCK components. In fact, the study approved the relationship between CK and the teacher's knowledge of students' understanding and knowledge of instructional strategies.

Aydın, Şen, and Öztekin (2017) carried out qualitative research with two experienced middle school science teachers' PCK and Pedagogical Content Concerns (PCC) in the context of sustainable development (SD). Collected data from semi-structured interviews analyzed deductively and inductively revealed that experienced science teachers had insufficient content knowledge regarding SD. Correspondingly, teachers had trouble with students' lack of interest and awareness of SD. In fact, teachers found to have goals and beliefs about SD to increase students' interest and awareness in social issues. Although experienced science teachers reported using student-centered instructional methods and alternative assessment techniques to teach SD, they did not provide the place of SD in the curriculum and the activities related to SD precisely. The study's findings regarding PCC showed

that teachers' main concern in teaching SD was a deficiency in the school's support to teachers and the high school entrance exam.

Sağbilge (2022) investigated the TSPCK of inservice science teachers in climate, weather, and season. Interviews, classroom observations, and teachers' documents were the sources of teachers' TSPCK. Three inservice science teachers' collected data were analyzed qualitatively. Participant teachers were found to have content knowledge of climate, weather, and the related issues of global warming, greenhouse effect, and climate change. On the contrary, teachers had some misconceptions about global warming, ozone layer depletion, and the greenhouse effect. In relation to their poor content knowledge, science teachers were not aware of students' difficulties and misconceptions and used teacher-centered instructional methods that did not address students' better understanding of the content. In fact, consistent with teacher substantive knowledge, teachers found to have poor knowledge of NOS influenced their teaching practices accordingly. Indeed, teachers' orientation towards teaching climate, weather, and season seemed not stable. That is, their beliefs and practices were not consistent. Although during interviews before classroom observations teachers indicated their teaching goals and beliefs related to encouraging students, they focused on curricular programs to prepare students for exams in their lessons. Science teachers are found to strictly follow the prescribed curricula by MoNE. Participant teachers appeared to have adequate knowledge of the curriculum. For instance, they were aware of the objectives, and vertical and horizontal relations. Conversely, science teachers indicated their deficiency in assessment methods and techniques. The researcher concluded teachers' subject matter knowledge forming a base for teachers' PCK components that affect on teachers' knowledge of students' understanding, and teaching strategies; in addition, teachers holding orientation influenced components of PCK in turn their way of teaching better enables students understanding.

The current subsection focused on inservice science teachers PCK on biology and life sciences. The next section will be about preservice science teachers' PCK and SMK on chemistry.

2.2.3 Studies regarding Preservice Science Teachers' PCK and SMK on Chemistry

Preservice science teachers PCK in chemistry topics was one of the areas of interest in PCK studies. In fact, there are several studies related to PCK of preservice chemistry teachers (Aydın, Boz & Boz, 2010; Boz & Boz, 2007; Coetzee, Rollnick & Gaigher, 2022; Jong, van Driel & Verloop, 2005; Faikhamta, Coll & Roadrangka, 2009; Gencer & Akkuş, 2022; Hume & Berry, 2011; Mavhunga, 2020; Mavhunga, & Rollnick, 2013; Nilsson & Loughran, 2011).

In Thailand, Faikhamta, Coll, and Roadrangka (2009) explored preservice chemistry teachers' PCK in a PCK-based chemistry methods course supported by field experience. The four preservice chemistry teachers enrolled in the course that was aimed to enhance preservice chemistry teachers' PCK to teach chemistry having two phases which were classroom-based activities and school-based activities. Classroom-based activities consisted of academic reading regarding the nature of science, science teaching approaches, students' science learning, and discussions around these topics related to the constructivist approach; school-based activities referred to activities preservice chemistry teachers had the opportunity to work collaboratively with experienced teachers that they observed their teaching practice and students learning in a real classroom setting. To reveal preservice chemistry teachers' PCK, multiple sources of data were collected from interviews, classroom observations, a chemistry concept survey, a beliefs survey, and documents. The collected data showed that at the beginning of the course, teachers were not aware of the impact of students' prior knowledge, learning difficulties in teaching chemistry,

and having sound knowledge of assessment methods. In fact, in the first phases, teachers indicated their limited PCK with the components. After teachers experienced in PCK-based methods course, they found to highly improve their PCK components. They found to learn the conceptual change approaches, science process skills, and cooperative work to elaborate students' learning in chemistry. Moreover, they improved their awareness of students' prior knowledge, learning difficulties, and assessment. The study put forward the positive impact of PCK-based content-specific methods courses on the development of preservice science teachers PCK. In addition, the study's essential findings regarding the teaching experience suggest the importance of providing opportunities to preservice science teachers teaching experience to enable them to improve their PCK.

In a case study, Hume and Berry (2011) conducted with nine preservice chemistry teachers to explore the CoRes construction with scaffolding approach influence the preservice teachers' PCK. CoRes is used as the framework defined by Loughran et al. (2006) as the explanation of the connection between content knowledge, teaching science, and learning for science teachers. That is, CoRes represents the holistic sight of PCK of science teachers in a particular science topic according to Hume and Berry (2011). Apart from CoRes, Pa-PeRs were used in the study to illustrate preservice chemistry teachers' complexity of learning to teach science by defining, analyzing, and modeling teachers' PCK. Researchers used Magnusson et al. (1999) PCK model as the theoretical framework to elicit the preservice chemistry teachers' PCK. Observations, semi-structured interviews, and documents were the sources. Although preservice chemistry teachers did not have teaching practice, teachers were found to build on their awareness of PCK in the components of knowledge of learners. Preservice chemistry teachers seemed to get the benefit of developing their PCK with the help of CoRes design. The findings of the study implied the effectiveness of CoRes in preservice chemistry teachers to improve their components

of PCK in a specific chemistry topic that enabled preservice chemistry teachers to form a knowledge base to design a lesson regarding chemistry.

Another line of research conducted with preservice science teachers to explicit their PCK in the context of science methods courses was Nilsson and Loughran (2011). The researchers introduced PCK in the science methods course to make preservice chemistry teachers plan and reflect upon their professional knowledge. As Hume and Berry's study (2011), Nilsson and Loughran (2011) using CoRe (content representations) design supported preservice science teachers to plan, assess their learning, and make their PCK explicit as well. The collected data from 34 preservice science teachers was analysed through mixed methods both quantitative and qualitative. Preservice teachers completed CoRe both at the beginning and at the end of the semester, they enrolled in the science methods course. Teachers determined a particular science topic either chemistry or physics to practice teaching. Teachers were interviewed with the aim of gathering their self-reflections regarding pre- and post-CoRe construction. Preservice science teachers compared and constructed their pre-and post-CoRes indicating improvement in their awareness in science teaching means also development of their PCK. Teachers had opportunities to understand their PCK and their teaching processes that they could reflect on and develop. Becoming more informed about their teaching experiences, preservice science teachers seemed to improve their knowledge of students become more aware of students' needs, and facilitate their teaching in a specific topic accordingly. Therefore, researchers recommended the CoRes as a mapping methodology of teachers' PCK to develop preservice science teachers' PCK components and challenge their thinking processes in teaching a particular science topic.

With the strong argument for PCK's nature of topic specificity, Mavhunga and Rollnick (2013) studied preservice science teachers' PCK on the topic of chemical equilibrium to enhance their PCK in a specific topic in a teacher education program.

A case study with mixed methods was applied in the study to 16 secondary preservice teachers in South Africa. The research design consisted of intervention, CoRes, and voluntary tutorial sessions. The discussions, CoRes development, and documents of the assignments were analysed qualitatively. In addition, the responses of the TSPCK (Topic-Specific PCK) tool were analysed quantitatively. The test results proved the positive impact on preservice science teachers' reasoning of teaching and their PCK regarding chemical equilibrium. Consistently, the findings of the qualitative data revealed that teachers improved their knowledge of students' prior knowledge and conceptual teaching strategies. The study's findings regarding improvement in preservice science teachers' TSPCK lead to the importance of discussions and reflections on teaching a particular topic to develop pedagogical reasoning.

Related to Topic Specific PCK, a further study from Mavhunga (2020) aimed to explore preservice science teachers' components of TSPCK in reference to the refined consensus model (RCM) of PCK (Carlson & Daehler, 2018) in the topic of chemical equilibrium. The research was conducted with 15 preservice teachers in the context of 6 weeks-interventions, CoRes accompanied by extended lesson plans on the topic of chemical equilibrium. The interventions aimed to foster teachers transforming their content knowledge to teaching by reasoning and enable analysis of content-specific components of TSPCK. In-depth qualitative analysis of collected data identified with the purpose of disclosing the preservice science teachers' components of TSPCK which were learner prior knowledge, curricular saliency, difficulty to understand, representations, and conceptual teaching strategies. The notable consequence of the study was that PCK and TSPCK shared common characteristics that were identified as idiosyncratic and complex. PCK and TSPCK were explained as rising from the interactions of the components that in some cases seemed to be merged, linear sequences of coexisting arrangements. The study highlighted the sophisticated nature of TSPCK that put importance to PCK-based teacher preparation programs in specific content areas.

Coetzee, Rollnick & Gaigher (2022) conducted research for topic-specific PCK of three preservice science teachers to investigate their progress in electromagnetism when they taught the topic first time. Researchers used the refined consensus model (RCM) proposed by Carlson and Daehler (2019). The data collection tools of the study were CoRes, lesson observations, and interviews. The findings of the study regarding curricular saliency were that all participant teachers followed the suggested sequence of national curricular documents. Teachers were found to not experience difficulties in teaching the topic. However, they concluded that teachers need to have solid CK to increase their quality of teaching. Moreover, among the three pre-service teachers, understanding what proved challenging to teach, as well as recognizing learners prior knowledge and misconceptions, appeared to be more influenced by their practical teaching experiences rather than the training they received. Researchers found that they fully grasped the significance of the training's content when they had to teach the subject on their own. This observation could imply that actively instructing the topic led to the improvement of their Content Knowledge (CK). In light of the study, Coetzee et al. (2022) claimed that teaching experience in a certain topic enhanced teachers' conceptual teaching strategies.

De Jong, van Driel and Verloop (2005) investigated postgraduate student teachers' PCK in terms of knowledge of teaching difficulties and student learning difficulties. The main scope of the training program was defined as 'learning from teaching' rather than 'learning of teaching'. That is, students' teachers were supposed to learn with the help of the training how to teach from their own teaching practices and experiences in an active manner instead of a passive way to learn how to teach. Eight student teachers were engaged in semi-structured interviews before and after lessons and also the teaching practices of student teachers were audiotaped by themselves. The findings of the pre-lesson interviews revealed student teachers' uncertainty about students' difficulties. Conversely, student teachers provided more students with learning difficulties in post-lesson interviews. Similarly, student teachers were

found to experience few teaching difficulties in pre-lessons; however, they explained more teaching difficulties in post-lessons. De Jong, Van Driel, and Verloop (2005) pointed out teachers' subject matter knowledge in explaining the difference between pre-lessons and post-lessons in terms of teaching difficulties. That is, they argue that student teachers' subject matter knowledge in chemistry develops over time. The study implies the importance of teachers' teaching practices for the improvement of teachers' knowledge of teaching difficulties and students' learning difficulties. Moreover, the impact of learning from teaching was stressed to foster student teachers' knowledge of teaching difficulties as well as awareness of students' learning difficulties.

There are PCK studies conducted regarding preservice science teachers in chemistry topics in Türkiye as well. One of these studies was a qualitative study conducted by Boz and Boz (2008). The study was to investigate prospective chemistry teachers' knowledge about instructional strategies which is one of the components of pedagogical content knowledge and the factors affecting their teaching decisions. They explored prospective chemistry teachers' knowledge of instructional strategies in light of the topic of the particulate nature of matter. Specifically, researchers aimed to identify prospective chemistry teachers' knowledge of topic-specific instructional strategies, issues shaping their choices, and how they design instruction on the particulate theory. The study was conducted with twenty-two prospective chemistry teachers attending their fifth year of chemistry education in one of the top universities of Ankara in Türkiye. Multiple data collection methods were used such as class vignettes, lesson plans about the particulate nature of matter, and semi-structured interviews prepared according to interview responses and their lesson plans. The results showed that most of the prospective participants would introduce the particulate nature of matter by using concrete objects like marbles in a container and sugar particles. Prospective chemistry teachers indicated the reason for their selection of concrete objects was those students' difficulties in conceptualizing the

empty spaces between particles of matter. The lesson preparations of prospective chemistry teachers showed that each of the teachers selected different instructional strategies. Researchers concluded that teachers' knowledge of students, general pedagogical knowledge, and their subject matter knowledge influenced their choice of instructional strategies and representations of a specific topic. In addition, the pedagogical content knowledge they possessed also influenced their decision on concrete objects for introducing the topic and choice of teaching methods in their lesson plans. The study pointed out the importance of the identification of topic-specific pedagogical content knowledge of prospective teachers with components. Furthermore, researchers recommended that teacher preparation programs should be provided with different topic-specific pedagogical courses that focus on different learning strategies and representations.

In order to find out the factors that influence preservice chemistry teachers' choices of instructional strategies in the context of methods of separation of mixtures, Aydın, Boz, and Boz (2010) collected data from six preservice secondary-level chemistry teachers through semi-structured interviews, with classroom observations, lesson plans and reflections of teachers on their teaching practices. Consistent with the Magnusson et al. (1999) PCK model, researchers examined knowledge of instructional strategies within two sub-components knowledge of subject-specific strategies and knowledge of topic-specific strategies. They focused on preservice chemistry teachers' knowledge of topic-specific strategies. The gathered data revealed that preservice chemistry teachers identified mentors as one of the influential factors in selecting the topic-specific teaching strategies in methods of separation of mixtures. The mentors' effect on teachers' selection was also divided into two categories mentor's request and mentor's instructional style that teachers found to be affected. Most of the preservice teachers mentioned the topic as the influential factor in determining teaching strategy. Moreover, General Pedagogical Knowledge was found to be selected mostly from preservice teachers to decide the

teaching method. The other factors identified in the study were students' demands, personal characteristics, time, SMK, materials available, classroom management, personal experience in teaching, and courses taken. Therefore, the study's findings implied the importance of supporting preservice science teachers a plenty of necessary courses on PCK, PK, and CK.

Preservice chemistry teachers' orientations toward teaching chemistry teaching were investigated recently by Gencer and Akkuş (2022). The researchers conducted the study in the context of teacher training programs including providing preservice chemistry teachers with theoretical background regarding learning cycles, inquiry-based teaching methods, cooperative learning, laboratory-based chemistry teaching, conceptual change, problem-based learning, project-based learning, and assessment in chemistry education. Teachers prepared a lesson plan regarding each of these instructional approaches. After getting feedback about their lesson plans teachers practice teaching to apply their lesson plans. The data collection tools were DASTT-C, card-sorting activity, semi-structured interviews, observations, and reflection papers. DASTT-C developed by Thomas et al. (2001) was used to obtain preservice chemistry teachers' beliefs on teaching and learning as well as the other data collection tools. Collected data from multiple sources analyzed with a deductive approach. In fact, teachers' orientations classified as academic rigor, activity-driven, and didactic orientations are traditional beliefs; guided inquiry, conceptual change, and process orientations are responsive beliefs; discovery, project-based, and inquiry orientations are reform-based beliefs. Researchers included also exam-oriented orientation based on the findings related to considering teachers' responses in preparing students for exams rather than learning chemistry. As teachers seemed to apply traditional teaching approaches to prepare their students for exams, exam-oriented orientation was classified in the traditional beliefs category. The overall findings of the study put forward that preservice chemistry teachers changed their orientations from teacher-centered to student-centered after the chemistry teaching

method course. The university entrance examination was found to affect teachers' goals and purposes in teaching chemistry. Moreover, the study highlighted the positive influence of teaching practice on teachers' approaches to teaching chemistry. For these reasons, the researchers suggested not only amplified preservice chemistry teachers with theoretical presentations but also opportunities to practice teaching and reflect on their experiences.

This section reviewed the prior studies related to preservice science teachers' PCK regarding chemistry topics conducted abroad and in Türkiye. The reviewed studies encompassed a variety of approaches, with some employing distinct PCK models and focusing on specific or comprehensive components. Some explored PCK progress, while others analyzed the interactions of preservice teachers' PCK components. The subsequent section delved into the research concerning PCK in inservice chemistry teachers' PCK.

2.2.4 Studies regarding Inservice Science Teachers' PCK and SMK on Chemistry

In this section, research conducted regarding PCK of inservice science teachers on chemistry was presented. First, studies conducted abroad were reviewed. Following the studies in Türkiye documented.

A series of studies was conducted by Clermont, Krajcik, and Borko (1993, 1994) to investigate the PCK of inservice chemistry teachers. In the first study, Clermont et al. (1993) investigated pedagogical content knowledge development of practicing teachers who were novice chemical demonstrators. Novice chemical demonstrators used in these two studies mean that participant teachers possess poor experience in practicing chemical demonstrations although they have significant teaching experience in other science domains. The development of chemistry teachers'

pedagogical content knowledge was aimed to be actualized by designing a two-week summer workshop. The training included instructions on chemical demonstrations, realizing demonstrations individually with feedback from colleagues and workshop instructors, and conducting demonstrations for middle school students. Data was collected from novice chemical demonstrators with semi-structured interview questions on videotape materials; clinical interviews with two parts of it as a think-aloud, critical-stop and a follow-up, semi-structured interview, and videotape viewing assignments implemented two groups of participants. Audiotaped and transcribed interviews were analysed qualitatively. The analysis of the collected data showed that teachers expressing alternative chemical demonstrations increased after the workshop. Teachers' awareness of the appropriate alternative demonstrations also increased and they rarely showed up in the preworkshop. Descriptions of demonstrations became more detailed during post-workshop interviews. After the workshop, analysis indicated that teachers emphasized the importance of questioning strategies, quality of explanations, and mechanics of demonstrations; and less to use of new terms, use of chalkboards and visual aids, overall organization, and presentation style. In other words, the workshop supported teachers to become more aware of the importance of inquiry in chemical demonstrations. Novice chemical demonstrators (participant teachers) improved their repertoire of chemistry demonstrations with the help of conducted workshops and became aware of preparing effective demonstrations in chemistry instruction.

Following the previous study using parallel sets of data sources, Clermont, Krajcik and Borko (1994) studied with teachers all registered National Science Foundation-supported summer inservice workshop on chemical demonstration teaching. The purpose of the study was to compare experienced and novice chemistry demonstrators' (i.e., teachers') pedagogical content knowledge. Novice chemical demonstrators signified as poor or any experience in conducting chemical demonstrations although they practiced teaching. Similar to the previous study in

1993, researchers collected data from novice and experienced chemistry demonstrators through clinical interviews following semi-structured interviews using videotape materials and videotape assignments. Qualitatively and quantitatively collected data revealed after analysis that experienced chemical demonstrators possessed a greater repertoire of alternative chemical demonstrations to the given videotape demonstrations. They could also criticize chemical demonstrations in terms of students' conceptualizations and suggest more simple ones not interfere with central concept students concentrated on. Moreover, experienced demonstrators were more aware of importance of the inquiry teaching during chemical demonstrations although novice chemical demonstrators showed poor knowledge of the importance of inquiry teaching. Still, they possessed adequate knowledge of instructional selection. That is, experienced chemical demonstrators were reported in this study to have integrated pedagogical content knowledge than novices with their intensive repertoire of representations, knowledge of students, and possessing more knowledge of the subject matter. In other words, it is indicated in this study that pedagogical content knowledge accumulates with practicing teaching in regularly thought topics. Clermont et al. (1994) suggested that teacher preparation programs should provide subject matter knowledge with necessary pedagogical content knowledge including various instructional methods and strategies to the teachers. They also recommended beginning teachers start practicing teaching with a mentor possessing high pedagogical content knowledge in a specific area.

An example of the research on pedagogical content knowledge of inservice science teachers conducted by Van Driel, Verloop, and De Vos (1998). They designed a qualitative study within a long-term research project in The Netherlands on chemical education, with the aim of displaying the development of PCK of chemistry teachers having chemical background knowledge and with more than five years of chemistry teaching experience in upper-secondary education. An inservice workshop designed on chemical equilibrium with enable teachers to discuss chemical experiments and

assignments in the chemistry textbooks, to interpret authentic students' responses, to prepare teachers for the experimental course, to reflect on their own practice of experimental course, and to discuss these individual experiences among group. Researchers selected the chemical equilibrium as subject matter to reflect teachers' instructional strategies and abilities of students' understanding which is also an appropriate subject matter for practicing conceptual change processes in experimental courses. The qualitative research was designed on the experimental courses' designing, implementing, evaluating, and reflecting in three cycles, and in the second and third cycles, two of the inservice workshops were designed, implemented, and evaluated. Audiotape records of the teachers' responses were taken and teachers' written responses to assignments and evaluative questionnaires were analyzed. In the first transcript of the study, it is understood that chemistry teachers are poor in theoretical arguments to facilitate students' conception of a forward and backward reaction taking place in equilibrium conditions. After the workshop session, some teachers broadened their repertoire of effective instructional strategies and representations regarding chemical equilibrium. Researchers concluded that chemistry teachers improved their knowledge of content-specific instructional strategies and their knowledge of students' understanding and learning difficulties about chemical equilibrium with the workshop sessions. They emphasized the importance of investigating science teachers' PCK within specific topics. Van Driel et al. (1998) mentioned that subject-specific training programs contribute to teachers' chances to improve both their SMK and particular learning strategies and ways of handling students' difficulties in learning.

Park and Oliver (2008) investigated experienced high school chemistry teachers' pedagogical content knowledge with its interacting aspects. The participants who have more than eight years of teaching were three high school chemistry teachers working in the same school Chattahoochee River High School in the USA. Data was collected from various sources which were classroom observation, semi-structured

interviews, lesson plans, teachers' written reflections, students' work samples, and researcher's field notes. Analysis of the data realized with different approaches including constant comparative method to deduce subjectiveness of the qualitative analysis of the data and to support identification of teachers' PCK aspects and in-depth analysis of PCK components from gathered data from interviews, written reflections, and other sources. It was found that teachers' capability to address students' misconceptions supported the development of their instructional strategies and representations; their assessment techniques and repertoires of assessment; and their decisions regarding the entire teaching process. That is, their PCK improved and became more sophisticated through the practice of teaching science. First of all, researchers claimed that PCK development and enactment is an active process. With these results, researchers included different aspects to their heuristic PCK model which were "knowledge-in-action" and "knowledge-on-action". Moreover, students' impacts on teachers' PCK were investigated. The teachers' written reflections demonstrated that students' responses have a significant impact on teachers' improvement in their SMK, instructional strategies, and representation and assessment. In this study, students' misconceptions were found to be one of the most significant determinants of teachers' planning and enacting. It was also indicated that science teachers' self-efficacy beliefs influence teachers' handling of students' misconceptions and effective teaching practices. Therefore, self-efficacy belief as another component was included in the researchers' heuristic PCK model. Furthermore, it was pointed out that the self-efficacy beliefs of teachers are highly domain and topic-specific. Teachers' high self-efficacy beliefs were indicated to stimulate their effective teaching practices. Experienced chemistry teachers, in this study, suggested that teachers' individual learning styles and preferences also affect their choice of instructional strategies. To sum up, in their study Park and Oliver (2008) identified experienced chemistry teachers' pedagogical content knowledge and influential components and suggested that both preservice and inservice teaching

education programs should support teachers with opportunities to analyze students' comprehension, reasoning, difficulties, learning styles, and motivations. They also pointed out the importance of the subject matter knowledge, teachers' self-efficacy beliefs, and experience in teaching in order to improve teachers' necessary knowledge bases.

In order to investigate novice science teachers' TSPCK on teaching particulate nature of matter in the context of South African schools by Pitjeng-Mosabala and Rollnick (2018). In order to investigate 14 novice science teachers' improvement in TSPCK during involvement in professional Development Intervention (PDI) multiple data collection tools were utilized. Among the two of the teachers enrolled in the case study to amplify the findings of quantitative data through teaching practices. The overall data collection tools were Content Representation (CoRe), TSPCK and CK tests, classroom observations, and field notes. TSPCK and CK tests were developed, piloted, and validated for the study. CoRe readjusted according to TSPCK components' prompts. A mixed method approach was applied to analyze both qualitative and quantitative data. Although researchers initiated their TSPCK research with the Consensus Model (Gess-Newsome, 2015), as the Consensus Model consisted of the construct of Topic-Specific Professional Knowledge (TSPK) differs from PCK notion, adjusting TSPK, they defined TSPCK as "specific knowledge needed for transformation of CK for teaching purposes" (p.745) and investigate PCK components in the light of Geddis et al. (1993). The findings of the study proved the improvement of CK and TSPCK during PDI. In fact, case study teachers showed high improvement in their CK by the end of the intervention. Therefore, it was inferred from the study that interventions focused on TSPCK helped the improvements of CK as well. Another prominent finding of the study was the influence of teaching practice on novice science teachers' TSPCK. In the case study teachers experienced designing CoRe and practice teaching a particular topic in addition to getting feedback to strengthen teachers' TSPCK.

The studies conducted in Türkiye with inservice chemistry teachers highlighted the importance of investigating PCK in a specific topic to make teachers' topic-specific nature of PCK explicit. In that respect, Aydın, et al. (2014) explored two experienced chemistry teachers' topic-specific PCK in two chemistry topics which were electrochemical cells and nuclear reactions. The purpose of the study was to understand whether PCK components were topic-specific for all and to what degree they were topic-specific. Inductive and deductive data analysis procedures were applied to analyze multiple sources of data such as cart sorting activity, Content Representation (CoRe), semi-structured interviews, classroom observations, and field notes. Magnusson et al. (1999) PCK model was selected as the commonly used theoretical framework to explicate teachers' PCK components. Cross-case analysis findings revealed participant teachers' teaching practice was similar. However, there were found differences between teaching two chemistry topics. Therefore, teachers were found to integrate different PCK components into their teaching of certain topics. For example, teachers found to use "content-based and teachers centered instruction" defined as the instructions focus on lecturing amplified with representations, demonstrations, hands-on activities, analogies, and comparisons to teach electrochemical cells; conversely, "less teacher-centered instruction enriched with implicit nature of science (NOS) and Science- Technology-Society-Environment (STSE)" was found in the study to teach nuclear reactions that were defined as teaching was more student-centered however still including lecturing less and based upon more relation to students daily life and NOS and STSE. Moreover, teachers' knowledge of learners varied in teaching two different chemistry topics. That is, teachers were found to have more awareness of students' prior knowledge, difficulties, and misconceptions in the topic of electrochemical cells, rather, they had weak awareness of these aspects in the topic of nuclear reactions. Participant teachers were found to have a didactic approach to teaching chemistry to 11th graders. On the other hand, they seemed to not hold a teacher-centered approach totally, their enacted

and believed PCK differed certainly. In fact, they found it to have a purpose to teach chemistry concepts relating to students' daily lives. Regarding knowledge of curriculum components, teachers indicated varied integration of vertical and horizontal relations between two chemistry topics. That is, teachers revealed highly integrated knowledge in terms of the electrochemical cells topic that they could indicate the objectives and vertical and horizontal relations. On the other hand, teachers were found to have limited knowledge of the curriculum on the topic of nuclear reactions they seemed to have few connections although they had proper knowledge of the purpose and objectives of the topic. On the contrary, among the components of PCK, teachers' knowledge of assessment was found to not be topic-specific. They used various assessment methods for each chemistry topic that seemed related to teachers' general PK. The study valued the further research about TSPCK contributing to the PCK components' topic-specific nature that were knowledge of instructional strategies, and knowledge of learners. The study recommended the professional development programs of inservice teachers in a way to develop their topic-specific instructional strategies and assessments.

As above mentioned inservice teachers' PCK on chemistry studies interested in comparing the topic and domain-specific nature of PCK or examining individual PCK components, the others focused on the relationship between those components or the impact of SMK on PCK, the others focused on the development of PCK. The next sections will be focused on the previous research on physics topics.

2.2.5 Studies regarding Preservice Science Teachers' PCK and SMK on Physics

PCK studies in physics seemed to be parallel to the studies conducted with preservice science teachers in other science domains. In general, studies focused on preservice science teachers' PCK components, components' interaction, and progress during

the intervention. For example, in order to explore mathematics (N=17) and biology teachers' (N=3) PCK on physics by providing classroom experience in a general physics course, Benegas and Villagas (2022) carried out an experimental design study using surveys. The participants in the study found simulations and videos to be effective instructional materials to teach physics. They mentioned experiments and daily life applications frequently. Moreover, they put more emphasis on peer instructional activities. However, few of the participants mentioned active learning strategies to teach physics. Participant teachers applied pre- and post-tests to uncover their content knowledge in physics. Finally, preservice teachers were asked to prepare a lesson plan to teach particular physics concepts to 11th graders. After the course, preservice teachers found to gain sound content knowledge regarding physics that was the preconditional for the development of PCK in physics. Preservice gained a sound repertoire and knowledge of active learning strategies in the course, they seemed to improve their personal PCK. The results showed that the post-instruction course performances of the participants were satisfactory. Researchers concluded that pre-service mathematics and biology teachers, not only achieved a satisfactory level of proficiency in physics content knowledge but also appeared to have integrated certain aspects of active learning into their physics Pedagogical Content Knowledge (PCK).

The preservice Malaysian science teachers' PCK components of knowledge of students' understanding and students' understanding and misconceptions in particular physics topics investigated by Halim and Meerah (2002). Twelve preservice science teachers were the participants of the study enrolled in the postgraduate teacher-training course. Teachers were collected data with a written survey including a series of physics questions related to lower school students and interviewed. Survey questions were targeted to elicit students' misconceptions and teachers' awareness of students' common misconceptions. Teachers further prompted with the interview questions further gain their knowledge regarding

students' misconceptions and their explanations about these misconceptions. The findings about teachers' awareness of students' misconceptions showed that teachers seemed to not be aware of the students' misconceptions because students provided the same answers as the preservice science teachers. Besides teachers who were found to be aware of students' misconceptions seemed to neglect these misconceptions. Preservice science teachers were found to have poor content knowledge that influenced their perception of students' understanding. The findings regarding preservice science teachers' knowledge in teaching strategies to overcome misconceptions showed that teachers tended to explain the concepts rather than represent the concepts for students understanding. The researchers offered teacher training focused on the development of PCK in particular content areas. Teachers were found to be supported to improve their content knowledge, knowledge of students understanding and misconceptions, and their repertoire of instructional strategies to overcome students' common misconceptions in particular science topics.

Juhler (2016) designed a time-lagged experiment as a part of a Norwegian research project that was Teachers as Students (TasS) aimed at developing Norwegian teacher education in Mathematics, Norwegian, English as a foreign language, Physical Education and Science. The main purpose of the study is to investigate the connection between preservice teachers' PCK and teaching practice. Two methods of intervention were used in the study. One of these interventions included lesson planning with the Lesson Study (LS) method and the second one was content representations (CoRes) design. LS method used in the study to make explicit the development of preservice teachers PCK. In fact, the LS generated by Fernandez & Yoshida (2004) seemed to be used to develop teachers' PCK with a cyclic process involving goal determination, planning, performing, discussion, and reflection on lesson plans to ensure the revision and development of new plans.

In a year period in the study, participants engaged in field practice with the guidelines of the university in the first year, however, LS and CoRes accompanied field practice in the second year as an intervention. 14 preservice teachers with four mentors were the participants involved in two stages of application of the study. In the first year, participants were expected to plan and practice lesson preparation according to National Curriculum Regulations (Ministry of Education, 2010) called Current State of Practice (CSP) that were functions as a control group. In the second year, the Intervention (INT) was to introduce and practice LS with CoRes consisting of both preservice teachers and mentors. For the first stage of the implementation, preservice teachers collected data for only planning. The recordings of the discussion were the data sources. On the other hand, in the second stage of INT, CoRe forms, lesson plans, and presentations are added to the video recordings. The collected data analyzed through deductive and inductive methods revealed that CSP group preservice teachers focused on curriculum and instructional strategies underestimated knowledge of students' understanding and assessment during their lesson plan preparation. Conversely, the INT group indicated harmony in integrating four groups of PCK components putting more importance on knowledge of students' understanding and assessment in their lesson plans. In fact, the INT group found better structure connections between lesson planning and practicing in the components of PCK. The intervention in the study seemed to provide preservice teachers to concentrate on the elements of lesson planning in equal in reference to PCK components. Therefore, the research highly recommended further studies on preservice teachers' development of PCK targeted to investigate their knowledge connections between theory and practice.

In the follow-up research under the umbrella of the Norwegian research project Teachers as Students, (TasS), Juhler (2018) explored the preservice teachers' PCK with similar extended purposes of the previous research that was solving teachers' knowledge gap between theory and practice with the help of content representations

(CoRe) and Lesson Study (LS). Juhler designed the study to investigate whether the development of preservice teachers' PCK resulted in a strong connection between theory and practice by using deliberative reflections on practice at the same time application of Lesson Study and CoRes. Juhler explained that in the study deliberative reflections on practice corresponded to knowledge, belief, and practices with higher-order thinking inspiring teaching practices to improve students' learning. As the previous research design, Juhler designed time-lagged research with two groups of preservice physics teachers one of the groups consisted of three and the other group was four teachers. Research took two years. In the initial year, both groups practiced 'current state of practice' in line with the National Curriculum Regulations (Ministry of National Education, 2010). The second year of the study was dedicated to introducing intervention consisting of LS accompanied by CoRe construction. The second-year intervention was conducted with different newly introduced preservice teachers in two groups; one group included three and the other included four preservice teachers in addition to two new mentors. The discussions, reflections, and teaching performances were video-recorded and transcribed for analysis in addition to that CoRe documents with lesson plans were the data sources. Deductive content analysis elaborated on Gess-Newsome and Lederman's PCK model (1999, p. 99) showed that although the initial focus of both the current state of practice and intervention groups was instructional strategies for physics, groups focus was shifted towards mostly assessment for physics and also knowledge of students' understanding. For the intervention group, it was explained the influence of LS and CoRe experiences of preservice teachers. In fact, in the planning stage of LS, knowledge of students' understanding gained immersed focus. During the reflective stage, preservice teachers mostly focused on goals for teaching, students' understanding, representations, and assessment techniques for the content. These reflections enabled preservice teachers to make connections between content knowledge, pedagogical competence, and teaching practice. All these findings

concluded with a positive impact on preservice teachers' development of PCK components in teaching physics. The researcher suggested further studies conducted with preservice physics teachers fostering the cycle of learning consisting of planning, practicing, and reflecting.

Relatively few studies conducted to investigate preservice teachers' PCK in physics topics. One of these studies was conducted by Sorge, Kröger, Peterson, and Neuman (2019) with 200 preservice physics teachers enrolled in teacher education at different universities in Germany. The purpose of the study identified is to explore preservice physics teachers' content, pedagogical and pedagogical content knowledge, to put forward the relations of these knowledge bases that differ across different stages of teacher education, and to reveal influential factors of each component in professional knowledge. After the development of an instrument to assess preservice physics teachers' CK and TSPK [Topic Specific Professional Knowledge is defined as the basis for the development of personal PCK and PCK/skills known as the 'PCK for teachers' (Sorge et al., 2019)], the instrument pilot tested, ensured expert review and to validate the instrument items guided interviews conducted. To find out the PK of the participants, the instrument developed by Hohenstein et al. (2017) was used. The final version of the instrument included 59 items for CK, 39 items for TSPK, and 67 items for PK. Researchers also carried out classroom observations and provided preservice teachers with teaching experience. The instrument covering all of the aspects of CK, PK, and TSPK revealed the results that CK, PK, and TSPK are the distinctive components. A significant high correlation between preservice physics teachers' CK and TSPK and PK and TSPK was found. The researchers found that preservice physics teachers depended on their responses regarding TSPK at the beginning of the teacher education to general PK. Teachers' responses shifted to CK when they gained further formal learning opportunities. Classroom observations and reflection on teaching practices were the recommendations for preservice teacher training based on the findings of the study regarding CK, PK, and TSPK. In fact, the

study suggested implications for the relation of preservice physics teachers' CK, PK, and TSPK through significant evidence.

Another research was conducted by Schiering, Sorge, Keller, and Neuman (2022) to investigate the proficiency level of preservice physics teachers' PCK in the light of teacher education. Pointing out the importance of CK, teachers' beliefs, and experience in PCK development, researchers designed research in two stages. One of which was "Measuring the professional knowledge of pre-service mathematics and science teachers", KiL (German acronym of the study) for preservice teachers' professional knowledge, and the other one was "The development of professional competence in pre-service mathematics and science teacher education", KeiLa (German acronym of the study) for preservice teachers' professional knowledge development over 4 years period of time in teacher education. Participants were from 12 universities in Germany a total number of 200 for the first study. The second study was conducted with 122 participants from 20 universities in Germany. Comparable samples' data was analyzed with a two-sample Kolmogorov–Smirnov test resulting in the merging of both samples. The final sample of the study was 200 and 427 observations of preservice physics teachers were done in total. One of the data collection tools was a paper-pencil test prepared in the KiL project with 39 items covering PCK components of Magnusson et al. (1999) PCK model to reveal participants' pPCK. Similarly, to uncover preservice physics teachers CK, a paper-pencil test was developed including 40 items (33 multiple-choice, 4 open-ended, 2 matching, 1 true-false item) in the project KiL. In order to collect preservice physics teachers' experiences and beliefs, they were engaged with 12 items four-point Likert scale. The Kruskal-Wallis test identified a significant difference between the three groups of participants in their pPCK. pPCK level of the participants was found to be significantly correlated to a year of the study. The participants who have more teaching experience in teaching physics appeared to have higher proficiency in pPCK. The findings of the study supported that high proficiency level pPCK required

a sound CK in a particular topic. Different from other research (Mavhunga & Rollnick, 2016), a positive relation between preservice physics teachers' student-centered beliefs and pPCK could be found. This contradiction was explained as a result of either the data collection tool used in the study or the students-centered beliefs of the participants. The implication of the study was that teacher education needs to be amplified with theory-to-practice applications to ensure the improvement of the teaching experience.

A descriptive longitudinal development research was conducted in Türkiye to find out PCK development of preservice physics teachers in electricity and magnetism (Karal & Alev, 2016). The researchers investigated the factors influential factors in preservice physics teachers' PCK development in the period during which the research was conducted. The participants of the study were 13 preservice physics teachers and further study was conducted with selected 8 of the participants. Three semesters in a teacher training program where participants enrolled in methodology lessons was the period of the longitudinal research. Multiple sources of data were collected to explicate preservice physics teachers' PCK which were PCK tests consisting of open-ended questions, classroom observations, lesson plans, and interviews. In order to gain the influence of the teacher-training program, the PCK test including 15 questions regarding PCK components implemented four times during the study. As the theoretical framework of Magnusson et al. (1999) PCK model, the collected data was analyzed inductively and deductively. Regarding subject matter knowledge, participant teachers were found to have misconceptions and indicated their poor knowledge of the magnetic effects of electric current. Teachers found to mention several instructional strategies to teach electricity and magnetism some of which were explanations, demonstrations, experimentations, illustrations, simulations, and analogies highly mentioned in lesson plans, and classroom observations. Magnusson, Krajcik, and Borko (1999) suggested nine categories of teachers' orientations, the findings of the research from lessons and

classroom observations demonstrated teachers held mainly didactic, academic rigor, drill, and practice; besides few of the participants were found to demonstrate activity-driven, inquiry and conceptual change. PCK test revealed that some of the preservice physics teachers were not aware of the student's learning difficulties; some of them focused on content-specific learning difficulties. The overall findings of the longitudinal research showed the development of PCK components not as a whole but separately throughout the period of experiences in teacher training. The necessity of SMK courses, methods courses, and teaching experience is stressed in the study for preservice physics teachers' development of PCK components. The influence of teaching experience especially providing preservice teachers opportunities to understand their teaching on a certain concept and enable them to practice and to make reflections to improve their PCK.

In Türkiye, Akdeniz ve Gürçay (2018) also studied service physics teachers' PCK to explore the influence of Content Representations (CoRes) construction and peer reflections. The PCK components of 16 third-year service physics teachers were to be explored in the concepts of heat and temperature by using Magnusson et al. PCK model (1999) as the theoretical framework. The case study was conducted in a classroom measurement and evaluation course for preservice physics teachers. To gain a deep understanding of preservice physics teachers' PCK components, researchers developed 18 questions to ask the participants. Participants were also asked prompting questions regarding their CoRe designs and the reflections of the participants. The result of the intervention revealed preservice physics teachers improved their PCK components. That is, preservice physics teachers, were found to enhance their knowledge of students' understanding, knowledge of instructional strategies, and knowledge of assessment and changed their belief and goals to teach heat and temperature concepts after they were involved in interventions. Preservice physics teachers seemed to be more aware of the student's prior knowledge, learning difficulties, and misconceptions about teaching heat and temperature. They were

detected to indicate plenty of instructional strategies and assessment methods regarding the concepts of heat and temperature. The study pointed out the importance of CoRes construction to detect preservice teachers' instructional and assessment strategies by revealing teachers' planning, documenting, and presenting a particular concept to students, and also the interviews to elaborate on preservice teachers' beliefs in teaching heat and temperature.

In this section, previous research regarding preservice science teachers in the context of physics topics was reviewed. In a general sense, some research focuses on PCK components of preservice science teachers either separately or with their interactions. Some explored PCK growth, while others analyzed the influence of teachers' PCK on student performance. The following section was about the studies regarding inservice science teachers' PCK and SMK on physics.

2.2.6 Studies Regarding Inservice Science Teachers' PCK and SMK on Physics

In this section, the previous studies regarding PCK of inservice science teachers on physics were reviewed. Studies supported the idea that experienced science teachers' knowledge and beliefs about science, subject matter, teaching, and learning are integrated in consistency which teaching practice shows coherency with this framework (Brickhouse, 1990; Van Driel, Beijaard & Verloop, 2001). Lack of instructional experiences of novice or prospective science teachers results in conflict between their actual teaching practice and their personal beliefs (Brickhouse & Bodner, 1992; Powell, 1994; Van Driel, Beijaard & Verloop, 2001). For instance, in a longitudinal study, Angell, Ryder, and Scott (2005) compared pedagogical content knowledge of novice and experienced physics teachers' first three years of teaching experience. A study was conducted with forty-one trainee physics teachers in six universities in the UK and with sixteen expert physics teachers having at least three

years of teaching experience. The questionnaire included eight items related to both content and pedagogical issues in the context of physics. Also, classroom observations and interviews following classroom observations were actualized as well. For the data analysis, the Mann-Whitney U test was used. According to the analysis, they found little difference between novice and experienced physics teachers' content knowledge; however, experts reported extensive pedagogical skills to form a rich learning environment and make necessary knowledge connections between different contexts. In other words, the critical difference between novice and experienced physics teachers was reported as their pedagogic reasoning rather than conceptual understanding of the content. Expert teachers listed with possession of a range of knowledge such as the logical sequence in their responses pedagogically, addressing children's everyday thinking, suggesting appropriate class activities and discussions, analogies, and supporting children's thought explicitly. Expert teachers were able to connect their knowledge domains in different contexts. However, novice physics teachers were reported as having a tendency to transmission content knowledge with separate bodies of knowledge and less focused on pedagogical considerations. It was suggested that novice physics teachers' demands on the development of their pedagogical reasoning abilities should be addressed with necessary teacher training programs.

Another PCK study was conducted to investigate the differences and similarities between reported and enacted PCK of inservice physics teachers Mazibe, Coetzee, and Gaigher (2018). Teachers reported PCK counted as collected data through Content Representation (CoRe) and enacted PCK as teachers' teaching practices of graphs of motion. The PCK of teachers was investigated in the light of the TSPCK model proposed by Mavhunga and Rollnick (2013) to gain detailed information about teachers' TSPCK on the topic of graphs of motion. A case study was designed and multiple sources of data were collected for this purpose. The data collection tools were CoRe designs, interviews, and classroom observations. Analyzing the data with

the help of the prepared rubrics for reported PCK and enacted PCK according to Mavhunga and Rollnick's (2013) TSPCK rubric. The findings of the teachers revealed that teachers enacted PCK was lower than reported PCK. Participant teachers could put into practice their knowledge of some of the components. For example, most of the participants seemed to be able to integrate their knowledge of conceptual teaching strategies components into their teaching practice. However, the curricular saliency component was reported to lower both in reported and enacted PCK of participants. The overall findings revealed teachers reported PCK was higher than enacted PCK which implies teachers had difficulties in integrating their knowledge into teaching practice. The possible reason for teachers' lower enacted PCK was indicated as their lack of CK in the topic they taught. From the findings of the study, teachers were recommended to improve their CK and PCK not only in knowledge level but also in enact.

Another study to discover PCK of an inservice high school physics teacher designed in a physics teacher training intervention program in Colombia (Melo, Cañada-Cañada, González-Gómez and Jeong, 2020). During the intervention process, the physics teacher's first year of teaching physics enrolled in the study by providing data sources of an open-ended questionnaire, semi-structured interviews, lesson plans, CoRe, and field notes. Magnusson et al. (1999) PCK model components were the theoretical framework to analyze teacher's PCK. The findings of the study revealed that PCK components develop separately and in the same direction. Moreover, Melo et al. found that each teacher had a personal PCK profile that could be constructed differently. In the intervention program, physics teachers were found to improve their confidence in teaching particular topics in physics revised their teaching approach generated new ways of didactic representations. The implications of the study mainly for intervention programs focused on teachers' knowledge of evaluation and teaching practice.

One of the studies conducted in Türkiye by Çoruhlu and Çepni (2010) who have explored the influence of inservice training course programs on teachers' PCK component of knowledge of assessment and attitudes. Six science and technology teachers were the participants in the case study. Achievement tests, an attitude survey, and a semi-structured interview were the data collection tools. Inservice training course had a design based on a system approach that included five stages of analysis, design, practice, and evaluation. Achievement test and attitude survey were analyzed quantitatively through Wilcoxon signed rank test for achievement test and Pearson correlation test was used to analyse attitude survey. In light of the collected data, teachers were found to have deficient knowledge of alternative assessment methods before the training program. Moreover, teachers' achievement test results showed significant differences between pre-and post-test. This could be concluded that the training program had a positive impact on participant teachers' PCK. In fact, attitude test results of pre-and post-tests indicated teachers' improved change in their attitudes. The study's findings stressed teachers' need for the development of PCK and knowledge of assessment with sufficient inservice training programs.

2.3 Studies Conducted Regarding Students' Understanding of Ecology

Besides focusing on students' conceptions researchers are interested in science teachers' conceptions of ecology. Since when science teachers have deep subject matter knowledge, they become more aware of students' conceptions and misconceptions (Park & Oliver, 2008; Käpylä, et al. 2009). Understanding the relationships between common ecological concepts, teachers will be more effective in guiding their students in developing their own understandings of these concepts (Buethe & Smallwood, 1987; Fulp, 2002; Gayford, 1998; Moseley et al., 2003; Mosothwane, 2002; Summers, et al., 2000). Ecology is an important interdisciplinary subject in which students should be literate in basic ecological concepts and

principles in order to understand how events occur in the world and manage environmental resources properly. But studies reported students' possession of naïve conceptions and experiencing difficulties in understanding ecological concepts and principles (Adeniyi, 1985; Aubusson, 2002; DeBoer, Quellmalz, Davenport, Timms, Herrmann-Abell, Buckley, Jordan, Huang & Flanagan, 2014; Çetin, Ertepinar & Geban, 2015; Eilam, 2002; Gallegos et al., 1994; Griffiths & Grant, 1985; Hogan, 2000; Manzanal et al., 1999; Munson, 1994; Musheno & Lawson, 1999; Opitz, Harms, Neuman, Kowalzik & Frank, 2014; Özay & Öztaş, 2003; Özkan, Tekkaya, Geban, 2004; Preston, 2018; Reiner & Eilam, 2001; Soylu, 2006; Webb & Bolt, 1990; Wernecke, Schütte, Schwanewedel & Harms, 2018). Therefore, it is also important to understand the students' understanding of ecological concepts and principles reported in the related literature to inform science teachers about students' possible learning difficulties and misconceptions regarding ecology.

Working with two hundred thirty-two Nigerian secondary school students, Adeniyi (1985) determined misconceptions of students in the basic ecological concepts of the ecosystem. Students were initially assessed through essay tests and further clinical interviews following instruction. Results showed that students held misconceptions about basic ecological concepts. For example, most of the students defined ecosystem, community, and population in an incorrect or conflicting manner. Some students, for example, equated ecosystem with habitat, biotic community with population, and biotic community with ecosystem. Most of the students gave conflicting answers when asked about the concept of producers. For instance, they once responded that only producers are plants because they can make their own food, later they stated that butterflies serve as food for bigger animals. Most of the students were also found to have a poor understanding of the aquatic environment. They thought that in water there are no producers. So, they did not include producers in the food chain of the aquatic environment. Another widespread belief among students was that the base of the energy pyramid is wider than the apex because of

the plants' being food for herbivores. In addition, they also thought that carnivores are more powerful than herbivores which they feed on. The students also believed that decomposers are at the top of the energy pyramid.

Likewise, Webb and Boltt (1990) examined the abilities of a hundred eight final year high school and fifty-four first-year zoology university students' explanations of relationships in the food web using a sample food web. Data was collected by asking open-ended questions related to the prepared food web with probing students' answers. Results of the study indicated that both secondary and university-level students differed in their responses to food web questions. No significant difference, however, was found between correct answers related to questions effects transmitted along more than one route questions. Misconceptions of students reported related to the proximity of populations in the food web. For example, students gave the answers to the questions based on population with distance like 'there is no effect as the populations are too far apart', 'not much effect as the chains are spread out', and 'nothing happens as they aren't really linked at all' (p. 189).

Munson (1994) discussed misconceptions about basic ecological concepts. Misconceptions were defined as not being lack of knowledge, factual errors, or incorrect definitions instead of comprehensions constructed by individuals. Twenty important concepts from Cherrett's list as the ecosystem, succession, energy flow, conservation of resources, competition, niche, materials cycling, the community, life history strategies, ecosystem fragility, food web, ecological adaptation, environmental heterogeneity, species diversity, density-dependent regulation, limiting factors, carrying capacity, maximum sustainable yield, population cycles, and predator-prey interaction were explained with their scientific conceptions and common misconceptions. For instance, contrary to the scientific conception of "food/energy relationships must be viewed as a complex web linking the organisms

within an ecosystem”, the common misconception determined as “food webs are interpreted as simple food chains”.

Similarly, Griffiths and Grant (1985) listed several misconceptions held by tenth grade (N = 200) students related with food web. The misconceptions of students related to a change in one population will only affect another population if two populations are directly related as predator and prey in a food web; a population higher on a food chain within a food web is a predator of all populations below; a change in a prey population has no effect on its predator population; 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. However, the majority (%72) of the students could identify multiple routes of transmission effect on a food web. The researchers pointed out the importance of developing the necessary ecological understanding at school in order to prevent persistent misconceptions at university. Also, they indicated that students had difficulty transforming food chain knowledge into food web concepts.

In another study, Reiner and Eilam (2001) examined twenty-eight ninth-grade students’ conceptions of the food chain in relation to their ontological beliefs. They collected data by observing students during twenty-four instructional sessions on ecology in a well-established urban school. Two hands-on activities were administered to enhance students-teacher interaction and students’ collaborative problem-solving. Students were also given pre and post-tests related to the food chain. Classroom discussions took place on the concepts of habitat and ecosystem. Students’ responses were categorized into factors of content and underlying beliefs for ontological beliefs. The results of the study indicated that the students’ food chain beliefs commonly identified as eating events, size hierarchy, and total elimination of the consumed organisms. One of the students mentioned that “a bacterium in our body is part of a food chain because it is eaten, which is like eliminated from the world...” (p. 557). Most of the students thought that a producer must be a complete

plant. Hence nectar was not considered as a producer by students. Moreover, they believed that organisms in food chains should be totally consumed and the consumed organism should be damaged. Students thought that if an element on the food chain becomes extinct, alternative organisms take place of the extinct element, instead of extinction of the beyond elements. Only a few students identified as recognizing the role of the bacterium as a decomposer. Most of the students thought that the food chain is unlimited because of its cyclic nature. For example, one of the students said “I don’t think there is a first or a last element because it’s a cycle, and in a cycle, you can’t have a beginning and an end”. About 20% of the students changed their views towards scientific meanings. Students’ ontological beliefs were listed as ‘food chain describing a hierarchical chain of eating events’, feeding on meaning to physically swallowing’, a food chain based on a size hierarchy’, ‘a consumed element considered as eliminated’ and ‘food chain viewed as a bead chain’.

In a separate study, Eilam (2002) collected data from ninth-grade students (N = 112) in the ninth-grade level. A nine-item questionnaire was administered pre-test and post-test to all students in two experimental groups with a designed learning environment and two control groups with traditional instruction. Video records of two experimental groups were taken. Quantitative data analysis was conducted using analysis of variance (ANOVA) with repeated measures to compare experimental and control groups’ questionnaire results and t-test for pre-test scores compared to post-test scores on each question. Qualitative data analysis was conducted by comparing students’ changes in feeding conceptions. Pre-test findings reported that both groups of students held a poor understanding of basic ecological concepts. Feeding relations were mostly perceived as a unidirectional linear or cyclic interdependency between prey and predator by students. The comparison of pre-test and post-test results indicated that experimental group students improved their understanding more than control group students in especially about interrelations within ecological systems. For example, in the control group, most of the students did not indicate nectar as a

producer. But experimental group students realized the function of sugar in the nectar as energy energy-producing compound produced through photosynthesis. So, they indicated nectar as first element of a food chain. About the basic, concrete concepts of feeding relations, both groups of students enhanced their understanding similarly. Both group students had difficulty in highly abstract, complex interrelations like the role of energy in the ecosystem, considering each organism holding different roles simultaneously. The results of the study supported the active involvement of students in inquiry. Engaging students in an inquiry learning environment facilitated their better understanding of ecological concepts compared with traditional learning environments. Analysis of the students' responses indicated also that some of the learning deficiencies regarding ecology continued even in experimental group students. Authors mentioned that especially related to the transfer of matter and energy in the ecosystem, the connection between biotic components and abiotic components. It is also stated that students did not understand the flow and role of energy in the ecosystem so the food chain length limitation. Apart from this, many students also were not aware of the population recovery and species extinction processes.

To investigate the middle school student's ability to use inquiry skills to understand the ecosystem, DeBoer, Quellmalz, Davenport, Timms, Herrmann-Abell, Buckley, Jordan, Huang, and Flanagan (2014) designed a comparative study to search for the effectiveness of three online testing modalities that were static, active and interactive. Each module provided students with a coherent and applied context for assessment through which one or more introductory screens followed test-item screens with total number of 24 items. The test items aimed to assess students' organisms' roles in the ecosystem, students' understanding food relationships between organisms in ecosystem, the capabilities of students to interpret on graphs, tables, food web, and flow of energy diagrams that illustrate the relationships in the ecosystem and students' ability to design, interpret and evaluate the experiments

related to depict the changes in one population on another population of organisms. The static modality module presented a tundra ecosystem; the active modality module presented a grassland ecosystem; and the interactive modality module presented a lake ecosystem to the participants. Every ecosystem presented included five kinds of organisms either producers or consumers none of the ecosystems include decomposers. The study was designed to consist of 1,836 students from 22 different middle school science teachers in 12 states when they engaged with regular classrooms. The results of the repeated measures ANOVA analysis showed a significant difference between students' performances on active and interactive modalities items. In detail, exploratory factor analysis revealed that %89 of the students answered energy flow diagrams correctly on the static version, %87 of them answered correctly on the active version. % 93 of the participant students were knowledgeable in decomposers, %79 of them knew the roles of the producers, % 90 of the students could identify the producers in the ecosystem. Related to consumers, %88 knew the roles of the consumers. When students were asked to draw an energy flow diagram, %57 of them could be able to draw a correct diagram. In general, students in the study were found to have an understanding of basic ecosystem concepts, organisms' roles, and their interactions in the ecosystem and interpreting graphs related to ecosystem relationships. Students were found to have an insufficient understanding of competition between organisms and experimental design applied related to ecosystem relationships and experimental design tasks.

The energy flow and the interaction of organisms in the ecosystem understanding of the students is the research area, researchers highly focused on. In addition to the previous study, as one of the ecological concepts' students experience difficulty in understanding in interdependency of relationships and energy flow in reading the food web diagram selected as the scope of the study by Preston (2018). Of the 21 participants of the study, 10 of them were 3rd grade (8–9 years old) and 11 of them was 5th grade (10–11 years) students in a government school in Australia.

Qualitative data analysis was used to analyze the collected data from interviews. Data collection was into three steps. First, participants showed a toy object and asked questions to determine their prior knowledge and bring a sense of confidence. Second, students were asked about a sample food web diagram by using the think-aloud method. Lastly, students were shown labeled food web with text naming the organisms. The findings of the study revealed that students had difficulties in reading the food web diagrams. Reading pathway, arrow meaning, repeat exposure, and depth of diagram processing were the assets highlighted from the findings of the study students experienced difficulty in. The implications of the study pointed out the capturing students' prior knowledge, challenging preconceived ideas, and encouraging deep food web diagram processing.

Highly related to most of the ecological concepts and issues, students' conceptual knowledge of energy was studied by Wernecke, Schütte, Schwanewedel, and Harms (2018). To increase students' comprehension of energy concepts, depictive representation and incorporation of errors are used as the method in the intervention process. Experimental research design with three different experiment groups applied to pre-and post-tests. The conceptual understanding of students tested through an 18-item test consisted of 8 multiple-choice items for assessing students' general understanding of energy and 10 items including 8 multiple-choice and 2 open-ended ones for assessing students' understanding of energy flow. Experimental groups received different learning material in which engaged with the correct diagram representing energy flow through a forest ecosystem; one group engaged with encircled error; the other was engaged with the same error rather not encircled. Two popular misconceptions among students and teachers were "plants get their food or energy from the soil" and "energy cycles in an ecosystem" inserted in the biological energy flow diagram. The diagram included realistic drawing of organisms, transfer of energy, trophic levels and labels levels and contains labels. The participants were 9th grade with a total number of 304 students in Germany. The

pre-test results were found not to have a significant difference between three groups ($F(2, 286) = 0.69, p = 0.500$). Students who gained the highest success were the ones who had accurate prior knowledge that students' prior knowledge is a crucial necessity to knowledge construction. On the contrary, students with low prior knowledge also improved their knowledge. This result approved the success of the study's learning from errors and depictive representations approach for students with low prior knowledge and high prior knowledge. In fact, results of the study indicated that students learnt from constructed errors more compared to serving the correct knowledge.

The energy conception of students in different discipline areas through student-generated analogies was also explored by Lancor (2012). The purpose of the study was to investigate students' understanding of energy by writing analogies in different contexts. The different contexts provided to students to explain their energy conception were ecosystems, chemical reactions, mechanical systems, and circuits. Students' analogies analysis with the help of metaphor theory. The analyzed students' conceptual metaphors showed that students' understanding of the energy concept is particularly dependent upon context. The participant of the study were undergraduate introductory courses in physics, chemistry, and biology students at two US institutions. An instrument was developed for the study based on the Bulgren et al. (2000) Anchoring Table used to map students' analogies modified with respect to the target of the study. The instrument was field tested twice once with a group of preservice science teachers taking secondary science teaching methods course and a group of students taking the introductory physics course. Through this instrument, participant biology students ($n=49$) were asked to write an analogy about energy in ecosystems; chemistry students ($n=36$) were asked to write an analogy about energy in chemical reactions; first-semester physics students ($n=65$) were asked to write an analogy about mechanical systems; second-semester physics students ($n=44$) asked to write an analogy about electrical circuits. Students were asked prompting

questions related to their analogies and classroom were observed. %26 of the analogies were found related to energy flow in the context of ecosystems; around %80 of the students wrote energy transfer in ecosystems; energy loss analogies were provided all about the ecosystem. The findings of the study indicated that students conceptualize energy concept differently in different contexts in which students generated a different set of characteristics of energy in different disciplines.

Another study was carried out in the scope of understanding the development of students' energy comprehension (Opitz, Harms, Neuman, Kowalzik, and Frank, 2014). The study designed to explore the progression of students' understanding of energy concepts in a biological context when they transitioned from elementary to secondary school. Cross-sectional study was conducted by using multiple choice items for grades 3-6 with a total number of 540 students. One-way ANOVA analysis for test results differences revealed a significant increase in both pre-and post-tests. That is, students were found to have progression in their energy understanding in a biological context. The study further implies that students' energy comprehension needs to be supported at an early age with proper learning facilities in a multidisciplinary approach.

There were also conducted researches in Türkiye to investigate students' ecology understanding. One of these researches was conducted by Tekkaya, Özkan, and Sungur (2001). They studied with high school students (N = 368) to find out students perceived difficult contents in biology and also interviewed with biology teachers about students' experiences difficulty in biology concepts. With the prepared instrument, students were asked about their perceived difficulty in biological concepts. According to descriptive statistics, frequencies of given responses to biology concepts were determined according to difficulty level as difficult, moderate, and easy. The interviews with biology teachers indicated mitosis and meiosis, photosynthesis and respiration are the biological concepts most of the

students perceived as difficult. Science teachers responded that students perceive ecology as the easiest concept in biology because of its daily life relatedness. Students reasoned their perception of ecology as an easy content that they studied ecology concepts from starting schooling and also ecology was generally introduced with different teaching methods such as analogies, and demonstrations. Although science teachers' interview responses pointed out students' difficulty in the concepts of photosynthesis and respiration which are more related concepts to ecology, %82 of the students' given responses did not mention these concepts as difficult. Researchers interpreted this conflict between teachers as students' responses as rote learning of the definitions and chemical formulas and students most probably did not understand the underlying meanings of the concepts. However, Tekkaya, et al. (2001) pointed out that in general teachers' interview responses to students' difficulties and students' responses on their perceived difficulty with thirty biological concepts were parallel to each other. That is, science teachers were mostly aware of students' difficulties.

Students' comprehension in photosynthesis, respiration, carbon cycle, and plants' nutrition was aimed to be explored in 9th-grade secondary school level students by Özay and Öztaş (2003). Multiple data collection tools were used to collect various sources of data from participants to gain deep insight. For example, multiple-choice tests, and written tests with open-ended questions. The total participants of the study were 88 students in 9th grade level. The results of the applied questionnaire revealed that few of the students knew the importance of photosynthesis although they had the comprehension on plants produces oxygen. Even though most of the students were found to have a weak understanding of the photosynthesis mechanism. Students found to have misconception regarding plants get their nutrient apart from producing through photosynthesis. Students were found to have difficulties understanding the necessary materials for photosynthesis and the reason for their necessity in producing food. The researchers suggested further studies related to students' misconceptions

that are stable and hardly recovered and there is a need to change teaching biology concepts enabling students effective learning.

In another experimental study by Özkan et al. (2004) identified fifty-eight seventh-grade Turkish students' conceptual changes in the light of conceptual change text-oriented instruction. The interviews related to basic ecological concepts were conducted at the beginning of the study. With the light of student interviews, Özkan et al. reported several misconceptions on ecological concepts such as population, every organism has its own energy, energy does not pass from one organism to another and man has more energy than plants. Some of the students also indicated that decomposers found on dead animals and some of them did not place decomposers on the energy pyramid because being too small. A two-tiered multiple choice ecological understanding test administered to both control and experimental group students at the beginning and at the end of the treatment. Analysis revealed that there is a significant difference between control and experimental groups in which experimental group indicated better performance than the control group according to independent t-test results. That is, the experimental group engaged in conceptual-change text-oriented instruction indicated better improvement than the control group enrolled with traditional instruction. Before the treatment average percent of correct answers of both groups were nearby. For instance, %31.9 of the experimental and %32.7 of the control group students selected appropriate combination. After the treatment, it was indicated that the experimental group performed better. For example, after the treatment, the students selected the appropriate combination in the control group %43.3, and in the experimental group %82.1. Although common misconceptions were reported both in experimental and control group students before the treatment, there were no misconceptions detected after the treatment in the experimental group. That is, conceptual-change-text oriented instruction was found to be effective to address students' misconceptions through determining their reason behind their unscientific conceptions. Özkan et al.

suggested that conceptual change text-oriented instruction was better able to address students' misconceptions.

Soylu (2006) examined eighth-grade Turkish students' misconceptions about ecology. The data was collected from six hundred students in Tosya, the biggest district in Kastamonu, through interviews, the Test of Ecology Concepts, the Attitude Scale towards Science, and the Test of Logical Thinking. It was found that students held several misconceptions related to basic ecology concepts similar to those reported by a previous study by Özkan et al. (2004) for seventh-grade students. The most common misconceptions detected were related to the primary consumers. Students thought that among the organisms of lion, rabbit, and man, man is the primary consumer because of eats everything. They also thought that energy is adding up through the food chain, so man possesses huge energy because of eating both plants and animals. Role of the decomposers were not clear in the students' minds. According to students, decomposers eat dead organisms and clear the environment. Students believed that a change in one population would only affect another population if two populations were directly related as predator and prey in a food web. The directions of the arrows in the food web were asked, and the given answers were mostly arrows' representation of prey and predator relation. When students were asked to draw a food chain, some of them indicated the food chain as cyclic; they thought that nectar could not be produced because of is part of a plant. Some students neither could nor draw the energy pyramid correctly and some of them put decomposers at the top of the energy pyramid. The overall findings of the study were that %36.2 of the students lack understanding and %43.1 of the students have misconceptions.

To explore the influence of Çetin, Ertepinar, and Geban (2015) carried out a quasi-experimental study to investigate the influence of conceptual change text-based instruction on 9th grade students. The purpose of the study was to understand

students' ecological concepts and also students' attitudes toward biology and environmental issues. During the five-week course period, participant students engaged in the Ecology Concepts Test (ECT), Attitude Scale towards Biology (ASB), Attitude Scale towards Environment (ASE), classroom observations and interviews. ECT was applied to both experimental (conceptual change text-based instruction applied) and control groups (traditional instruction applied) as pre-ECT and post-ECT tests to gain the effectiveness of conceptual change text-based instruction on students' understanding and to detect students' levels of understanding and possible misconceptions. ASB was a 5-point Likert-type scale consisting of 15 items applied to determine students' attitudes towards biology. Similarly, ASE was a 5-point Likert-type scale consisting of 22 items applied to determine students' attitudes towards ecology. The participants were two teachers and 82 students of four biology classes in the same high school in Türkiye. Before treatment both experimental and control groups replied to pre-ECT and independent t-test results showed no significant difference between the two groups. However, there was found significant increase between pre-ECT and post-ECT scores of the experimental group. Similarly, the control group's post-ECT score was found to get higher compared to pre-ECT; however, the increase was not as much as the experimental group. Students' misconceptions were decreased after treatment in both groups which was higher amount in the experimental group. Moreover, there was found a slight increase in mean score of the ASB and the ASE of the both groups of students. The positive influence of conceptual change text-based instruction on students' understanding and misconceptions was the studies' outstanding findings. However, students' attitudes did not find to change towards biology and the environment accordingly. In fact, researchers indicated there needed long time to see the changes in attitudes.

Ahi and Balçı (2018) studied with either 5- or 4-year-old kindergarten students to investigate their knowledge level on the concepts of forest and deforestation.

Phenomenological research and a modified analytical induction approach were the methods used in the study to gain a deep understanding of the participants. The data was collected through interviews with 29 kindergarten students. Students were interviewed individually and provided with related photographs and followed the related questions. Children's knowledge of concepts was defined in the analysis as “elaboration scores” and each scientifically correct answer from participants counted as one point and wrong answers as zero points. With the elaboration scores of the participants, researchers constructed concept maps. A descriptive analysis of the collected data revealed that sixteen of the students could define the forest. On the other hand, most of these defining children stated that only animals live in the forest apart from two children stated animals and plants live inside the forest. Researchers also conducted the chi-square test for independence for understanding the correlation between students’ age and gender, and elaboration scores on the concept of forest. The result of the test showed that there was no significant correlation. The implication of the study was related to children’s need to engage them with the concepts of forest and deforestation in preschool years by providing field trips enabling students with direct experience in the environment.

The common conclusion of the above studies revealed students possession of plenty of misconceptions and a poor understanding of ecological concepts. As the teachers are the facilitators of students’ understanding of ecology, it is important to explore teachers’ SMK and PCK on ecology. In fact, as there were several studies to unveil science teachers’ PCK in particular science domains presented in the previous sections, there is still a need to investigate expert and novice science teachers’ SMK on ecology and compare PCK in teaching ecology.

CHAPTER 3

METHODOLOJI

In this study, expert and novice science teachers are key issues to compare their PCK regarding teaching ecology. In this chapter, the design of the study, selection of participants, participants of the study, data collection procedure, data analysis procedure, trustworthiness, ethical considerations, limitations, and assumptions of the study are presented.

3.1 Design of the Study

Qualitative research methodologies were used to gain extended insight into expert and novice science teachers' pedagogical content knowledge on ecology. The qualitative approach emphasizes gaining insight into the meanings of individuals have created, their understanding of the world, and their experiences within it (Meriam, 1998). Qualitative research methodologies focus on the process and rely on detailed descriptions, words, and visuals rather than numerical data (Bogdan & Biklen, 2007; Fraenkel et al., 2012; Meriam, 1998). As pedagogical content knowledge is a tacit, internal construct in teachers' minds (Kagan, 1990; Kind, 2009b), thick descriptions of participant novice and expert science teachers' knowledge components were required in this study to compare this essential PCK components of expert and novice science teachers within certain boundaries specified with research questions and utilized theoretical framework. Therefore, in this study, a qualitative approach was employed to compare the SMK and PCK of participating novice and expert science teachers in the context of teaching ecology.

There are several qualitative approaches (Creswell, 2007); however, this study had identifiable cases with boundaries, which were expert and novice science teachers and sought to be investigated in depth and to be compared (Patton, 1987). Because Merriam and Tisdell (2016, p. 37) described a case study as “an in-depth description and analysis of a bounded system”, in order to capture sound information about the cases, extended and multiple sources of data were needed to be collected. With these multiple sources, detailed information about the cases emerged. When handling this detailed information, the main focus was understanding the issues within cases and comparing them with each other without generalizing beyond the participant cases instead of within their boundaries (Merriam, 2009), as these were all main characteristics of the case study (Creswell, 2007; Stake, 1995). Additionally, each case of the study served its individual characteristics, description, and explanation within the scope of the study. The approach of this current study was a multiple case study. Merriam (2009) outlined the method for conducting multiple case studies, which involves initially analyzing individual single cases, comparing their similarities and differences, and then providing a detailed presentation of the findings were also valid for this study.

The qualitative research employed a case study strategy, as outlined in this study. According to Merriam (2009), a case can encompass an individual, program, institution, or even an entire community. Case studies offer a focused perspective on specific situations, events, or programs, highlighting their unique aspects. Furthermore, case studies are marked by their descriptive nature, presenting in-depth insights (Merriam, 2009). Various types of qualitative case studies exist (Merriam, 2009). In the context of the present study, employing multiple case studies was deemed appropriate. As Stake (2010) elucidates, individual cases may share common characteristics, and each case can exemplify a phenomenon. Thus, utilizing multiple case studies introduces greater variation to the research, thereby enhancing external validity, a point also asserted by Merriam (2009).

There are some disadvantages to conducting a multiple case study (Meriam, 2009). One of which is multiple cases are harder than a single case to investigate; second, collecting detailed information about the cases could be more time-consuming and require more effort and money; third, the researcher needs to be more sensitive and integrated into the data collection and analysis to prevent possible bias regarding ethics, reliability, validity issues (Meriam, 2009). Indeed, there is no guideline for researchers in conducting case studies and reporting the findings (Meriam, 2009). The researcher conducting multiple case studies is an important part of the research, and the role of the researcher in this study is explained in the following sections.

The overall design of the study is illustrated in the Figure 3.1.

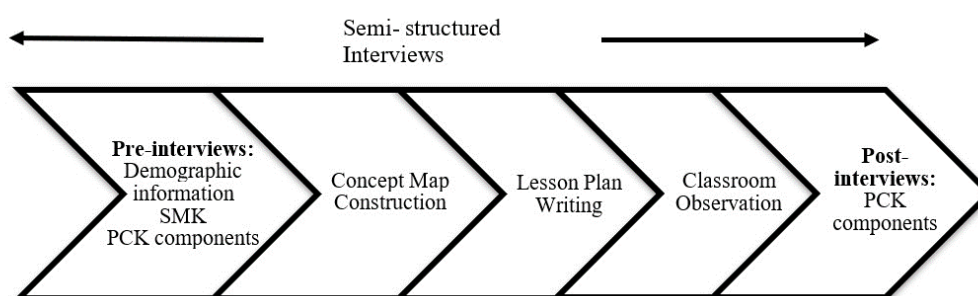


Figure 3.1 The Representation of The Design of The Study

Ecology in 8th grade was selected in order to investigate and compare novice and expert science teachers' PCK regarding teaching ecology. The 8th-grade level was selected to compare novice and expert science teachers because of the reason that the developed science curriculum in 2004 by MoNE in Türkiye was based on spiral curriculum formation in which the learners build progressively on their understanding of concepts. Therefore, at the 8th-grade level, teachers were supposed to cover all of the concepts and issues building upon the previous ones. Therefore, they expected to start teaching each unit by reviewing the basic concepts learned in previous grade levels and introducing new concepts and principles. In this way, the

researcher planned to gain deep information about their PCK in teaching ecological concepts and principles at the 8th grade level in the light of determined curricular goals in Türkiye (MoNE, 2004).

3.2 Selection of Participants

Expert and novice science teachers were selected by using purposeful sampling in order to gain extended insight into their SMK and PCK (LeCompte & Preissle, 1993; Patton, 2002). During the selection of expert and novice science teachers, criterion sampling as one of the types of purposeful sampling is also considered. Time, money, location, availability of participants, and effort of the researcher were also taken into account (Meriam, 2009). Taking into consideration the criterion of their science teaching years as being more than five years or less than ten years, the novice and expert science teachers of the study determined (Akerson, 2005; Arzi & White, 2008; Berliner, 2004; Borg et al., 2014; Gathbonton 2008; Turner, 1995).

Moreover, novice and expert science were selected from science teachers from public schools with similar contextual characteristics. Expert science teachers were from different public schools in Ankara (the capital city of Türkiye), and novice science teachers were also from different public schools in Bursa (the metropolitan city northwest of Türkiye). All of the teachers' school facilities, demographic information of students, and the number of students in the classrooms were highly similar to each other. Novice and expert science teachers in the current study were selected with the criteria that they teach 8th-grade students ecology units.

3.3 Participants of the Study

The participants in this study were four science teachers with teaching experiences ranging from 1 to 28 years. Two of them were experts, and two of them were novice

science teachers. In the present study, science teachers were classified as expert teachers if they have more than five years of experience in teaching (Akerson, 2005; Arzi & White, 2008; Berliner, 2004; Borg et al., 2014; Gatbonton, 2008; Turner, 1995); and as novice science teachers' teaching experience was less than five years.

For convenience and ethical concerns, pseudonyms were given to each of the participants and used throughout the study, in which the same pseudonym was referred to the same teacher. Expert science teachers were given the pseudonyms Expert 1 (E1) and Expert 2 (E2); novice science teachers were given the pseudonyms Novice 1 (N1) and Novice 2 (N2).

Both expert and novice teachers taught ecology units to 8th-grade students. The schools' facilities were almost similar to all public schools in Türkiye. For example, all of the expert and novice science teachers' schools possess science laboratories with the necessary equipment inside them; they had teachers' guidebooks that they could follow the science units with the related objectives, explanations, and suggested activities. There were almost 30 students in all of the participant teachers' classrooms except Novice 2, whose class included twenty-five students in each classroom. Each science teacher indicated that they generally used students' regular classrooms except Expert 2, who conducted his science lesson in the laboratory. Although Novice 2 indicated that she conducted her lessons in regular classrooms, during the study, she used a science laboratory. Therefore, for the study, it could be said that the education environments of Novice 1 and Expert 1 were similar in that seats were arranged according to the traditional arrangement, which was a highly common classroom setting in Türkiye. That is, the classrooms of these teachers were formed in straight rows, each row with a pair of chairs consisting of five to seven chairs. Related literature indicated that the arrangement of the classroom determines instructional communication (McCorskey, McVetta, 1978). Traditional arrangements of classrooms facilitate limited classroom discourse that is a teacher-

to-student, student-to-teacher interaction and minimizes student-student interaction. This kind of arrangement also limits experimentation. Lightening of the classroom of teachers was appropriate. On the other hand, as Expert 1's classroom was narrow, she had limited places to move. Novice 1 had slightly more flexible places in terms of movement during teaching and had a walking area between rows. In Expert 1's classroom, there was a computer with a projector that was working properly. Novice 2's and Expert 2's teaching environment was similar to being a science laboratory, whose arrangement was in modular arrangement during the study. Modular arrangements provide an appropriate learning environment for student-student interaction and increase communication during lessons (McCorskey, McVetta, 1978). According to socioeconomic status, ethnicity, and culture, every participant science teacher of the study shared similar but not the same characteristics in terms of science teaching.

The demographic and background information of science teachers are presented in Table 3.1.

Table 3.1 Demographic Information of Participants

Teachers	Gender	Degree/Degree in	Teaching Experience (year)	School Type	Grades taught
Expert 1	Female	B.S. in science education	28	Public	6,7,8
Expert 2	Male	B.S. in science education	30	Public	6,7,8
Novice 1	Female	B.S. in elementary science education /M.S. in measurement and evaluation in education	1	Public	6,7,8
Novice 2	Female	B. S. in elementary science education /M. S. continuing in educational administration and management	1.5	Public	6,8

3.4 Researcher's Role

Meriam (2009) described the researcher as “the primary instrument of data collection and analysis.” The researcher’s role in the field was being an onlooker observer to the related issues in their natural setting. Before, during, and after data collection, the researcher gave necessary information about data collection procedures and for which purposes these procedures were done to the participant's expert and novice science teachers. The researcher, as an interviewer, posed participant science

teachers a set of pre-established questions related to the purpose of the study. The researcher was the interviewer and was given the pseudonym “I” in the study. During the interview, the researcher did not impose her ideas on the participant science teachers or direct them to give a specific expected answer; on the other hand, the researcher tried to make teachers casual and friendly to get sound information from their responses. Even the researcher did not criticize or judge the participants in their responses. The classroom observations were done overtly and all of the people in the setting were aware of what was being studied (Patton, 2002). Hence, in order not to influence the natural happenings in the classrooms, the researcher was introduced by the teachers as a teacher trainee who conducts educational research, sat backstage in the classrooms, and did not have any interaction with the students and lesson during observations.

3.5 Data Collection Procedure

The qualitative study was a multiple case study in which two experts and two novice science teachers were considered to serve the main scope of the study as to be an expert or a novice science teacher. The participant cases were investigated in-depth by collecting multiple sources within certain boundaries specified with the research questions of the study (Stake, 1995). Selecting two novice and two expert science teachers to replicate the results, either predicting similar or contrasting results also gave confidence in the validity of the results (Miles & Huberman, 1984; Yin, 2003). In order to gain plentiful insight into cases, multiple sources of data collection procedures were followed (Table 3.2) (Yin, 2003). Data collection time lasted from February to May 2010.

To gain insight into what teachers know, what they believe, what they do, and their reasons for this, a combination of data collection approaches was ensured (Baxter & Lederman, 1999). Therefore, multiple data sources were used to compare the PCK

of novice and expert science teachers. Data collection tools were presented with their purposes in Table 3.2.

Table 3.2 Data Collection Tools

Data Collection Tool		Purpose
Semi-structured Interviews	Pre-interview questions	To collect information about demographic information, science teachers' SMK regarding ecology, PCK components (knowledge of curriculum, knowledge of students' understanding, knowledge of instructional strategies and knowledge of assessment) in teaching ecology
	Post-interview questions	To collect information about science teachers' PCK components (knowledge of curriculum, knowledge of students' understanding, knowledge of instructional strategies and knowledge of assessment) and teaching experience in teaching ecology
Teachers' Concept Maps		To gain information about science teachers' SMK regarding ecology
Teachers' Lesson Plan		To gain knowledge about science teachers PCK components (knowledge of curriculum, knowledge of students' understanding, knowledge of instructional strategies and knowledge of assessment) in teaching ecology
Classroom Observation		To gain knowledge about science teachers PCK (knowledge of curriculum, knowledge of students' understanding, knowledge of instructional strategies and knowledge of assessment) components in teaching ecology

3.5.1 Interviews

The interviews were widely acknowledged as the primary source of qualitative data essential for gaining an in-depth understanding in this study to elicit rich, in-depth, and detailed information from novice and expert science teachers SMK regarding ecology and PCK in ecology teaching (Meriam, 2009). Semi-structured interviews were conducted throughout the data collection process. Each interview lasted approximately one hour. Depending on the reflections and answers of the participants, the researcher benefitted from semi-structured interviews with probes or follow-up questions to deepen or elucidate the information (Meriam, 2009). Semi-structured interviews provided flexibility through less structured interview questions comprised mostly pre-determined list of questions (Meriam, 2009). The interviews in this study were divided into two phases which were pre-interviews and post-interviews. Pre-interviews were semi-structured interviews conducted before classroom observations and consisted mainly of questions for participants' demographic information, SMK regarding ecology and PCK components of knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment. Post-interviews were also semi-structured interviews conducted after classroom observations including the questions related to participants' PCK components of knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment. The pre-interviews and post-interviews were explained in the following sub-sections in detail. "I" was used as the pseudonym of the researcher as an interviewer in the reporting of the findings.

The interview protocol (Appendix A) consisted of following questions in subsequent headings;

- i. Demographic information of participant science teachers,

- ii. SMK regarding ecology,
- iii. Components and sub-components of PCK including;
 - a. Knowledge of curriculum;
 - i. Knowledge of goals and objectives
 - ii. Knowledge of materials
 - b. Knowledge of students' understanding;
 - i. Knowledge of requirements for learning science
 - ii. Knowledge of difficulties in science teaching
 - c. Knowledge of instructional strategies;
 - i. Knowledge of subject specific strategies
 - ii. Knowledge of topic specific strategies
 - d. Knowledge of assessment;
 - i. Knowledge of methods of assessment
 - ii. Knowledge of science learning dimensions for assessment

Interviews were conducted in the natural settings of the participants, mostly in their schools. The interview setting was selected from silent, not disturbed by others to ensure better communication with participants and their feeling of confidence and comfortable throughout the interviews. Science teachers were interviewed individually by the researcher which were audiotaped and transcribed verbatim for analysis. The researcher was polite and respectful to the participants and provided

necessary information about the process. After interview schedules, the field notes were taken by the researcher.

3.5.1.1 Pre-interview Questions Regarding Ecology

Starting with obtaining the participants' demographic information, after then, the pre-interview questions proceeded with pre-interview questions regarding ecology. Pre-interview questions regarding ecology were asked by participants to gain their SMK in ecological concepts and issues. There were several main questions and sub-questions to gather participants' SMK regarding ecology. The questions were prepared by the researcher in light of the related literature and the curricular content of the ecology suggested by MoNE (2004). The questions consisted of open-ended questions regarding basic ecological concepts, exemplifications, interpretations of sample cases about the ecological concept or issue, and related drawings such as the food chain, and energy pyramid (see Appendix A).

3.5.1.2 Pre-interview Questions Regarding PCK

Pre-interview questions regarding PCK were aimed at collecting participants' understanding of PCK components in the light of Magnusson et al. (1999) PCK model before classroom observation. The questions were prepared by the researcher based on the related PCK literature (see Appendix A). The questions were related to knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment. Each component is divided into subcomponents in reference to related literature. In this case, knowledge of curriculum questions consisted of questions regarding knowledge of goals and objectives and knowledge of materials; knowledge of students' understanding of science consisted of questions regarding knowledge of

requirements for learning science and knowledge of difficulties in science teaching; knowledge of instructional strategies consisted of questions regarding knowledge of subject-specific strategies and knowledge of topic-specific strategies and knowledge of assessment consisted of questions regarding knowledge of methods of assessments and dimensions of science assessment.

3.5.1.3 Post-interview Questions Regarding PCK

In order to validate the collected data from pre-interviews and classroom observations and to resolve the conflicting findings, post-interview questions regarding PCK components were prepared by the researcher after examination of collected findings from pre-interview and classroom observation regarding participants' PCK. For this reason, each participant's post-interview questions were different from each other (see Appendix G for Novice 1' post-interview PCK questions; Appendix H for Novice 2's post-interview PCK questions; Appendix I for Expert 1's post-interview PCK questions; Appendix J for Expert 2's post-interview PCK questions).

3.5.1.4 Concept Maps

Science teachers' SMK regarding ecology was also collected through concept map construction. Concept map preparation illustrates individuals' conceptual knowledge within a specific content area (Novak, (1991; Novak, J. D., & Musonda, D. (1991). Yin, Vanides, Ruiz-Primo, Ayala & Shavelson, 2005; Wandersee, J. E., Mintzes, J. J. and Novak, J. D. (1998)). Therefore, science teachers were requested to construct a concept map about ecological concepts before pre-interview questions regarding SMK on ecology. Teachers were given freedom to select the ecological concepts to identify in their concept maps and they linked the concepts how they wanted to

represent. The researcher was taking the role of an observer when teachers constructed their concept maps.

3.5.1.5 Lesson Plans

Teachers were asked to prepare a lesson plan regarding the 8th grade ecology unit of science course that they used during their ecology lesson. Since lesson plans of the science teachers in this study were appropriate to gain knowledge about participants' knowledge of instructional strategies, knowledge of curriculum, knowledge of students' understanding of science, and knowledge of assessment regarding teaching ecology.

Lesson plans are essential for understanding science teachers' knowledge of planning and designing an ecology lesson concerning PCK components (Macalalag, 2012). Indeed, a lesson plan provides a comprehensive and thorough account of the learning procedure. Minken, Macalalag, Clarke, Marco-Bujosa, & Rulli (2021) argued that lesson plans disclosing teachers designing and planning of learning was an important aspect of robust PCK. Accordingly, lesson plans revealed teachers' PCK components and how well structured their SMK was that they integrated their SMK to design a well-structured learning in ecology.

The participant teacher provided with a lesson plan template prepared by the researcher. The lesson plan template was prepared according to cover PCK components well enough that teachers observed in real classroom settings. Teachers prepared their lesson plans by themselves and gave them to the researcher before classroom observations. (see Appendix K for Novice 1's lesson plan Turkish version, Appendix L for Novice 1's lesson plan for the English version; see Appendix M for Novice 2's lesson plan Turkish version, Appendix N for Novice 2's lesson plan

English version; see Appendix O for Expert 1's lesson plan Turkish version, Appendix P for Expert 1's lesson plan English version).

3.5.1.6 Classroom Observation

PCK is an implicit construct in teachers' mind that need to be uncovered through several attempts (Abell, 2008). Moreover, teachers had a chance to develop their own unique PCK through teaching practice in a particular topic (Cochran-Smith & Lytle, 1999). Teachers reflect their PCK by planning and practice as well (Cochran-Smith & Lytle, 1999). In the light of teachers preparing lesson plans, teachers observed in their real classroom settings to observe their teaching in ecology. In fact, observations provided engagement with the natural setting of the teachers they could reflect their PCK that the researcher could encounter (Meriam, 2009). The classroom observations were used to triangulate the data obtained from lesson plans and pre-interview questions regarding PCK (Meriam & Tisdell, 2016)

Classroom observations were carried out for two hours by the researcher. The classroom observations were conducted overtly, meaning that everyone in the setting was aware of being studied (Patton, 2002). To ensure that the natural occurrences in the classrooms were not influenced, the researcher was introduced by the teachers as a teacher trainee conducting educational research. The researcher was a complete observer (Merriam, 2009), seated backside of the classroom that did not disturb and interfere with the process of teaching and learning.

Classroom observations were audiotaped with the permission of the teachers and transcribed verbatim for analysis. The field notes were taken and memos were written by researchers about the context of teachers' practices in order to gain extended insight.

3.6 Data Analysis Procedure

Collected data from multiple sources was analyzed qualitatively. The categories and subcategories were established according to the theoretical framework of the study. Therefore, the interview transcripts, concept maps, lesson plans, and classroom observation transcripts are read and coded according to categories. Codes and categories were compared and contrasted between expert and novice science teachers. Checklists, matrixes, memos, and summaries were used to help organize data for analysis and drawing conclusions as suggested by Miles and Huberman (1984).

The data analysis procedure is presented in two sections to reveal the procedures applied to analyze the SMK and PCK of the participants.

3.6.1 Data Analysis Procedure for SMK

Although SMK was identified as two types which were substantive and syntactic, novice and expert science teachers substantive content knowledge in ecology was collected in this study. In fact, syntactic content knowledge is related to the Nature of Science (Khalick & Boujaoude, 1997) which was beyond the scope of this study.

The pre-interview questions were transcribed and coded. The coding procedure was done in accordance with the Tıraş (2014). There were 55 questions in total with the sub-questions in the pre-interview protocol about SMK regarding ecology. With the guidance of the related literature, collected data was compared and contrasted with the scientific definitions and accordingly categorized as limited knowledge and no understanding. Participants' answers indicated insufficient understanding regarding the concept or issue put under the category of limited. If the participants have no idea or no response about the concept or issue put under the category of no understanding.

Table 3.3 presents the scientific definition and explanations of ecological concepts and issues under the interest of the study.

In addition, the concept maps of the science teachers were analyzed with a holistic and visual approach (Kinchin, 2000, 2001; McClure, Sonak, & Suen, 1999; Williams, 1998). All concept maps were compared visually with one another and analyzed according to their structure, organization, and content. Then, each concept map was broken into propositions to evaluate concept maps, which is a general step in analytical approaches (McClure, Sonak, & Suen, 1999). Each proposition was analyzed in terms of the originating concept, the linking words, and the linked concept (Zak & Munson, 2008). The propositions were grouped by identifying similar propositions and compared according to propositions formed by expert and novice teachers and their making associations between concepts. The propositions were also compared with the curriculum control list regarding objectives of the national-wide applied curriculum of Turkey (MoNE, 2009) and scientific definitions of the ecological concepts (Table 3.3)..

Table 3.3 Scientific Definitions and Explanations of Ecological Concepts and Issues (Adapted from Tıraş, 2014)

Concepts in ecology Definitions	Definitions	Source
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 non-living 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.	
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.	
Population	All of the member of one species that live in a particular geographical area.	Reece & Campbell, 2011
	A group of organisms of a same species have certain structural, functional and behavioural traits in common dynamic groups of organisms that adapt and behavioural traits in common dynamic groups of organisms that adapt to changes in environmental conditions by changing their size, distribution genetic makeup.	
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 Cont'd

Concepts in ecology Definitions	Definitions	Source
Habitat	The place where an organism normally lives out its life. Wide array of resources necessary to sustain growth & reproduction: 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's 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. Early naturalist-explorers noted that plants and animals occupying different regions of the world were often very different in their appearance. Biodiversity depends on the size of a region, colonization rates, disturbances and rates of extinction.	Gaston & Spicer, 1998; Reece & Campbell, 2011; Smith & Smith, 2003; Starr, 2006
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 Cont'd

Concepts in ecology Definitions	Definitions	Source
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 trophic 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

Table 3.3 Cont'd

Concepts in ecology Definitions	Definitions	Source
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 is 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 A graphical representation of the relationship between 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 levels 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. In biogeochemical cycles, an essential element moves from the environment, through ecosystems then back to the environment Decomposers help cycle of nutrients in ecosystems. Various prokaryotic species help transform solids and ions into gases and then back again. By this way, they convert some of the elements that are nutrients to form that primary consumer can take up. The carbon cycle is closely tied to energy flow. All of the major biogeochemical cycles (carbon, nitrogen, phosphorous, sulfur, oxygen) are linked, as the nutrients that cycle are all components of living organisms, constituents of organic matter.	Reece & Campbell, 2011
Energy pyramid	Only about 10% of the energy stored at each trophic level is available to the next level. The maximum number of trophic levels 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. In biogeochemical cycles, an essential element moves from the environment, through ecosystems then back to the environment Decomposers help cycle of nutrients in ecosystems. Various prokaryotic species help transform solids and ions into gases and then back again. By this way, they convert some of the elements that are nutrients to form that primary consumer can take up. The carbon cycle is closely tied to energy flow. All of the major biogeochemical cycles (carbon, nitrogen, phosphorous, sulfur, oxygen) are linked, as the nutrients that cycle are all components of living organisms, constituents of organic matter.	Reece & Campbell, 2011
Material cycles	Only about 10% of the energy stored at each trophic level is available to the next level. The maximum number of trophic levels 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. In biogeochemical cycles, an essential element moves from the environment, through ecosystems then back to the environment Decomposers help cycle of nutrients in ecosystems. Various prokaryotic species help transform solids and ions into gases and then back again. By this way, they convert some of the elements that are nutrients to form that primary consumer can take up. The carbon cycle is closely tied to energy flow. All of the major biogeochemical cycles (carbon, nitrogen, phosphorous, sulfur, oxygen) are linked, as the nutrients that cycle are all components of living organisms, constituents of organic matter.	Starr (2006) Smith & Smith (2003)

Table 3.3 Cont'd

Concepts in ecology Definitions	Definitions	Source
Photosynthesis	Photosynthesis has two stages: the light-dependent and the light-independent reactions. The equation summarizes the process: $12\text{H}_2\text{O} + 6\text{CO}_2 \longrightarrow 6\text{O}_2 + \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{H}_2\text{O}$ Photosynthesis is the process by which plants transform carbon dioxide into simple organic compounds. The first step, referred to as light reactions, involves the absorption of sunlight by molecules of the pigment chlorophyll contained in the leaf. The energy absorbed by the chlorophyll molecule is then used to produce the high-energy compound called NADPH, which are required for the second step in photosynthesis- the conversion of CO₂ into simple sugars, or glucose (C₆H₁₂O₆) In the process of photosynthesis, molecules of water (H₂O) are split. The hydrogen (H) is used in the transformation of CO₂ into glucose and oxygen (O₂) for every unit of CO₂ they transform into glucose.	Starr (2006) Smith & Smith (2003)
Energy	Energy inputs to most of the ecosystems are in the form of sunlight. Energy transfers, cannot be 100 per cent efficient. Over time, the energy originally captured by producers escapes to the environment, mainly as metabolically generated heat. The inherent inefficiency in energy transfers between trophic levels limits the length of food chains.	Starr (2006)

Furthermore, participants were asked to draw a food chain and energy pyramid. These drawings were also analyzed qualitatively in accordance with the empirical studies (Barman & Mayer, 1994; Beals et al., 2015; Özkan et al., 2004; Tıraş, 2014). Depending on the prepositions that emerged, each of the drawings was analyzed and compared to the scientific definitions of the related ecological concept. Each drawing was redrawn in English version by the researcher while remaining true to the original version in order to clarify the findings of the participants. Original drawings of the participants were presented in Appendixes (see Appendix C for Novice 1's original drawings; Appendix D for Novice 2's original drawings; Appendix D for Expert 1's original drawings; Appendix E for Expert 2's original drawings).

3.6.2 Data Analysis Procedure for PCK

The collected data from participant teachers was analyzed based on the Magnusson et al. (1999) PCK model. In line with the qualitative research, inductive and deductive coding were conducted throughout the data analysis process. The components of the PCK model which were knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment of novice and expert science teachers were analyzed qualitatively with reference to the theoretical framework. The components and sub-components of PCK analyzed in the current study are presented in Table 3.4.

Table 3.4 Components of Components and Sub-Components of PCK

Components	Sub-components
Knowledge of curriculum	Knowledge of goals and objectives
	Knowledge of materials
Knowledge of students' understanding	Knowledge of requirements for learning science
	Knowledge of difficulties in science teaching
Knowledge of instructional strategies	Knowledge of subject specific strategies
	Knowledge of topic specific strategies
Knowledge of assessment	Knowledge of methods of assessments
	Knowledge of science learning dimensions for assessment

3.6.2.1 Knowledge of Curriculum

In line with Magnusson et al. (1999) model, novice and expert science teachers' knowledge of curriculum was analyzed within two dimensions which were knowledge of goals and objectives and knowledge of materials. The interview questions, teachers' lesson plans, and classroom observations were data sources for the participants' knowledge of the curriculum. All teachers are obligated to follow the prescribed science curriculum by MoNE (2009). Therefore, participants asked related questions and did not expect to follow a different curricular program apart from MoNE.

The collected data was analyzed qualitatively. The codes for knowledge of the curriculum are listed in Table 3.5.

Table 3.5 Codes for Knowledge of Curriculum

Codes for Knowledge of Goals and Objectives	Source
The placement of ecology topic in the curriculum	McComas, 2002,
Vertical curriculum	2003, Cherrett, 1989 Clark, 2000; Magnusson et al., 1999
Horizontal Curriculum	Brown, 1990; Kindfield, 1994; Lewis et al., 2000
Ecology objectives	MoNE (2004)
Misconception caution in objectives	Aydemir, 2014
Codes for Knowledge of Materials	Source
Sources used by teacher	Magnusson et al., 1999; Shulman, 1986; Yarden & Cohen, 2009; McComas,
Aim of using sources	Yarden & Cohen, 2009, McComas, 2002, 2003

3.6.2.2 Knowledge of Students' Understanding of Science

Novice and expert science teachers' knowledge of students' understanding of science was analyzed with two dimensions which were knowledge of requirements for learning and knowledge of students' difficulties. Interview questions, teachers' lesson plans, and classroom observations were analyzed to determine participants' knowledge of students of science within subcomponents.

Teachers' knowledge of requirements for learning was gathered with the interview questions. There were ecological concepts students were required to know at the 8th-grade level according to previous years' curricular program (MoNE, 2009) which

were; “Living and non-living things”, “examples for living things”, “examples for non-living things”, “ecosystem”, “the relationships between living and non-living things in an ecosystem”, “specie”, “habitat”, “population”, “food chain”. In fact, the related literature put forward the students’ requirements in ecology learning as; living and non-living things (Vold & Buffett, 2008), organisms (Randler, 2008), environment and human relationships (McComas, 2002, McComas, 2003), energy (Sander et al., 2006; Vance et al., 1995).

The other sub-component of knowledge of students’ difficulties was analyzed with respect to collected data via interviews, teachers’ lesson plans, and classroom observations. There were several misconceptions students had regarding ecology in the literature. The list of common students’ misconceptions regarding ecology, identification of misconceptions, sources of misconceptions, and the methods to overcome these misconceptions are presented in Table 3.6.

Table 3.6 Students' Misconceptions Regarding Ecological Concepts and the Methods to Overcome Misconceptions

Misconception	Source
Varying the population size of a species will only affect the others that are directly connected through a food chain.	Griffiths & Grant 1985, Munson 1991
Varying the population size of a species may not affect an ecosystem, because some organisms are not important.	Munson 1991
Varying the population size of a species will affect all other organisms to the same degree.	Griffiths & Grant 1985
Organisms higher in a food web eat everything that is lower in the food web.	Griffiths & Grant 1985
The top of the food chain has the most energy because it accumulates up the chain.	Adeniyi 1985
Populations higher on a food web increase in number because they deplete those lower in the web.	Munson 1991
Communities change little over time.	D'Avanzo 2003
More herbivores than carnivores because people keep and breed herbivores.	Leach et al. 1996
Decomposers release some energy that is cycled back to plants.	Lavoie 1997
The nitrogen cycle is used to provide energy for the carbon cycle.	Lavoie 1997
The carbon cycle consists of photosynthesis and respiration.	Lavoie 1997
The number of producers is high to satisfy consumers.	Leach et al. 1996
Plants do not live in water.	Adeniyi 1985
Plants are dependent on people, not vice versa	Eisen and Stavy 1992
Energy is not lost in trophic transfer.	D'Avanzo 2003
Humans provide food for other organisms.	Leach et al. 1996
The relative sizes of prey and predator populations have no bearing on the size of the other.	Gallegos et al. 1994
In a food web, a change in size in one population will only affect another population if the two populations are directly related as predator and prey.	Gallegos et al. 1994

Table 3.6 Continued

Misconception	Source
Populations higher on a food web increase in number, because they deplete those lower in the web.	Munson 1991, 1994
Food chains involve predator and prey, but not producers.	Gallegos et al. 1994
Carnivores are big and/or ferocious. Herbivores are passive and/or smaller.	Gallegos et al. 1994
Carnivores have more energy or power than herbivores do.	Adeniyi 1985
Plants take in food from the outside environment, and/or plants get their food from the soil via roots.	Bell 1985, Smith & Anderson 1984
Organisms higher in a food web eat everything that is lower in the food web.	Griffiths & Grant 1985
The top of the food chain has the most energy because it accumulates up the chain.	Adeniyi 1985
Populations higher on a food web increase in size because they deplete those lower in the web.	Munson 1991, 1994
More herbivores than carnivores because people keep and breed herbivores.	Leach et al. 1996
Decomposers release some energy that is cycled back to plants.	Lavoie 1997
The number of producers is high to satisfy consumers.	Leach et al. 1996
Carbon dioxide is a source of energy for plants.	Lavoie 1997

Table 3.6 Continued

Sources of Misconceptions	
Teachers	Sanders, 1993
every day use of language	Ben, 1985; Gilber et. al., 1982
Students' perception of ferocity and size concerning producer and consumer	Özkan, 2001
Textbooks	Yip, 1998

Identification Methods of Misconceptions	
Interviews	Fisher, 1985
Concept maps	Arnaudin and Mintzes, 1985; Sungur, Tekkaya and Geban, 2001
Multiple choice tests	Rollnick and Mahooana, 1999
Two-tier diagnostic tests	Haslam and Treagust, 1987; Özkan, 2001

Remediation Methods of Misconceptions	
Conceptual change approach	Özkan, 2001; Özkan et. al. (2004)
Concept mapping	Odom and Kelly (2001)
Learning cycle	Odom and Kelly (2001)
Computer-assisted instructions	Hameed, Hackling, Garnett (1993)

3.6.2.3 Knowledge of Instructional Strategies

In this study, teachers' knowledge of instructional strategies was examined in two segments: knowledge of subject-specific strategies and knowledge of topic-specific strategies. The knowledge of subject-specific strategies was the instructional preference of teachers in general meaning; the knowledge of topic-specific strategies was teachers' instructional decisions regarding a particular science topic. Knowledge of subject-specific strategies in this study represented teachers' instructional preferences in teaching ecology like teacher-centered (e.g. direct teaching, questioning) and student-centered (e.g. conceptual change approach, inquiry, learning cycle). Two aspects of knowledge of topic-specific strategies were knowledge of representations and knowledge of activities. The knowledge of representations identified as illustrations, examples, models, or analogies (Magnusson et al., 1999). The knowledge of activities was demonstrations, simulations, problem-solving, and experiments (Magnusson et al., 1999). The interviews, teachers' lesson plans, and classroom observations provided evidence for novice and expert science teachers' knowledge of instructional strategies with sub-categories. Table 3.7 revealed the examples of subject-specific strategies, representations, and activities in ecology teaching gathered from the related literature.

Table 3.7 The Examples for Subject Specific Strategies, Representations and Activities in Ecology Teaching Gathered From the Related Literature

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. PBL increase students' self-regulation, goal orientation, task value, use of elaboration learning strategies, critical thinking, metacognitive self-regulation, effort regulation, and peer learning compared to traditional instructional approaches.	Lewinsohn et al, 2014 Sungur, Tekkaya, 2010
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
Project-based learning	project-based activities in environmental education caused student teachers' profiles to become more proactively environmentally friendly. PBL supporting students' transition to the role of actively engaged learner.	Kılınç, 2010; English & Kitsantas (2013)
Learning cycle	To promote students' reasoning ability in understanding photosynthesis and respiration, one of the ways was learning cycle.	Cavallo, 1999; Yenilmez, Sungur & Tekkaya, 2007

Table 3.7 Continued

Topic Specific Strategies	Examples	Source
Representations		
Visuals	Teachers can use branching, radiating and cycling diagrams for students to understand the connectedness in a food web system.	Grotzer, 1989, 1993; Killemann, 1998
Videos	Teachers show pictures, slides, models and preserved animals 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
Activities		
Computational modelling activities	To promote students' reasoning ability in understanding photosynthesis and respiration, one of the ways was computer simulations.	Yenilmez, Sungur & Tekkaya, 2007
Role playing	Food web relations and biodiversity were experienced by students with role-playing activity in which they actively participate to the learning material, deepen their appreciation to little-known organisms and explore ecological webs. Role-playing has positive impact in science learning and increase students' interest	Byrne, 2012; Küçükler, 2004

3.6.2.4 Knowledge of assessment

Knowledge of assessment was analyzed within two sub-domains that were knowledge of dimensions of science learning to assess and knowledge of methods of assessment (Magnusson et al., 1999). Knowledge of dimensions of science learning was essential for assessing students in science. That is, teachers' purpose is to assess student's learning in a particular science in a science topic (i.e., conceptual understanding, nature of science, science process skills). The other sub-domain of knowledge of assessment was knowledge of methods of assessment represented by the teachers' ways of assessing students in ecology (i.e., portfolios, multiple choice questions, concept maps).

In fact, there were several ways for assessment in science (Magnusson et al., 1999). In this study, the participants' knowledge of methods of assessment was divided into two categories formative and summative assessment (Earle, 2014). Formative assessment refers to assessment conducted throughout the learning process. That is, students are assessed at the beginning, at the middle, and at the end of the learning process to foster students' learning more (Harlen & James, 1997). Summative assessment refers to assessing students at the end of the learning process (Earle, 2014). This could be at the end of the unit or at the end of the year (Earle, 2014). The main difference between formative and summative assessments lied in that summative assessments depend on written tests while formative assessments are based on verbal and interactive methods (Earle, 2014; Şen, 2014). The interview questions, teachers' lesson plans, and classroom observations were used to compare novice and expert science teachers' knowledge of assessment.

The examples of summative and formative assessment techniques presented in Table 3.8.

Table 3.8 The Examples of Summative and Formative Assessment Techniques (adopted from Tıraş, 2014)

Assessment Techniques	Examples	Source
Summative Assessment	Multiple choice questions gap filling Matching problem solving true false questions essay types questions	(Aydın & Balım, 2009; Clausen, 2017; Earle, 2014; Lewis & Robinson, 2000 Lucero, Petrosino, & Delgado, 2017; Sağbilge, 2022; Şen, 2014; Şen, Öztekin, & Demirdöğen, 2018; Tıraş, 2014; Uşak, 2009)
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	(Akerson, 2005; Clausen, 2017; Earle, 2014; Kaya, 2009; Lucero, Petrosino, & Delgado, 2017; Magnusson et al., 1999; Sadler, 1998; Sağbilge, 2022; Şen, 2014; Şen, Öztekin, & Demirdöğen, 2018)

3.7 Trustworthiness of the Study

Qualitative studies conform to validity and reliability different than quantitative research. Meriam (2009) argued that qualitative studies are “not linear, step-by-step process”; rather in qualitative studies data collection and data analysis are conducted

simultaneously (Aydemir, 2014; Bogdan & Biklen, 2007). When the first data collection starts, the first analysis starts at the same time (Merriam, 2009). To ensure the trustworthiness of qualitative studies, different terms are defined by Lincoln and Guba (1985) to establish qualitative studies' assumptions and worldviews. These adopted terms for qualitative research were credibility, transferability, dependability, and confirmability.

In the following sections, the strategies of the current study to ensure credibility, transferability, and dependability were provided. The ways for trustworthiness in the current study are summarized in Table 3.9.

Table 3.9 The Ways for Trustworthiness in The Study

Aspects of trustworthiness	Strategies Applied in the Study	Sources
Credibility	Triangulation (multiple sources of data, multiple cases) adequate engagement in data collection Peer review (peer examination) Member check Reflexivity (researcher position)	(Lincoln & Guba, 1985; Merriam, 2009; Patton, 2002; Sağbilge, 2022)
Dependability	Triangulation (multiple sources of data, multiple cases) Peer examination Reflexivity (researcher position)	(Lincoln & Guba, 1985; Merriam, 2009; Sağbilge, 2022)
Transferability	Rich, thick description Maximum variation	(Lincoln & Guba, 1985; Merriam, 2009; Sağbilge, 2022)

3.7.1 Credibility

Seeking to find out the question of how research findings address reality (Merriam, 2009), credibility (internal validity) in this study was ensured through triangulation, adequate engagement in data collection, peer review, member check, and reflexivity.

First, triangulation of the data supported the credibility of this study. As Denzin (1987) suggested multiple sources of data, multiple methods, multiple theories, and multiple investigators, in the current study, multiple sources of data, and multiple methods ensured increased credibility. The semi-structured interviews, concept maps, lesson plans, classroom observations, and field notes were triangulated. Moreover, as there were two experts and two novice science teachers, the findings from both experts and novices were confirmed by comparing findings among experts and novices. Related to teachers' SMK, pre-interview questions, concept maps, and drawings were collected as the sources of data to address credibility. Similarly, not only for SMK, PCK findings were triangulated with pre-interviews, post-interviews, lesson plans, and classroom observations. Field notes are compared and constructed among each other and with the other sources of data such as interview transcripts.

Second, the researcher also spent adequate time in the field and tried to be close to the participant science teachers in order to gain valid information. The researcher conducted interviews in the natural environments of the participants at several separate times to have a chance to observe and engage with the participants' contexts. Moreover, classroom observations were conducted in line with the scope of the study when teachers taught ecology topics to 8th graders.

Third, peer review (peer examination) was another aspect of this study to support the credibility. The supervisor and the thesis committee read and provided recommendations for the findings of the study.

The fourth strategy in the study for credibility was a member check. Meriam (2009) suggested member checks or another term respondent validation for seeking feedback on the findings from the studies' participants. In order to better capture participants' perspectives and experiences and remove researchers' biases and misunderstandings, post-interviews were conducted and participants asked further probing questions with the same meaning to validate their responses.

The last strategy for credibility in this study was reflexivity (researcher position). The researchers' integration is required to be explained in qualitative research as their potential biases, dispositions, and assumptions (Merriam, 2009). In fact, reflexivity (researcher position) was the term called "human as instrument" in the research by Lincoln and Guba (2000, p.183). The researcher enrolled in a qualitative research methods course in graduate education and read several articles and books regarding qualitative research methodologies. Having adequate knowledge of qualitative research methods, assumptions, and views, although the researcher did not have much experience in conducting qualitative studies, the researcher was aware of the roles of a qualitative researcher and how to gain appropriate, credible data from the field. Therefore, the researcher took necessary precautions to prevent potential biases, dispositions, and assumptions.

3.7.2 Dependability

Having similar meanings in studies with reliability and consistency necessitates replicating the findings (Merriam, 2009). However, qualitative studies did not have a single reality and could be isolated (Merriam, 2009). To ensure the dependability of the findings, the replication of the study did not provide the same result in any way. Merriam (2009) stated that if the findings of the study are consistent with the data presented, then the study could be considered dependable as well. In fact, multiple sources of the data revealed in this study consistent findings regarding participants. For example, participants' interview responses regarding one of the aspects of PCK were consistent with their lesson plan and/or classroom observations. Merriam (2009) also stated that triangulation, peer examination, investigator's position, and audit trail can be used for the dependability of the findings. In the previous section (see Section 3.7.1), the first three strategies were explained to be

used in this study to ensure credibility. The last one which is an audit trail was not used in this study.

For consistent findings, a coding scheme was utilized and emergent codes were listed with their definitions. Coding was done by the researcher and an independent coder who had knowledge about the topic of the study. The independent coder was given the list of codes with their definitions. Codes were compared between researcher and independent coder. If incongruities emerged, they were discussed and negotiated. The inter-rater agreement was satisfied.

3.7.3 Transferability

Transferability refers to external validity concerned with the applicability of the findings in another situation (Merriam, 2009). It is not usual for qualitative studies to generalize the findings to another situation; however, were suggested two strategies to ensure transferability in qualitative studies (Merriam, 2009). These strategies were rich, thick descriptions and maximum variation.

Lincoln and Guba (1985) stressed the influence of rich and thick descriptions to ensure transferability in studies. In fact, they stated “thick description of the sending context so that someone in potential receiving context may assess the similarity between them.” (Lincoln & Guba, 1985, p. 125). The current study aimed to gather several sources of cases to ensure rich and thick descriptions of the cases with their context in line with the scope of the study.

Maximum variation was also another aspect of this study to satisfy the transferability of the findings. As there were four cases of science teachers, two of whom were experts and the other two were novices, maximum variation was ensured.

3.8 Ethics

Fraenkel, Wallen, and Hyun (2012) put forward the importance of studies to take into consideration ethical issues. Therefore, in the current study, the researcher provided information to the participating teachers regarding the study's purpose and conditions before the study. Upon the teachers' voluntary agreement to participate, the study received approval from the METU Human Subjects Ethics Committee and the Ministry of National Education (Appendix Q and R). Once the necessary ethical permissions were obtained, the school administrations were informed about the study and with necessary permissions to conduct the study by using the school facilities in classroom observations and audio recordings during lessons. Before data collection, the participating teachers signed a consent form. To save the participants' personal information, pseudonyms were used. The schools', students', and teachers' names and information were kept confidential throughout the study and after the study. Participants and no one were harmed physically, psychologically, and emotionally throughout the study. The researcher did not criticize or judge the participants. Additionally, no photos or videos of students were taken during the classroom observations.

3.9 Assumptions of The Study

In this study it was assumed that;

1. Magnusson et al. (1999) model was effective for comparing novice and expert science teachers' PCK.
2. Teachers having more than five years of teaching in science were assumed to be expert science teachers and teachers having less than five years were assumed to be novice science teachers.

3. Teachers' actions, behaviors, and reflections in the classroom observations were natural during interviews and observations and were not influenced by the presence of the researcher.
4. Teachers' responses were assumed to be sincere.

3.10 Limitations of The Study

The current study has several limitations to consider. First, the findings of the study cannot be generalized to all of the novice and expert science teachers' PCK on ecology teaching. Second, the study is limited to comparing novice and expert science teachers' PCK within their certain boundaries determined according to the PCK model used (Magnusson et al., 1999), and research questions attempted to be answered in this study rather than describing distinguishing characteristics of participant expert and novice teachers' PCK. Third, the science teachers determined either expert or novice according to their teaching years, although being an expert in a domain defined differently, such as possession of certain kinds of experiences, skills, characteristics, and knowledge (Hogan et al., 2003). That is, how science teachers teach science was not considered in the selection of expert and novice science teachers. Fourth, expert science teachers graduated almost thirty years ago. In Turkey, at this time, there were no departments of elementary science education in universities. This might cause differences between participant expert and novice science teachers. Fifth, each expert, and novice science teacher has practiced science teaching in different public schools in Türkiye. Although the school facilities of all teachers were similar as all being public schools in Türkiye, there can some factors like students' socioeconomic status, students' families, school administrations, and colleagues of teachers may influence the results of the study. The sixth limitation was that teachers' settings, practices, activities, and interactions may not be fully described by the researcher. Schools are a complex social system; however, as the

study's main focus was on the expert and novice science teachers, other influential factors were not considered, such as students, administrators, parents, and so on. Seventh, classroom observations were done only by the researcher may cause possible researcher effects in terms of the validity of findings. Eighth, the classroom observations were not video-recorded, and the researcher did not take any photos of the classroom activities. Ninth, the researcher's background knowledge of expert and novice science teachers may influence the findings of the study since the researcher possessed from past school experiences that expert science teachers have sound knowledge on how to teach science effectively and knowledge of students' learning difficulties, misconceptions, how to handle this lack of conceptions and misconceptions with considering students' attitudinal features. Lastly, the current studies' findings were collected in 2009-2010. As the conditions and the context of these years might be different (schools' facilities, students, curriculum, administrative approaches, teachers' teaching approaches and preferences, educational and training opportunities), this study's findings regarding the comparison of novice and expert science teachers' PCK regarding teaching ecology was limited to the context of the data collection period of time.

Therefore, the studies' findings cannot be generalized to recent novice and expert science teachers' PCK regarding teaching ecology.

CHAPTER 4

FINDINGS

The focus of the present study was to set forth the novice and expert science teachers' PCK regarding ecology teaching in the light of Magnusson et al. (1999) PCK model. In this chapter, the findings were presented case by case starting with novice science teachers and following with expert teachers. Each case's findings are reported under the headings of "subject matter knowledge in ecology" and "pedagogical content knowledge in ecology". First, each case's SMK was presented, and then, the PCK of each case was documented. PCK aspects identified in line with Magnusson et al.'s (1999) PCK model presented in separate parts as "knowledge of curriculum", "knowledge of students' understanding", "knowledge of instructional strategies", and "knowledge of assessment".

4.1 Novice 1's Subject Matter Knowledge and Pedagogical Content Knowledge Regarding Teaching Ecology

4.1.1 Demographic Information

Novice 1 was a science teacher with one one-year teaching experience who was labeled in this study as Novice 1. Novice 1 is female and has a BS degree in elementary science education and a master's degree in measurement and evaluation in education. She has been continuing her graduate education in the department of elementary science education doctorate program. She indicated that she took ecology courses as electives during her undergraduate years. She took courses in educational

psychology, development and learning, teaching techniques, and instructional planning and evaluation. She said she attended inservice training on instructional techniques; however, she could not benefit much from this training. She thought that biology concepts are easier both to teach and to be learned by students. She added that students found biology concepts more interesting and related to their daily lives. Moreover, she mentioned her special interest in ecological issues, and she likes to follow documentaries, books, and magazines about ecology. She has experience in teaching at 6th, 7th, and 8th grade levels in her 1-year teaching experience. She does not prefer to teach in the science laboratory in the school. Because the laboratory is so small and unsuitable for her crowded classes to practice science experiments inside although there are necessary enough materials.

In the following parts, Novice 1's SMK and PCK on ecology are represented in the light of multiple data collection tools. The first part put forward Novice 1's SMK on ecology.

4.1.2 Novice 1's Subject Matter Knowledge on Ecology

Novice 1's subject matter knowledge on ecology was collected through interview questions, drawings, exemplifications, interpretations, and concept map construction. During the interviews, Novice 1 asked several questions regarding basic ecological concepts and principles. To elicit her subject matter knowledge on ecological concepts and principles, Novice 1 was asked twenty-nine questions with sub-questions. Findings regarding Novice 1's subject matter knowledge in ecology were divided into two main categories basic ecological concepts and energy flow in ecosystems. Within the basic ecological concepts category, basic ecological concepts' definitions which were ecosystem, species, population, community, habitat, ecological niche, biological diversity, producer, consumer, and decomposer were documented. In the other category, there were asked questions to understand

SMK in the energy flow in ecosystems in light of the food chain, food web, and energy pyramid concepts. These findings are documented in a separate part.

Interview responses, concept maps, drawings, and figures drawn by Novice 1 were likely to indicate that Novice 1 had difficulties in some basic ecological concepts like ecosystem, habitat, community, and extinction-prone species. She seemed to have no idea about ecological niche and she did not provide any definition. She did not provide the scientifically correct definition of energy and the flow of energy in ecosystems. She did not explain the roles of producers, consumers, and decomposers in matter cycles in ecosystems. She identified biological diversity in terms of species diversity and genetic diversity rather than ecological diversity. She failed to have a grasp of photosynthesis, respiration, and matter cycles. Nevertheless, she was found to have knowledge of species, population, limiting factors in photosynthesis, prey-predator relations of organisms, energy pyramid, and food web.

The following parts presented Novice 1's SMK findings collected through interviews, figures, exemplifications, drawing related figures and their interpretations, and concept map drawing documented. The next part presented Novice 1's SMK in basic ecological concepts.

4.1.2.1 Novice 1's Subject Matter Knowledge on Basic Ecological Concepts

The interview questions, figures, interpretations, exemplifications, and concept map were the sources to gain Novice 1's SMK on basic ecological concepts. She was asked to define ten basic ecological concepts in the interviews. The first ecological concept Novice 1 asked to define was the ecosystem.

I: What is an ecosystem?

Novice1 (N1): Ecosystem! Ecosystem, what could it be? Um, can we say that it is a place where organisms exist together both biotic and abiotic components? It is an environment including the animals living in the mountains, inside the forests and lowlands, water resources, etc... [interview]

I: Okay...Can you give examples to the ecosystem?

N1: Mountain ecosystem or desert ecosystem. What is a desert ecosystem? It is the soil structure of the desert ecosystem, there are growing plants and living creatures. that's the animals and insects, so... I guess so. [interview]

Novice 1's concept map related to basic ecological concepts is presented in Figure 4.1. The hierarchical concept map consisted of ten concepts that were ecosystem, living organism, non-living organism, producer, consumer, decomposer, energy pyramid, photosynthesis, respiration, and food. Novice 1 seemed to identify two central concepts which are ecosystem and food. The ecosystem was as one of the central concepts that branched into living and non-living organisms. In fact, she established branches for central concepts. She branched living organisms into producers, consumers, and decomposers. In the concept map, Novice 1 used linking words to form scientifically correct relationships of ecological concepts. For instance, related to the ecosystem she formed "producers are the example for living organisms". Moreover, Novice 1 provided an example for the ecosystem in her concept map to settle the ecosystem as the central concept. However, in general, she used the same linking words to form the relationships between concepts indicating limited knowledge of connections between ecological concepts. Novice 1 cross-linked the ecological concepts. For example, she linked food with producers and producers linked back to the food; consumers crosslinked to living organisms,

respiration, and the energy pyramid. She seemed to be able to make various connections between ecological concepts such as producers, consumers, decomposers, photosynthesis, and respiration. On the other hand, Novice 1 did not include some basic ecological concepts like species, population, community, biological diversity, habitat, ecological niche, food chain, and food web. The interactions among species, the flow of energy, material cycling, and the interrelatedness of ecosystems were not seen in her concept map drawing. Although Novice 1 did not mention the interaction between biotic and abiotic components, she knew the components of the ecosystem, such as living and non-living organisms, and provided examples such as mountains, deserts, lakes, forests, and oceans. It was seen in her interview responses that she defined an ecosystem as an environment, a place where there are living and non-living things inside.

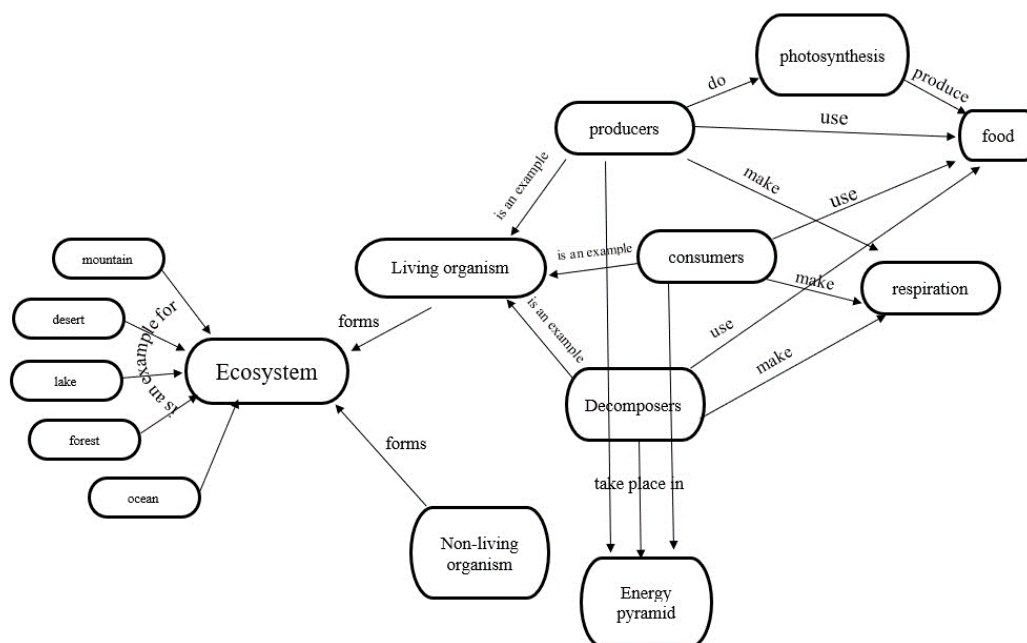


Figure 4.1 Novice 1 Concept Map (see Appendix B for original drawing)

To gain more insight into her knowledge, Novice 1 engaged with a short script: “You asked your class to construct a closed ecosystem as a homework assignment. From your students, Ali and Ceren decided to prepare this homework together. They meet after school for the homework. Ali suggested that: ‘Let’s take three large glass containers. In one, we will put all the non-living things like rocks, soil, water, and air and we will hang a light bulb over it to represent the sun. In another container, we will put just the plants and in the third container, we will put just the animals. It will be cleaner this way if we keep everything separate!’”. Novice 1 responded to the related questions as follows.

I: How would you evaluate Ali’s ecosystem suggestion?

N1: Now, this [Ali’s suggested ecosystem] may not be an ecosystem... Because in the ecosystem, all of these [living organisms and non-living things] must be found together, not separately. In other words, he actually tried to create an ecosystem, but he could not. [In fact] none of them is not an ecosystem... These are not considered as ecosystems. In order to be an ecosystem, all three [living and non-living things] must coexist. So, he should have put all three in a single jar... [interview]

I: Predict, what would happen in the three jars over time. Explain your ideas.

N1: Nothing will happen inside the first jar. Because it is lifeless, nothing will happen even if it is exposed to the sun. As I remember, plants were in the second jar. In the second container, there are producers. They [producers] will die, of course. Hence if there is sun in the environment, they [producers] consume carbon dioxide continually and give off oxygen. They [producers] could not find

carbon dioxide or if there was no light, they [producers] would only respire. In the end, they will die. [pre-interview]

Novice 1's responses indicated that her knowledge about ecosystems consists of biotic and abiotic components as she stated previously in the interviews and her concept map drawing. Although she did not talk about the interaction between biotic and abiotic components in her concept map, she explained the relationship between biotic components and abiotic components. She stated that producers used sunlight and carbon dioxide and produced oxygen. As she identified producer, consumer, and decomposer initially, she asked about those concepts.

I: Then, what are the producers?

N1: Producers are plants, plants with green leaves. [interview]

I: What is the importance of producers in ecosystems?

N1: We call them producers because they can produce their own foods by themselves. All organisms in an ecosystem need energy, including producers. Well, producers can meet their needs by themselves. But what about consumers? They [consumers] need producers to get energy. In fact, there would be no life without producers. When we think of plants, they do not produce energy only... While they [plants] produce their own energy, they also produce oxygen for us. Is it possible to imagine a life without oxygen? For us [human beings] it is not. Yeap, in every sense, we need producers, and producers occupy an important place in the ecosystem... when we look at that [energy] pyramid, they [producers] are located at the bottom of the pyramid. That is, they form the base of the energy pyramid. We cannot think of a life that way, that is to

say, we need producers and producers have a serious place within the ecosystem. [interview]

I: Then, what is the importance of consumers in the ecosystem?

N1: First of all, if there is a living thing in nature, it could not be unimportant. Of course, they are important too, I guess... Nature has a balance, and for me, every living thing exists for a purpose. When you remove an organism from an environment, you're actually upsetting the balance of the ecosystem there. Do consumers have a specific task? I mean, I can't explain it [your question] like that, but yes, every living thing has a specific task. Consumers do not exist in the ecosystem just to consume. Perhaps they [consumers] contribute, in some way, to the survival of other living things in the ecosystem... [interview]

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

N1: I could not anything specific about consumers, but decomposers are indispensable [part of the ecosystem] ... for me, consumers would also be indispensable. Decomposers are located at every step in the energy pyramid. They are not on one level... They don't decompose the consumers only, but all organisms, from bottom to top, are located at the pyramid. They are sweepers... in fact, they are not just sweepers, in fact, they have a serious role in the balance of nature, just like every living thing. You know, like every living thing, they have a crucial role in the balance of nature. Decomposers are the organisms that convert the wastes to a form that can be usable. They have roles in matter cycles... Their food resources are also wasted. When they are feeding on these wastes, they are doing something useful for nature by

decomposing. They produce gasses or other products in the decomposition process.

I think decomposers have a role in matter cycles and they are also important for the soil, for nitrogen cycle, etc. They are useful for the soil in various ways; let's just say for the purification of the soil. Also, plants take advantage of this.

Because these plants are growing in the soil, they can get various things from the soil. [interview]

I: How do you explain the relationship between producers, consumers, and decomposers, if any?

N1: They are [producers, consumers, and decomposers] related to each other. Producers produce, but producers, in fact, are dependent on decomposers in a way, consumers... (stopped)... I mean, I think they are all dependent on each other, just like in the food web, they are dependent on each other. The removal of one organism from the environment, in some way, will affect the others adversely, maybe causing the others to disappear. So, I cannot say one is very important and the others are not less important. For me, they are dependent on each other. [interview]

Novice 1 explained the roles of producers in terms of their roles in the production of energy, giving of oxygen, and their importance for sustainability. She did not explain the relationship between producers and consumers in detail. In fact, she did not talk about producers' essential roles in material cycles. However, she explained the importance of producers in material cycles another time during interviews. Moreover, she integrated producers in her concept map and correlated the producers

with the concepts that are food, photosynthesis, respiration, energy pyramid, and living organisms (Figure 4.1). The statements in the concept map were “Producer is the example for the living organism”, “food is used by producers”, “respiration is done by producers”, “producer takes place in energy pyramid” and “producer do photosynthesis”. Similar to interviews, she did not state the connection between producers, consumers, and decomposers in the concept map (Figure 4.1). Also, the relation between material cycles and energy transfer was not mentioned in the concept map related to producers. Novice 1 emphasized producers as producing their own food for organisms and being the base of the energy pyramid. Related to consumers, in her concept map, Novice 1 linked it to respiration and living organisms (Figure 4.1). The statements in the concept map about consumers were “respiration is done by consumers”, “consumers take place in an energy pyramid”, “food is used by consumers” and “consumer is an example of a living organism”. Therefore, Novice 1 was likely to have a weak understanding related to consumers. In fact, she did not speak of many roles of the consumers in ecosystems in the interviews. But she indirectly demonstrated her knowledge of the relatedness of organisms with the statement “Perhaps they are contributing to the living of other organisms within the ecosystem.” although she was not certain about it. She did not identify the roles of consumers clearly. For instance, she did not mention the roles of consumers in material cycles, the flow of energy in ecosystems, creating or modifying habitats, and forming relations with other organisms. On the other hand, she seemed aware of consumers’ possession of essential roles in ecosystems. When Novice 1’s concept map was analyzed, it was seen that she included decomposers in relation to respiration, food, energy pyramid, and living organisms. The statements that emerged in the concept map were “decomposers are an example for living organisms”, “food is used by decomposers”, “respiration is done by decomposers” and “decomposers take place in an energy pyramid”. She did not talk about decomposers’ role in transforming organic material into inorganic forms during

interviews as well and it was not seen in her concept map. Similarly, Novice 1's answer to the interviews showed that she knew the decomposers' role in converting dead matter into usable forms. She stressed the decomposer's roles in the energy pyramid and the long-term survival of the ecosystem. Although she indicated decomposers' role in the cycle of nitrogen, she did not provide any detailed explanation. To sum up, although Novice 1 did not state the relation between producers, consumers, and decomposers in her concept map, she explained their dependent relation in the related interview question. However, she did not provide detailed explanations. She based her explanation on these producers, consumers, and decomposers' relations in the food web. She did not mention the flow of energy between producers, consumers, and decomposers.

The other ecological concept asked to be defined as species.

I: So, what is species?

N1: Firstly, species can inbreed with each other and reproduce offspring that are similar to themselves. What else.... their living areas and feeding habits... after all they are genetically similar organisms that can reproduce new organisms which are similar to each other. [interview]

I: Can you tell me the characteristics of extinction-prone species?

N1: Now, living things need to meet certain needs in order to survive... What are these needs? It may be a need for food, a need for shelter, a need for reproduction, a need to find a mate or a need for mating. For example, if you destroy the habitat of a living thing, that organism has to migrate to another place. Mm, if it immigrates then it may adapt to the new area to survive. If it adapts, it lives, if it does

not, it is eliminated and dies. ..in this way, it could become extinct. [This leads to] elimination of organisms in that environment on which it feeds, it cannot take food, or it may try to feed on other living things which influence it negatively. If it doesn't find shelter, it also dies. When their numbers have decreased, this may be difficult for them to reproduce anyway. This leads to a decrease in their numbers as well. And after a while, they become extinct. Actually, there are many factors... [interview]

Novice 1 appeared to understand species concepts that share common characteristics and interbreed. On the other hand, she did not include species in her concept map (Figure 4.1). Therefore, Novice 1 appeared to not be able to connect the species concept with the other ecological concept indicating her deep comprehension. Novice 1 also appeared to have an understanding of extinction-prone species. In fact, the characteristics of extinction-prone species were explained through habitat destruction, not finding food and shelter, decrease in reproduction rate. Conversely, she did not explain fixed migratory patterns of organisms, possession of specialized feeding habits, to be found in only one place or region, limited specialized resting or breeding areas, feed at high tropic levels.

Another basic ecological concept she was asked to define was population.

I: What is population?

N1: A population is a group of organisms that include the same kind of species only; that should not include any other kind of species, as I suppose. [interview]

Novice 1's responses indicated her understanding of the population. Conversely, she did not place population in her concept map (Figure 4.1).

I: So, what about community?

N1: Community... is it a group? that live together. I cannot make an exact definition. Because... Frankly, I don't know exactly the definition of community. The community may be something that is formed by a species... Though it was population. What could be a community, more than one type of species? Is it the environment where more than one species lives together? I think it is something like that. [interview]

Her responses indicated her lack of understanding of the community. In fact, she was unsure about her definition. The community was not included in Novice 1's concept map as well (Figure 4.1). Next, she defined habitat and ecological niche.

I: What is habitat?

N1: Habitat is the address of an organism [laughing]. This definition remains in my mind for this reason. That's how we teach children. We teach them "Just like your home is an address, a habitat is the address of an organism". There is an appropriate environment for each living thing to live, adapt, and meet their needs. So, we can call that environment as their habitat. In short, a habitat is a place where an organism can meet all of its needs, shelter, feed, and reproduce... [interview]

I: What about ecological niches?

N1: I do not know; I do not remember it [ecologic niche] at all. [interview]

The answer to Novice 1 revealed her understanding of habitat. It was true in terms of defining as the place where organisms live; meet their needs, shelter, and feed. Therefore, she seemed to know the components of habitat like food, shelter, and space to reproduce and survive. On the other hand, she neither mentioned nor gave a specific example of the interaction of organisms. Moreover, she expressed that she remembered the habitat definition from her teaching experience. So, her habitat knowledge could be limited to the curricular content. Moreover, Novice 1's concept map included neither ecological niche nor habitat (Figure 4.1). In fact, it was seen that she had no response regarding ecological niche.

Biological diversity was the next ecological concept Novice 1 was asked to define.

I: What is biological diversity?

N1: Biological diversity is something different...that is to say a group of various organisms...they are genetically different, also different with respect to reproduction, feeding [habit], and the environment that they live. [interview]

To deepen her knowledge of biological diversity, Novice 1 asked “Is biological diversity advantageous for organisms?”

N1: Biological diversity... it can be an advantage. In fact, maybe each one [organism] takes on a different task every has a different responsibility. We can link these responsibilities with the food chain or even the food web. So, yeah, that is an advantage in my opinion. We can associate this task with the food chain; we can associate it with the food chain or even the food web. Yes, I think it is an advantage. [interview]

Although she did not provide a clear explanation of the advantages of biological diversity for organisms, she had an understanding of biological diversity that she explained as formed with various kinds of organisms of different genetic, feeding, breeding, and environmental habits. She was likely to interpret biological diversity in terms of species diversity and genetic diversity. She did not mention ecological diversity. Biological diversity was not included in her concept map (Figure 4.1).

Novice 1's subject matter knowledge on energy flow in ecosystems, including energy, photosynthesis, food chain, food web, and energy pyramid was presented in the next section.

4.1.2.2 Novice 1's Subject Matter Knowledge on Energy Flow in Ecosystems

The interview questions documented within parts as energy, photosynthesis, food chain, food web, and energy pyramid. The sequence of the questions, exemplifications, drawing-related figures, and their interpretations are presented below.

Energy is highly related to ecological concepts and issues. So, teachers' subject matter knowledge on energy was elicited through several interview questions regarding ecological concepts and issues.

I: What is energy?

N1: Energy, in the physical sense, is defined as the power to do work... I tell the students like this, sometimes we get so tired that we can't raise our arms. [happens] when we can't eat at work ... We need energy.... In other words, what enables us to raise our arms, or to

walk, or to move, to sustain our lives, is energy [Energy is what keeps us alive] ... [interview]

I: How do you explain the flow of energy in ecosystems?

N1: Energy flow in the ecosystem, that is, producers produced their own energy in a way, they used it, ... consumers benefit from their [producers'] energy. I guess we can explain it this way. [interview]

I: You said 'Producers produce their own energy in a way'. Do you remember how?

N1: They produce the food as a result of photosynthesis. They take energy from the sun and convert it into the chemical form they will use to grow up. [interview]

I: What is the food of plants?

N1: The food of plants is produced by themselves by photosynthesis. [interview]

I: So, what is the purpose of photosynthesis?

N1: The primary aim of photosynthesis is to produce food for the plant, not to produce oxygen for us. That is to say, the plant is doing its own work there [during photosynthesis]. Photosynthesis is not for us but for plants themselves. [interview]

I: Can you explain the mechanism of photosynthesis?

N1: It is about a plant using the sunlight. Plants have an organelle, called chloroplast where sunlight is subjected to various chemical

events. Plants also need to take some water from the soil or carbon dioxide from the outside. The food is produced with the combination of all these elements and it does not only produce the food but also gives oxygen outside. [-interview]

I: Do you think that photosynthesis obeys the first and second laws of thermodynamics?

N1: Yes, I think it does. In the end, we say that plants convert solar energy into the form that they can use.... There is a conversion of energy within nature, energy is transformed from one to another. For this aspect, photosynthesis obeys the first and second laws of thermodynamics.

The plants produce energy for themselves ...and animals use this energy. But, do animals use the all energy that plants produce?

No, they do not. So, where did the rest of this energy go? What percentage of that energy produced by plants is used by animals? I do not know so I cannot give an exact percentage, to be honest. But if we are, let's say, using sixty percent of it, where did the remaining forty percent go? I think it turned into another form. [interview]

I: Why would an increase in the atmospheric concentration of carbon dioxide not necessarily result in a corresponding increase in photosynthesis?

N1: Plants need carbon dioxide for photosynthesis, but they need it in a certain amount, that is to say, excess carbon dioxide within an environment will not be used...so you cannot say the more carbon dioxide amount the more frequently photosynthesis done. We cannot

say so, in my opinion. It is like that... (stopped). When you increase the amount of something in chemical reactions, the reaction will also accelerate, but after some time, it does not matter how much you increase the amounts. The reaction will not accelerate anymore after reaching this peak point. [interview]

I: What are the factors that limit the reaction?

N1: The cells that use carbon dioxide... There is a certain number of these cells. if the number of cells that can perform photosynthesis is limited, ...yes, if there is little [low concentration] carbon dioxide in the environment, these cells will produce less carbon dioxide. But if there is too much carbon dioxide in the environment, they will only use as much as they can use, and the excess remains. [interview]

Novice 1 had an understanding of plants' produced food by photosynthesis. However, she did not state it as glucose. She also explained how plants produce their own food in pre-interviews. In fact, Novice 1's concept map included photosynthesis in relation to food and producers indicating her comprehension of the relation of photosynthesis with food production and producers. In fact, the statements of the concept map were "photosynthesis produce food" and "producer do photosynthesis" (Figure 4.1). In interviews, she expressed plants produce food as a means of photosynthesis in which light energy is converted into a chemical form of energy. However, she did not again mention this chemical energy stored in the bonds of glucose produced as the result of photosynthesis. In addition, the explanation of Novice 1 about the aim of photosynthesis revealed her limited understanding of photosynthesis. In fact, she did not explain the sequence of chemical reactions that occur in photosynthesis. Although she explained the aim of photosynthesis was to produce plants' food themselves and oxygen, she did not make any connection

between photosynthesis with material cycles and energy flow in ecosystems during interviews. Moreover, Novice 1 appeared to explain the mechanism of the photosynthesis occurring in the organelle, chloroplast not in detail. She stated reactants and the end products of the chemical reaction of photosynthesis. She could explain how photosynthesis obeys thermodynamics' first law. She stated energy conversion in the interviews; however, she did not provide any example of the transformation of energy. In addition, she could provide an insufficient explanation of photosynthesis regarding the second law of thermodynamics. She could not state the rate of energy efficiency when flowing in ecosystems. Novice 1 could explain the limiting factors in line with the photosynthesis. She did not include these issues and relations in her concept map. Her concept map included a few relations regarding photosynthesis.

Novice 1 was likely to have knowledge regarding energy flow in an ecosystem. She explained the flow of energy as the event in which producers produced energy transferred to the consumers. However, she did not explain sun energy is converted to chemical bond energy stored within glucose as ATP which is important for the energy flow in an ecosystem.

4.1.2.2.1 Novice 1's Subject Matter Knowledge on Food Chain

Novice 1's SMK on the food chain was investigated through interview questions, drawing figures, and her concept map. The first question was to define the food chain.

I: What is a food chain?

N1: The food chain is actually...hmm in the food web, to meet the energy needs of living things, how can we say, it's like a flow they

[living things] create, that is, the energy will flow from one to the other, but this is not a linear messy thing... [interview]

Novice 1 appeared to think food chain as part of the food web in which energy flows among organisms. The food chain was not included in her concept map (Figure 4.1). To clarify her understanding, she was asked to draw a food chain. Figure 4.2 presents Novice 1's food chain drawing.

plant → grasshopper → frog → snake → bird

Figure 4.2 Novice 1 Food Chain Drawing (see Appendix B for original drawing)

I: Can you draw a food chain?

N1: Yes, I started the food chain with grass, what should eat [feed on] grass? Let the grasshopper eat [the grass] ...Then, which animal eats the grasshopper? Let the frog eat the grasshopper, in turn, eaten by the snake. This is a food chain, that I remember from last year (laughing). What is next, let the bird eat the snake. This is a chain, not a web [interview]

I: Could you explain your food chain drawing?

N1: I began with grass, the producer.

Grasshoppers, frogs, snakes, and birds, are all consumers. But the things we call producers are plants, so there should be herbivores in the second level, followed by either carnivores or herbivores... So where are the decomposers located in this food chain? Decomposers are everywhere. [interview]

Novice 1 drew her food chain emphasizing organisms' feeding relations. She explained the trophic levels and the arrows consistent with the scientific explanation. She could explain producers, consumers, and decomposers in relation to the food chain. She started a food chain with a producer in line with the scientific explanations. She did not draw any decomposers in the food chain. But Novice 1 explained decomposers operated at each trophic level in interviews.

Novice 1 was asked follow-up questions to understand her knowledge regarding food chains further.

I: Is the length of a food chain limited?

N1: I think it is limitless... For instance, my example included five steps, I think there are more than that, but is it "limitless"? It is not limitless, I guess (hesitate), but if you ask me, "How many levels there will be?" I can tell you an estimated number of 15 or 20, but ... I have to think about it...if we go into more detail, we can increase the levels. Yet, I'm sure it's not limited [interview]

I: If you think so, why did you draw a 5-level food chain then? Could it be 7-8-9-10 too?

N1: Yes, it could be. [interview]

Novice 1 seemed to not have an understanding of the length of the food chains and limiting factors. Although she drew five levels in her food chain, she thought that the food chain levels could be increased. To dig her food chain knowledge more about the food chain, she asked about the meanings of the arrows in the food chain.

I: What do the arrows in the food chain represent? Please explain.

N1: These arrows represent the flow of energy. For instance, I drew an arrow from the grass to the grasshopper and said that the energy in the grass will pass to the grasshopper, but not a hundred percent as I said before... it [the energy] will be transferred to the upper levels by a decreasing amount. [interview]

Novice 1 appeared to have knowledge of the arrows in the food chain. She explained the arrows indicate the direction of the flow of energy. She neither mentioned organisms' roles as producers, consumers divided into first, second, and top consumers nor feeding types as herbivores, omnivores, and carnivores in the food chain specified with the help of the arrows. Besides, she mentioned the trophic levels that after producers there come herbivores and then carnivores. Moreover, Novice 1 thought that the trophic levels in the food chain were limitless. Moreover, she pointed out the decrease of energy in each higher trophic level.

Novice 1 was provided with some food chain examples from literature and asked several related questions about it.

I: Are the -nectar, a butterfly, a bird, and decomposers- constituents of a food chain?

N1: No, they do not. Decomposers should be everywhere. That is to say, you cannot think of putting the decomposers at the top. What else can I say.... a bird can feed on nectar, not only on a butterfly. So, we could not make it linear, it would be like a web. [interview]

I: What about a bacterium inside the human body? Could it be a part of a food chain?

N1: Yes, it could be... After all, if we talk about the bacteria in the intestines... there are a lot of bacteria in our body... [according to the

food chain] we get food from producers. We used a certain amount of that energy, and a certain part of it gone... what will they [bacteria] do with them, they will benefit from our energy, I guess [interview]

I: If so, what could be the other living things that make up this food chain?

N1: lettuce... a plant or a producer... or a sheep. I eat the meat of the sheep. Okay, it starts with it. I guess I can make such a food chain, right? Let the person eat the lettuce, and the bacteria use that energy, then how can I say, let the decomposers decompose the feces... like this...[interview]

Novice 1 seemed to have a conceptualization of organisms' complicated feeding relation in ecosystems. She pointed out the feeding relations of organisms like a web. Moreover, although Novice 1 placed producers on the first step in her food chain drawing without hesitating, she appeared to have difficulties when telling the first level of the food chain was about bacteria inside the human body. She was unsure about the producers of the food chain one of the parts of this food chain is a bacterium inside the human body. On the other hand, Novice 1 appeared to have an understanding of the importance and the place of decomposers in food chains. However, Novice 1 seemed to not comprehend that bacteria are decomposers. That is, she was confused about the organisms that have a role as decomposers in the food chain regarding a bacterium inside the human body. During answering the question, she seemed to be unsure about which organisms were decomposers. She said "What can be the decomposers organisms (stops), can fungi be decomposers? "Bugs maybe decomposers.... or maybe that...I am not sure... I am thinking by myself, I am thinking out loud".

The 8th-grade ecology unit included a link between the material cycles and food chains [the related objective in the curriculum: 1.19. Explain the material cycles in parallel with the energy flow in the food chain.], so Novice 1 asked a question to get her understanding regarding the relation between food chains and material cycles.

I: Is there any relationship between material cycles and food chains?

Please explain.

N1: When we think about the carbon cycle, carbon... let's talk about carbon dioxide... Who uses carbon dioxide? Plants or producers use carbon dioxide to produce their food. They give us oxygen as a product. Who uses this oxygen? Consumers use. They give off carbon dioxide as a product. If we talk about the water cycle, there are juicy fruits in green leafy things, for example, what do we do with that water, we use it in our own cells. What do we do with the excess, we give it out as urine or somehow by sweating. It mixes with the water or with the soil, and the plants take it again. Yes, they are related... Yes, they are related. [interview]

Novice 1's response about the relation between material cycles and food chains revealed that she underestimated some factors that contributed to this relation. For instance, in relation to the water cycle, she did not identify the clouds, rivers, seas, glaciers, ground, and underground water as the water compartments. However, she talked about the roles of soil, plants, and animals in relation to the water cycle. She also did not express the physical states of water in evaporation, boiling, and condensation in relation to food chains. Regarding the carbon cycle, Novice 1 neither mentioned the food chain's being a path of carbon flux in ecosystems nor many of the sources of carbon in ecosystems like atmospheric CO₂, terrestrial particulate, and dissolved organic carbon, carbon resides in living aquatic and terrestrial organisms

and refractory terrestrial carbon. Rather she mentioned the carbon flow from producers to consumers in relation to the oxygen cycle. She did not provide an explanation of aquatic and terrestrial carbon relations of organisms in ecosystems, yet. She did not talk about nitrogen and phosphorous cycle relations with food chains. Overall, Novice 1 was unaware of the complex relations of organisms in food chains regarding the flux of matters. To further deepen her knowledge about the complex relation of organisms in ecosystems, Novice 1 asked questions about the food web that will be presented in the next section.

4.1.2.2.2 Novice 1's Subject Matter Knowledge on Food Web

Novice 1 responded to several questions during interviews regarding the food web. However, she did not include the food web in her concept map drawing. First, Novice 1 was asked to define what the food web is.

I: What is a food web?

NI: Food web ... in nature, living things feed by eating one living thing another. If this relation was linear, we would call it as a food chain. In other words, we would call it a food chain if an organism (i.e., organism A) feeds on only one organism (i.e., organism B), in turn eaten by another organism (i.e., organism C). But this is not usually the case in nature. [For example] Organism X can eat organisms A, B, and C, at the same time, eaten by a variety of organisms, such as organisms E, F, and G, etc. It is a rather complex web network such as a spider web. Because in nature, as far as I know, no living thing feeds on one kind of organism. [interview]

I: What is the difference between a food chain and a food web?

N1: Now, as far as I know, the food chain is more linear.

It is more complicated in the food web. [referring to her food chain drawing (Figure 4.2.)], the arrow points to the grasshopper [from grass] in fact there are lots of organisms that eat grass. [interview]

Similar to the food chain, the food web was not included in the concept map of Novice 1 (Figure 4.1). However, Novice 1 seemed to have an understanding of the food web and she explained organisms' complex feeding relations in the interviews. She pointed out food chains are linear and interconnected food chains form a food web. In addition, she indicated that in the natural environment, organisms do not feed on a single type of nutrient. She did not mention trophic levels, especially with their scientific terms of producers, and consumers like herbivores, omnivores, and carnivores. To reinforce her knowledge of the difference between the food chain and the food web, she asked a question. The answer of Novice 1 underlined her understanding of the complex relationship in the ecosystem between organisms from the food web. In fact, Novice 1 was asked several questions according to the food web diagram (Webb & Bolt, 1990, p. 188) to reveal her understanding of the relations in the food web. The letters in the food web diagram represented a population. The following questions are targeted to uncover teachers' knowledge of complex relations of the populations in the food web. The questions probed the understanding at different levels of complexity and disclosed the possible misconceptions teachers had. The findings of the sample food web questions presented in relation to common related misconceptions in the groups of "A change in one population will only affect another population if the two populations are related as predator & prey."; "A population located higher on a food chain within a food web is a predator of the next adjacent populations located below."; "A change in the size of a prey population has no effect on its predator population"; "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” (Griffiths & Grant, 1985).

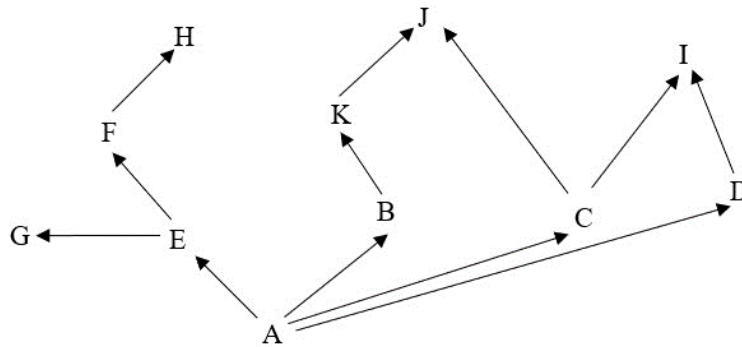


Figure 4.3 A Sample of Food Web (Webb & Bolt, 1990, p. 188)

Group1. “A change in one population will only affect another population if the two-populations are related as predator & prey.” (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population H have on population E? Explain your answer.

N1: What was population H? It was fed on population F. Population F fed on population E. If you decrease population H, this time, the number of population F increases. Increasing population F means decreasing population E. [interview]

I: What effect will a sudden decrease in population E have on the size of population H? Explain your answer.

N1: This decrease indirectly effects population H. Because population F feeds on population E. A decrease in population E

affects population F. The decrease in population F affects E as well. [interview]

The above initial question was asked with the aim of understanding Novice 1's knowledge "to determine the effect of a sudden size change in one population on a second non-adjacent population located lower on the same food chain" (Webb & Bolt, 1990). The second question was targeted to elicit "the effect of a sudden size change in one population on a second non-adjacent population located higher on the same food chain when the effect is transmitted along only one route" (Webb & Bolt, 1990). Novice 1 seemed to be aware the one population will affect another population not only if they are interrelated as predator and prey populations. If the populations are more distantly connected in the food web, Novice 1 appeared to identify interactions of populations correctly.

Group2. "A population located higher on a food chain within a food web is a predator of the next adjacent populations located below." (Griffiths & Grant, 1985).

I: What effect will a sudden increase in population H have on the size of population F? Explain your answer.

N1: Population F... then, their numbers decrease. After all, population H feed on population F. Eventually, population F decreases. [interview]

I: What effect will a sudden decrease in population J have on B? Explain your answer.

N1: If J decreases, can K also increase? Since if K increases, B can decrease. Similarly, what are we looking for? We are looking for the effect on B. If J decreases, C can increase, if C increases, A will decrease. The meaning of the decrease in A will be a decrease in B. Because the food source of B is A [interview]

Above are the food web questions targeted to Novice 1's ability to identify "the effect of a sudden size change in a predator population on its prey population" (Webb & Bolt, 1990). Novice 1 seemed to be able to determine the effect of a sudden size change in a population on a second non-adjacent population located higher on the same food chain where the effect is transmitted along one than one route which was targeted in the second question of Group 2. Indeed, Novice 1 could determine "the effect of a sudden size change in one population on a second population which is not on the same food chain, when the effect may be transmitted along more than one route" (Webb & Bolt, 1990). Hence, she was able to identify the population relations correctly. She did not seem to have a common misconception of populations depicted high on the food chain of the food web will not always be predators of populations lower in the food chain.

Group3. "A change in size of a prey population has no effect on its predator population" (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population F have on the size of population H? Explain your answer.

N1: Population H decreases as well because, here, the energy in F passes to H. If you reduce the energy source of F, the number of population H also decreases. [interview]

I: Write down the letters indicating populations through which the effect of an increase in population A is passed on to population J. Explain your answer.

N1: All of the populations. Because population A is actually the producer here. So, producers will affect all populations. I mean, it

will affect all living things listed here until it until it comes to populations J. [interview]

I: What effect will a sudden increase in population B have on population J? Explain your answer.

N1: The increase in population B... If population B increases, as population K feeds on it, population K increases as well. Then, population J increases. If population B increases... population A decreases. But at the same time population, A is the food source of population C. J is the food source of population C. Yes, it can affect in that way...when population B increases, population C decreases. [interview]

he questions were asked to understand Novice 1's knowledge to determine "the effect of a sudden size change in a prey population on its predator population" (Webb & Bolt, 1990). In that respect, Novice 1 was likely to have knowledge of the relationships of populations identified as prey and predator. In fact, she could both recognize "all the possible pathways through which effect of a change in one population is transmitted to a second" and determine "the effect of a sudden size change in a population on a second non-adjacent population located higher on the same food chain where the effect is transmitted along one than one route" (Webb & Bolt, 1990). It is inferred from Novice 1's responses that she had the conception of a change in the size of a prey population affects its predator population.

Group4. "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" (Griffiths & Grant, 1985).

I: What effect will a sudden increase in population G have on population F? Explain your answer.

N1: A sudden increase in population G means that... population G is a population fed with population E, and if population G increases, the rate of consumption of E will increase but population E, at the same time, is the food source of population F. This means that the food supply of population F also decreases. This situation adversely influences population F and their numbers decrease. [interview]

I: What effect will a sudden increase in population have on the size of population K? Explain your answer.

N1: If I increase, D will decrease, if D decreases, A will increase, if A increases, B will increase. [interview]

The above food web questions were targeted to elicit Novice 1's knowledge "to determine the effect of a sudden size change in a population on a second population not located on the same food chain when the effect is transmitted along one than one route" (Webb & Bolt, 1990). Moreover, she was like to have the knowledge "to determine the effect of a sudden size change in one population on a second population which is not on the same food chain, when the effect may be transmitted along more than one route (Webb & Bolt, 1990). Novice 1's responses revealed that she had an understanding that a change in the size of one population in the food web does not correspond to the change in the other populations of the food web in the same way.

To summarize the findings of Novice 1 related to the food chain and food web, Novice 1 tended to select the proper pathways the populations interact and consider successive predator-prey links. Therefore, Novice 1's responses to the food web and food chain questions indicated her understanding of the complex relations of populations. Hence, she could explain the interaction of the population although the populations are in different pathways. Moreover, she could identify multiple routes

for transmission of the effects. She seemed to have knowledge of the relation that emerged from energy transfer and feeding relations in food chains and food webs. She was likely to interpret the arrows in the food web with their scientific explanation. One of the scientific explanations of arrows in the food web is related to representing which populations have a direct relation to another. Novice 1 explained the arrows as populations' feeding relations and energy transfer between populations in the food web. She could identify producers, consumers, and decomposers in both the food chain and food webs. Moreover, consumers were identified with their roles as herbivores, carnivores, and omnivores. Although when she asked about the flow of energy in the ecosystem, she did not provide a detailed explanation, she explained the flow of energy in food chains and food webs in decreasing amounts to the upper levels.

4.1.2.2.3 Novice 1's Subject Matter Knowledge on Energy Pyramid

Novice 1's SMK on the energy pyramid was delineated through interviews and her concept map drawing. Novice 1's concept map comprised the ecological concept of the energy pyramid (Figure 4.1). She linked the energy pyramid with the concepts of producers, consumers, and decomposers. The statements regarding the energy pyramid in the concept map were "producers take place in an energy pyramid.", "consumers take place in the energy pyramid." and "decomposers take place in energy pyramid.". Although Novice 1 indicated her sound comprehension of the energy pyramid in interviews, she presented a few relations of the energy pyramid in her concept map. In fact, she did not indicate the relation of the energy pyramid with some ecological concepts like ecosystem, energy, populations, photosynthesis, and respiration.

In the interviews, Novice 1 asked several questions to reveal her understanding of the energy pyramid. First, she was asked to define the energy pyramid.

I: What is the energy pyramid?

N1: Energy pyramid is a food pyramid or pyramid formed by organisms. An energy pyramid is a pyramid that illustrates the flow of energy. Who supplies the energy first? Producers supply first. Where do producers get this energy from? They get the energy by producing their own food. That is, the higher energy is on producers. That is, the efficiency of energy is higher on them [producers]. On the other hand, to the higher levels in the energy pyramid - even if it is understood from its [energy pyramids'] shape, the bottom area is greater, it gets smaller in the upper levels – the usable form of energy continually decreases. We can say that energy flows from producers to the consumers. Of course, energy will not be destroyed; however, the usable part of it is reduced. [interview]

Novice 1's definition indicated her understanding of the energy pyramid. She seemed to have an understanding that the energy pyramid represents the percentage of energy each trophic level possesses. In fact, she pointed out producers have higher energy in the energy pyramid placed at the bottom. She also expressed a reduction in energy efficiency at the top levels. Novice 1 mentioned the producers as the first trophic level in the energy pyramid however, she did not express consumers in relation to feeding types as herbivores, omnivores, or carnivores. She specified the consumer's roles when she drew her energy pyramid (Figure 4.4). Figure 4.4 represents Novice 1's energy pyramid drawing.

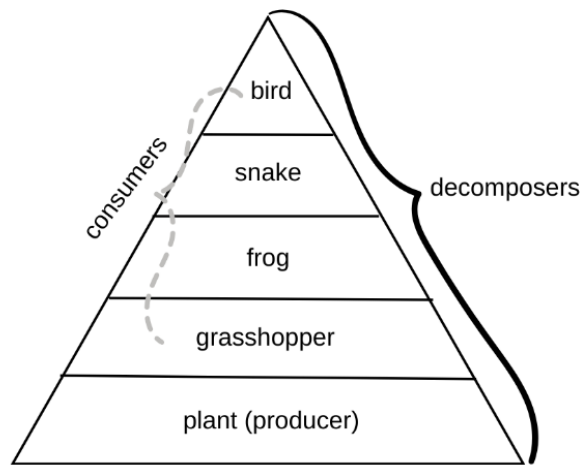


Figure 4.4 Novice 1 Energy Pyramid Drawing (see Appendix B for original drawing)

I: Can you draw an energy pyramid?

N1: There will be a producer, grass, at the bottom of the pyramid then. Followed by the grasshopper, frog, snake, and bird... We called them consumers, right? But here there is such a thing, you know, what we are called producers are plants which occupy the first level. For this reason, there should be more herbivores in the second level, followed by both carnivores and herbivores. What about decomposers? They are everywhere. [interview]

Novice 1's answer implied that she knows the place of producers, consumers, and in the energy pyramid, their trophic levels, and their feeding types as herbivores, carnivores, and omnivores. Novice 1's energy pyramid appeared to be scientifically correct. To reveal her understanding deeply, Novice 1 asked further questions regarding the energy pyramid.

I: Why is the pyramid of energy pyramid in shape?

N1: Because the base of the pyramid is wider, that is, it is larger in volume, and it occupies more space in terms of area. [interview]

I: Does the energy pyramid represent something?

N1: Of course, it tries to explain something the larger area at the bottom means more energy produced by the producers. there may be more producers in nature. When we think in terms of energy, yes, producers produce the most energy, then it [energy pyramid] shows us that the amount of energy decreases as we go up [higher levels]. [interview]

Overall findings of Novice 1 regarding subject matter knowledge on ecology indicated that she had an understanding of basic ecological concepts like species, producers, decomposers, food chain, food web, and energy pyramid. She defined ecosystem, consumer, habitat, extinction-prone species, and biological diversity; however, these concepts were identified to have deficiencies in terms of their scientific definitions. For example, related to the ecosystem she did not mention the interaction of living things among themselves and with non-living things. She defined consumers without mentioning their roles in the ecosystem and did not provide any examples or detailed information. Habitat definition was found deficient in the relation of organisms and the related examples. She underestimated evolutionary diversity in her explanation of biological diversity rather she mentioned species diversity and genetic diversity. Novice 1 did not provide an explanation for the extinction-prone species' characteristics related to their habitat destruction, their difficulties in finding food and shelter, and a decrease in reproduction rate. She had difficulty in defining energy by means of an ecological perspective. She also did not explain energy flow in the ecosystem when she was asked in pre-interviews. She did not include the relation between organisms and the flow of energy in the ecosystem

in her concept map. Although she did not explain the flow of energy when she was asked, Novice 1 explained the food chain and food web relation by means of energy transfer between trophic levels. In addition, she could explain the energy pyramid. Although Novice 1 did not identify the roles of producers, consumers, and decomposers in the food chain and food web, she explained the roles of each trophic level in the energy pyramid. In fact, she integrated an energy pyramid into her concept map in relation to producers, consumers, and decomposers. Related to producers, Novice 1 could identify their food. Although she did not provide the detailed chemical sequence of reactions during photosynthesis, Novice 1 seemed to have an understanding of the purpose of photosynthesis, limiting factors, and its relation with the first and second laws of thermodynamics.

In this section, Novice 1's subject matter knowledge was revealed. In the next section, Novice 1's pedagogical content knowledge in teaching ecology was documented.

4.1.3 Novice 1's Pedagogical Content Knowledge Regarding Teaching Ecology

Novice 1's pedagogical content knowledge (PCK) was investigated in the light of Magnusson et al. (1999) model of PCK in terms of four components. These components are knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment. PCK pre-interviews, PCK post-interviews, lesson plans, and classroom observations were used to set forth Novice 1's PCK regarding teaching ecology. In the present study, the findings related to knowledge of curriculum were collected in 2009-2010. Therefore, Novice 1's knowledge of curriculum findings was analyzed in line with the prescribed ecology curriculum in 2009 by the Türkiye Ministry of National Education (MoNE, 2009).

4.1.3.1 Novice 1's Knowledge of Curriculum

Knowledge of curriculum is one of the components of pedagogical content knowledge referring to teachers' knowledge of the goals and objectives of the subject and specific curricular programs and materials (Grossman, 1990; Magnusson, 1999). Goals and objectives include the knowledge of teachers regarding vertical and horizontal curricula outlined within the national documents. Teachers' knowledge of curriculum programs and materials, on the other hand, consists of knowledge of programs, activities, and materials offered for a specific topic. To get the advantage of the spiral nature of the science curriculum and to gain a deep understanding of science teachers' PCK in ecology, science teachers were analyzed while teaching the 8th-grade ecology unit in the study.

Two constituted components of knowledge of curriculum which are knowledge of goals and objectives, and knowledge of materials are presented in this section under two separate sections. The data on Novice 1's knowledge of the curriculum was collected through pre-interviews, post-interviews, classroom observations, and Novice 1's lesson plan. In the first section, Novice 1's knowledge of goals and objectives on ecology was presented.

4.1.3.1.1 Novice 1's Knowledge of Goals and Objectives

According to the Türkiye national science curriculum (2009), ecology units first appeared in 4th grade as the 2nd unit under the heading of "world of life". The specified objectives in the 4th grade level were "as a result of the observations, students provide daily life examples to living and non-living things", "living and non-living things decided through questioning", "discovering that there are different types of habitats around", "predicting the living things that can be found in a living space.", and "observing and recording living things in a living space around".

Moreover, in the 5th grade ecology was included in the 6th unit named “identifying the world of life and natural life in our country and in the world”. The objectives of the 5th grade ecology unit were “As a result of the observations, students give examples of various living things living in their surroundings.”, “providing examples of living and non-living things unique to their country”, “comparing the similarities and differences in the nutrition of living things in a habitat students observe.”, “constructing a sample food chain illustrating feeding relations of the organism”, “discussing the consequences that may arise with the disappearance of a link in the food chain.” and “searching for endangered species and creating projects to protect these species”. In the 6th grade level, there was not included a unit related to ecology. In the 7th grade level, the 6th unit of “organisms and life” consisted of ecology objectives which “explains the concepts of species, habitat, population and ecosystem and the relations of these concepts.”, “explains the relations of living organisms with each other and non-living factors in an ecosystem, defines food chain and food web, and gives examples.”, “make predictions about living things that can be found in different ecosystems (lake, sea, forest, etc.)”, “recognize and emphasize the importance of biodiversity in the ecosystem.”, “give examples of extinction-prone species in the country and in the world.” and “offer suggestions to protect extinction-prone species.”

In the current study, Novice 1 was interviewed, asked to create a lesson plan, and observed later while teaching ecology to 8th graders. The curricular objectives prescribed by MoNE and related responses by Novice 1 were presented in Table 4.1.

Table 4.1 Novice 1's Knowledge of Goals and Objectives regarding G-8 ecology objectives in the Science and Technology Curriculum (MoNE, 2009)

Unit	Interviews	Classroom observations	Lesson plan
6: Living things and energy relations			
Content: Food chains			
1. Related to organisms in the food chains, students are able to;	<i>They [the objectives] are related to the food chain. In fact, it is the importance of producers in the food chain.</i>	Teacher (T): food chain wouldn't constructed if there were no producer. Because there is no energy source. It won't be a food chain.	Regarding the living things in the food chain, students will infer that producers are located at the beginning of food chains.
1.1. Infer those producers are at the beginning of food chains.			
1.2. List what is required for photosynthesis.	Not mentioned	T: how do plants produce their own food? Student1 (S1): by photosynthesis T: what is required for photosynthesis? S2: sun light, water from the soil and carbon dioxide from the air.	Regarding the living things in the food chain, students list what is required for photosynthesis.
1.3. Observe the necessity of light in photosynthesis by experimenting.	Not mentioned	Not mentioned	Not mentioned
1.4. State that producers produce simple sugars and oxygen by photosynthesis.	Not mentioned	T: What is produced by photosynthesis? What do plants produce? S3: Oxygen T: What is next? S4: Glucose	Regarding the living things in the food chain, students state that producers produce simple sugars and oxygen by photosynthesis.

Table 4.1 (cont'd)

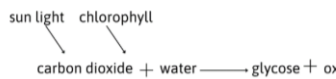
Unit	Interviews	Classroom observations	Lesson plan
1.5. Express photosynthesis with an equation.	<i>There is an equation of photosynthesis [within the objectives of ecology curriculum].</i>	T: If we write the equation of the photosynthesis: carbon dioxide, then? S5: water T: carbon dioxide plus water from the soil, then what is needed to photosynthesize? S6: sunlight S7: chlorophyll T: what is produced in photosynthesis? S8: oxygen and sugar T: sugar is simple sugar, that is glucose 	Regarding the living things in the food chain, students' express photosynthesis with an equation.
1.6. Discuss the importance of photosynthesis for living things.	Not mentioned	T: plants take in carbon dioxide and produce oxygen. Do you think this is the aim of the photosynthesis? S9: I do not think. They photosynthesize to produce their food. S10: I think it is both to produce food and oxygen. T: The main purpose of the photosynthesis is to produce plants their food. Oxygen is given off as the sub-product.	Regarding the living things in the food chain, students discuss the importance of photosynthesis for living things.

Table 4.1 (cont'd)

Unit	Interviews	Classroom observations	Lesson plan
1.7. State that producers convert solar energy into usable energy by photosynthesis.	Not mentioned	T: Plants transform the solar energy into a form that they can use. So, they were producing their own energy, their own food. T: Plant can photosynthesize under the sun light to produce basic sugar.	Regarding the living things in the food chain, students state that producers convert solar energy into usable energy by photosynthesis.

Table 4.2 (cont'd)

1.8. Explain that living things need energy to survive.	<i>There are energies that the other organisms need. There is energy flow within food chains.</i>	Not mentioned	Not mentioned
1.9. Explains that consumers in the food chain meet their energy needs from producers.	Not mentioned	T: plants conduct the photosynthesis to produce food and consumers get energy from the producers.	Not mentioned
1.10. Discuss the importance of respiration for living things.	<i>There are aerobic and anaerobic respirations and their equations.</i>	Not mentioned	Not mentioned
1.11. Define respiration.	Not mentioned	Not mentioned	Not mentioned
1.12. Lists what is required for respiration	Not mentioned	Not mentioned	Not mentioned

Table 4.1 (cont'd)

Unit	Interviews	Classroom observations	Lesson plan
1.13. Indicate the products formed as a result of respiration with oxygen by experimenting.	Not mentioned	Not mentioned	Not mentioned
1.14. Estimate the equation of aerobic respiration as a result of his/her observations.	Not mentioned	Not mentioned	Not mentioned
1.15. Explain that some living things provide the necessary energy to survive without using oxygen.	Not mentioned	Not mentioned	Not mentioned
1.16. Gives examples of anaerobic respiration from daily life.	Not mentioned	Not mentioned	Not mentioned

Table 4.2 (cont'd)

1.17. Establish a relationship by comparing the aerobic respiration equation with the photosynthesis equation.	Not mentioned	Not mentioned	Not mentioned
1.18. Explain the relationship between producers and consumers in terms of nutrition and energy flow.	Not mentioned	T: Who used the energy produced by plant? (Referring to the food chain example in the textbook) S11: rabbit. T: the arrows in food chain show energy transfer. Then, the energy passes from rabbit to whom? S12: to snake.	Not mentioned

Table 4.1 (cont'd)

Unit	Interviews	Classroom observations	Lesson plan
1.19. Explains the material cycles in parallel with the energy flow in the food chain.	<i>There are matter cycles that are parallel to food chains.</i>	Not mentioned	Not mentioned

Overall data revealed Novice 1's knowledge of the goals and objectives of the ecology curriculum. For example, the pre-interviews, her lesson plan, and classroom observations revealed that she could identify the objectives regarding producers, food chains, photosynthesis, and matter cycles apart from respiration (Table 4.1). Novice 1 was found to be well-informed about curricular objectives and purposes. However, she seemed to have difficulty in the place of ecology in the 8th-grade curriculum. In pre-interviews, she hardly provided the correct response to the place of ecology curriculum. That is, she was likely to be unsure about the grade levels of ecology taught in the elementary school curriculum. She taught ecology topics in 7th grade, she appeared to answer the place of ecology unit confidently in 7th grade in contradiction to the other grade levels in pre-interviews. Moreover, she seemed to know the horizontal and vertical relationship. In fact, Novice 1 could state the related units in 8th grade and the previous grades ecology taught. She also had comprehension of misconception cautions in objectives she expressed in pre-interviews.

In pre-interviews, Novice 1 asked about the place of ecology in the elementary school curriculum program.

I: Do you know the place of ecology in science curricular programs?

N1: They were in both 7th and 8th grades. But, not in 6th grade, I think. Ecology units also appeared in primary education; either in grade 4 or 5, I don't know exactly. In the teacher's guidebook, it is

written that the topic should be related to the 'Man and the Environment' unit that was taught in the 4th grade... but I'm not entirely sure it can be either 4 or 5 or both. But grades 7 and 8 have it. [pre-interview]

Although remained hesitant about the place of ecology units in the Grade 8 curriculum, Novice 1 correctly stated the place of ecology in other grade levels. According to MoNE (2009), ecology units were included in the 4th, 5th, 7th and 8th-grade levels.

Although Novice 1 responses related to the grade levels ecology taught seemed to have uncertainty, she knew the place of the ecology in previous grades indicating her knowledge of vertical relations of ecology.

I: In 8th grade, in which unit, ecology is taught?

N1: In which unit? I think it was in the 7th unit... towards the end [of the unit]. I don't remember...just before the last one. [pre-interview]

Similarly, Novice 1 appeared to not be certain about the unit of the 8th-grade level ecology. The 8th grade ecology was included in the 6th unit which was “Living things and energy relations”. Therefore, she was wrong about the place of ecology in 8th grade.

I: Is there any science unit taught in 8th grade associated with ecology?

N1: In 8th grade, there is a unit which is adaptation, etc... related to ecology. They will learn additional concepts of ecology like aerobic respiration, material cycle and anaerobic respiration [pre-interview]

The question targeted to assess Novice1's understanding of horizontal relationships. In fact, she was likely to be aware of the horizontal relationship. She could associate adaptation with ecology. The 8th-grade science curriculum included the adaptation and evolution in the 1st unit, 5th content.

Novice 1 asked the purpose of the ecology topic in the science curriculum.

I: What is the specified purpose of the ecology in the program?

N1: The purpose of ecology [teaching] may be to relate the ecology to the units that children have seen in previous years.

We had a unit similar to this one [Living things and energy relations] in 7th grade; it was about the food chain and food web. I taught energy flow in the food chain in this unit and in this past unit, I taught food chain, food pyramid and food web. Now, they [students] learnt new things to build on what they had already learned in the previous year [in 7th grade]. That is to say, this year [grade 8], they will learn additional concepts of ecology like aerobic respiration, material cycle and anaerobic respiration [pre-interview]

I: I want to ask whether you find these aims appropriate.

N1: The purposes may be correctly specified. We started teaching the topic in 7th grade, but not cover completely. We said that you will learn more about ecology next year. I think it is not appropriate to say that. On the other hand, if we teach all of the content in the 7th grade, there will be no time left for other topics. But it seems not appropriate to leave some contents to the 8th grade... [pre-interview]

Novice 1 indicated that ecology is placed in the 8th-grade science curriculum because of the spiral curriculum offered by MoNE. The specified purpose of the ecology in the 8th-grade curriculum was “In this unit, students are aimed to understand photosynthesis, respiration, energy transformations, to explain the food chain and the elements that make up this chain, to discover the relationship between the elements, to realize the material cycles in life-related to environmental science, to know environmental problems and to offer solutions to environmental problems, to gain interest and skills in these.” (MoNE, 2009). Novice 1 neither stated the purpose of the ecology unit consistent with the prescribed program nor mentioned that much of the related contents shape the purpose of the ecology curriculum during pre-interviews. Although Novice 1 mentioned the purpose of the 8th-grade ecology unit as to associate the ecology contents they learnt in 7th grade that was related to the food chain, food web, food pyramid to the contents they learnt in 8th grade expressed as aerobic respiration, material cycle and anaerobic respiration. That is, Novice 1 indicated the spiral curriculum helps students to associate the concepts they learned previously. She mentioned she taught energy flow, food chain and food web in 7th grade and students learned related topics of aerobic respiration, anaerobic respiration and matter cycles. In fact, classroom observation findings were consistent with the pre-interview responses. In the classroom observation, Novice 1 was observed to remind the students about the previous years’ topics about ecology. She reminded the objectives they learnt the previous year during the classroom observations. The sample excerpts from the classroom observations are provided below.

Teacher (T): What did we [the students] learn last year [in 7th grade]? Let's take a look at our topics [students are supposed to learn] first. Maybe it [8th grade's topics] has some connotations to you. In 8[8th grade], we have 3 topics: energy flow, matter cycles, and lastly, energy sources and recycling. Frankly, last year we

mentioned the food chain and even the food web. Well look, there is a picture on page 183 on the side. They showed something with arrows there. Veli, yes, what could it be?

S1(Student1): For example, the arrows point to the predator that some consumers ate the producer, while on the other side is prey eaten by the predator.

T: Well, you said producer, you said consumer, we learned all these last years? Then, tell me, what is a producer?

S2: The organisms producing...

T: What do they produce?

S3: Producers produce food and the consumers consume this food.

[classroom observation]

Apart from reminding prior knowledge of students in her lesson, in classroom observations, Novice 1 observed strictly following the prescribed curricular ecology objectives determined by MoNE in 2009. As provided in Table 4.1, Novice 1 stated goals and objectives in her lesson plan parallel to the determined curricular program by MoNE in 2009. In line with her lesson plan, Novice 1 observed that practising ecology teaching depends on the prescribed objectives in the teachers' guidebook and her lesson plan. Novice 1 tended to not exceed the degree of curricular knowledge regarding goals and objectives of ecology while preparing lesson plans and teaching in the class. Because Novice 1 could be observed for two lesson hours, she prepared her lesson plan accordingly and stated the objectives that can be accomplished in two lesson hours. The reason for the limited objectives provided

regarding respiration in Novice 1's lesson plan and classroom observation findings in Table 4.1 could be Novice 1's preparation for two lesson hours.

I: Do you think that the objectives of the ecology unit are suitable for the class levels?

N1: I think they [objectives of the ecology] are suitable because students can understand them [ecological concepts and issues] very easily. There are some misconceptions, especially about photosynthesis and respiration. You have to warn them about how and when photosynthesis takes place and when respiration occurs. We have been teaching the same concepts for years. Students are found to have similar misconceptions that photosynthesis takes place during the day, respiration occurs at night. It is difficult to eliminate such misconceptions, but I tried to remediate them as much as I could. Other than that, I don't think it's something they can't understand. The topics are not only suitable for their grade level but also applicable to their daily life. It is a subject that students constantly encounter in their daily life... Students, therefore, should learn concepts of ecology... [pre-interview]

I: You mentioned about misconceptions students in ecology. Then, is there any information provided in the curricular program to warn teachers about misconceptions?

N1: Yes, there is. The teachers' guidebook contains warnings about some contents like "there is such kind of incorrect thought about this content, and this must be corrected", I think that is a good thing. Because sometimes a teacher can have the misconception too. S/he can say "Yes that is true for me also", and then s/he can try to correct

his/her misconception. If a teacher is not aware of such kind of incorrect thought, then the students cannot recognize it too, hold the same misconception. [pre-interview]

Novice 1 stated the objectives in the 8th-grade ecology unit related to the food chain, photosynthesis and material cycles. However, she appeared to not be knowledgeable in some of the determined objectives prescribed in the 8th-grade curricular program offered by MoNE in 2009 (Table 4.1). For example, the objectives related to respiration was appeared to underestimated. Besides, she mentioned the energy sources which was the next content of the ecology when she was asked about the appropriateness of the objectives in terms of skills that tend to be achieved.

Novice 1 seemed to find ecology objectives suitable for the class levels. She pointed out the fact that students learn ecology concepts easily. Moreover, she mentioned the ecology concepts being adaptable to students' daily lives makes the concepts learned easily making ecology objectives suitable in terms of class levels. She also stated students' misconceptions about ecology. In fact, Novice 1 was aware of the misconception cautions in the teachers' guidebook provided by Türkiye MoNE in 2009. Teachers follow the objectives and explanations about the content they teach from these guidebooks. She stated that these misconceptions provide teachers with help to be aware of the possible misconceptions in the ecology to take precautions to detect and remedy.

In summary, Novice 1 appeared to not be certain of the place of ecology in the curriculum in 8th grade. However, she had a comprehension of horizontal and vertical relations of ecology. Although she did not express some ecology objectives, the objectives she mentioned were consistent with the curricular program and also she prepared lesson plans and classroom observations. She seemed to follow a determined ecology program strictly she prepared her lesson plan and practiced

teaching ecology accordingly. She was aware of the misconceptions provided in the program. The ecology objectives were set by Novice 1 appropriate in terms of students' knowledge levels and skills aimed to be achieved.

The next part presented Novice 1's knowledge of materials which is another sub-component of knowledge of the curriculum aspect of PCK.

4.1.3.1.2 Novice 1's Knowledge of Materials

Novice 1 was found to use few materials in her ecology teaching. Briefly, she used teachers' guidebooks, students' workbooks, notebook and board. She mainly used students' workbooks to follow the content and made students exercise about the ecology topics and issues. Table 4.2 summarizes the Novice 1's mentioned and used instructional materials that promote her ecology teaching.

Table 4.2 Novice 1's Knowledge of Materials

Materials used	Interview questions	Lesson Plan	Classroom observations
Teachers' guidebook	<i>It [the aim of to use teachers' guidebook] is to teach the lesson better [pre-interview]</i>	Materials and equipment used (students/teachers): workbook, teachers' guidebook, board, chalks (see Appendix K & L)	Novice 1 followed of the prescribed content from teachers' guidebook (MoNE, 2009).
Students' workbook, notebook	<i>They [the aim of to use students' workbook, notebook] are to teach the lesson better, to enrich the lesson, to ensure students' understanding. [pre-interview]</i>	Materials and equipment used (students/teachers): workbook, teachers' guidebook, board, chalks (see Appendix K & L)	Used to make students enroll to the lesson, to repeat and to evaluate the learned content.
Board	<i>It [the aim of using teachers' guidebook] is to teach the lesson better, to enrich the lesson, to ensure students' understanding. [pre-interview]</i>	Materials and equipment used (students/teachers): workbook, teachers' guidebook, board, chalks (see Appendix K & L)	Used to make the content concrete with drawing figures and writing concepts to make concepts better understood by students.
Experiment materials	<i>It [my ecology teaching] would be more effective, if I could perform the related experiments suggested in the guidebook and use these experiments' materials. [post-interview]</i>	Not mentioned	used to take students' attention and interest.
Computer	<i>If I had a computer [in my classroom] I could show animations to the students by using this computer [post-interview]</i>	Not mentioned	Not mentioned

To understand Novice 1's knowledge of materials, she was asked related questions before classroom observations. The excerpts from pre-interviews were presented below.

I: What kinds of materials do you use for ecology teaching?

N1: Textbook, teacher's guidebook, board, chalks, eraser...I used the materials of the experiment I conducted last year. In fact, I did a yeast experiment. There is nothing [the materials used in ecology] apart from all these [textbook, teachers' guidebook, board, chalks, eraser and the yeasts experiment's materials]. [pre-interview]

I: Then, what was your aim to use these materials?

N1: It [my aim] is to teach the lesson better, to enrich the lesson, to ensure students' understanding. [pre-interview]

I: Do you think the materials you used in your ecology lesson were effective?

N1: I did not use too many materials. I used a guidebook, notebook, and board as you see [the materials found in the classroom were seen in the interviews by the researcher]. I tried to use them effectively. [pre-interview]

I: So, are there any materials that you cannot reach for some reasons; however, you want to use?

N1: Of course, there are. I did not use some of the experimental materials involved in the activities because I did not have time to do the activity, as I said, due to time constraints. [pre-interview]

I: What kinds of materials are they, for instance?

N1: For instance, test tube. The plant will breathe, and you will collect carbon dioxide gas. There were such things [activities] that can be done with test tubes. That is tubes that can be used in chemical experiments, for instance. [pre-interview]

Novice 1 stated her purpose to use the materials in her lesson to provide students with better learning opportunities in ecology during pre-interviews. Although Novice 1 mentioned that she used the materials effectively, she thought that she would like to use materials to conduct experiments related to ecology to make students comprehend the ecological concepts and issues better. In fact, she expressed to conduct an anaerobic respiration experiment with the related materials that she aimed to take students' interest and attention to the content previous year when students were in 7th grade.

Parallel to the pre-interviews, Novice 1 used the teacher' guidebook provided by MoNE, the board and the students' workbook in her lessons. In the lessons, she asked students to do activities in their workbooks and made them write notes on their notebooks related to ecology. Besides, the mentioned experiment in the pre-interviews was not observed during classroom observations as it was said to be conducted in 7th grade. However, for this experiment, she explained the materials she used as yeast, sugar, bottle, balloon and hot water. Yet, she was not observed to conduct any experiments and activities besides using questioning and making students draw food chains and energy pyramid figures on the board during classroom observations. To understand her views and purposes to use the materials in her lessons, she was asked further questions after classroom observations.

I: Which materials did you use in your lesson?

N1: I did not use so many materials as you already saw. I used notebooks, books, backboard, etc. [post-interview]

I: Then, were these materials you used effective?

N1: They [the materials I used were] are effective as possible. [post-interview]

I: So, what would be more effective instead of these materials?

N1: If I had a computer, it [my ecology teaching] could be more effective. I could show animations to the students by using this computer. And it [my ecology teaching] would be more effective if I could perform the related experiments suggested in the guidebook and use these experiments' materials. [post-interview]

To conclude, Novice 1 appeared to have knowledge of goals and objectives. Regarding knowledge of materials, she preferred to use textbooks, workbooks and teachers' guidebooks as the main materials in her ecology lesson. Although she was aware of the other materials that can be used in ecology teaching like computers, experimental materials and activities, she stated the reason for not preferring to conduct activities and experiments because of the time constraints. In this section Novice 1's knowledge of the curriculum with the sub-sections was presented, the next section documented Novice 1's knowledge of students' understanding of science.

4.1.3.2 Novice 1's Knowledge of Students' Understanding of Science

Novice 1's knowledge of students' understanding of science was presented in two sub-components which are knowledge of requirements for learning and knowledge

of students' difficulty regarding ecology. Novice 1's knowledge of requirements for learning regarding ecology was explored in terms of teachers' knowledge of variations in approaches to ecology learning which include considering students' developmental level, learning styles and abilities and teachers' beliefs about prior knowledge that students possess in a specific ecology concept. Knowledge of students' difficulties regarding ecology was investigated in terms of students' difficulties, errors and misconceptions with their reasons.

4.1.3.2.1 Novice 1's Knowledge of Requirements for Learning regarding Ecology

Novice 1's knowledge of students' requirements, learning styles and prior knowledge in ecology was aimed to be presented through pre- and post-interview questions, Novice 1's lesson plan and classroom observations in this section.

Novice 1 mentioned students' requirements for learning ecology as providing daily life examples and adopting lessons according to students' prior knowledge and students' learning styles. She thought that students need to learn ecology to be competent and knowledgeable in ecological issues to deal with real-life problems. Novice 1 mentioned students' experience with a disease which was avian influenza which happened a few times before the data collection. Novice 1 stated that her students were able to associate this case with previously learned ecological concepts and issues. Hence, she explained that the students need to relate what they learned to their daily lives. Novice 1 also stated students' prior knowledge as necessity for learning ecology. Although she did not express students' prior knowledge in interviews regarding ecology, she listed students' prior knowledge in her lesson plan prepared before the lesson. In the lesson regarding ecology, she started by reminding students prior the knowledge they learnt before. Moreover, related to student requirements for learning ecology, the learning style of the students was mentioned

in terms of promoting students' motivation, and interest for effective learning. Table 4.3 presented the gathered insights of Novice 1's knowledge of requirements for learning regarding ecology.

Table 4.3 Novice 1's Knowledge of Requirements for Learning regarding Ecology

Requirements for learning ecology	Interviews	Lesson Plan	Classroom Observation
Relating with daily life	<i>While I was teaching food chain and food web, this event [the killed chickens because of the avian influenza result of increase in numbers of ticks] actually happened...[pre-interviews]</i>	Not mentioned	T(teacher): Which organism are producers? S(student)1: plants. T: Which organisms are primary consumers then? S2: Animals. T: Could you provide examples for these animals? S3: Grasshopper, butterfly and frog. T: Last year, you learnt food chain and food web... T: Did you remember producers, consumers and decomposers you learnt last year? T: We talked about producers; do you remember what are the producers? T: We drew food chains last year...
Prior knowledge	Not mentioned	Students' prior knowledge: In previous years, students had learned the basic concepts of "ecosystems", "food chain", "food web"(see Appendix)	
Learning style of the students	<i>When you consider the learning style of the students and when you take them to a trip and field observation, student will learn the subject better and will like the ecology better.</i>	Not mentioned	Not mentioned

I: What are your goals and purposes in teaching ecology?

N1: Maybe, it is about understanding the prey-predator relationship in daily life. When avian influenza emerged last year, it destroyed the chickens in the environment and as we experienced, the number of ticks has increased. While I was teaching food chain and food web, this event actually happened. It was about the end of the semester last year. They said "Teacher we killed the chickens, they were eating the ticks, so the number of ticks increased now" They did not mention the flow of energy in the food chain but they said, "The chickens were eating them [ticks]...". At this stage, that is a good thing for them [students] to be able to state this issue like that. [pre-interview]

I: In ecology teaching, what do you think about students' requirements?

N1: In ecology teaching, students' past experiences like watching documentaries related to content may increase the motivation of the students. When you consider the learning style of the students and when you get them on a field trip and make an observation, the student will learn the subject better and they will like the ecology more. [pre-interview]

Novice 1's knowledge of the requirements for learning ecology was gained in pre-interviews. She mentioned students' requirements to associate the learning content with their daily lives and adjust teaching by considering the learning style of the students. She pointed out these requirements enable students to learn ecology effectively. In the lesson plan Novice 1 prepared, she stated students' pre-requisite knowledge in ecology as an ecosystem, food chain and food web (Table 4.3). She added also environmental problems students learnt in 7th grade. On the other hand,

she did not include ecological concepts like species, population, habitat, and biological diversity that students learned previously. Although she did not list producers, consumers and decomposers in her lesson plan as prior knowledge, she observed to recall students these concepts they learned in her lessons. In fact, Novice 1 was observed to remind students' prior knowledge consistent with her lesson plan. In classroom observations, she asked students questions about the ecosystem, food chain and food web at the beginning of the lesson (Table 4.3). The related excerpt from classroom observation is provided below.

T: Last year, you learnt food chain and food web...what was the food chain?

S1: It was some consumers who ate some producers.

T: You said producers, consumers... Do you remember what the producers, consumers and decomposers you learned last year? Well, we talked about producers; do you remember what are the producers?

S2: Producers produced food; consumers consumed this food.

T: What were producers?

S3: Plants.

S4: For example, trees.

T: What were consumers?

S5: Animals.

T: We talked about these consumers divided as omnivores, carnivores and herbivores. What were decomposers, then? We learnt this concept [decomposers] last year, do you remember?

T: We learnt food chain as well. We drew a food chain last year. Is there anyone who can draw a food chain on the board?

S6: (drawing a food chain on the board) The first [level of the food chain] is plant, the second [level of the food chain] is frog, the third [level of the food chain] is snake and the last one [level of the food chain] is eagle.

[classroom observation]

To summarize, Novice 1 stated students' prior knowledge, relating learning content with daily life and taking into consideration students' learning styles were the requirement of students to learn ecology. Regarding students' prior knowledge, Novice 1 was found to express producers, consumers, decomposers, food chains and food web in ecology. She ignored the other ecological concepts like species, population, habitat, and biological diversity. She mentioned the importance of facilitating the learning environment to students according to their learning style like watching documentaries, field trips, and observations. Novice 1's knowledge of students' areas where students experience difficulty difficulties was presented in the next part as the other sub-component of Novice 1's knowledge of science learners.

4.1.3.2.2 Novice 1's Knowledge of Students' Difficulties regarding Ecology

In this section, Novice 1's knowledge of students' difficulties was documented. Pre- and post-interviews, Novice 1's lesson plan and classroom observations were the data sources. The findings revealed that although Novice 1 could hardly mention

students' misconceptions and learning difficulties in the pre-interviews before practising teaching ecology for 8th grade, she could state several misconceptions and their learning difficulties in post-interviews after teaching ecology for 8th grade. She also highlighted some of the mentioned misconceptions and difficulties during interviews in her lesson. The findings showed that Novice 1 stated students' learning difficulties in the flow of energy in ecosystems, drawing arrows in energy flow, producers photosynthesis and respiration. She pointed out students' misconceptions about the ecological concepts of producers, ecosystem, producers' food, arrows in the food chain, respiration and photosynthesis.

I: Do your students have difficulty understanding ecological concepts?

N1: I mean, they [students] may have difficulties in energy, they [students] may have difficulties in energy flow, but when we say that they [organisms] are eating this and that [organism], they [students] understand. But they [students] can have difficulties in energy. So, the more abstract the concept becomes, the more difficult it [concept] becomes to understand. Because for children at this age, apart from this age, many people do not understand [energy concept] even at university. They [people] may not be interested, you know, even if s/he says. [pre-interview]

I: Then, what are the ecological concepts that students experience more difficulty with?

N1: For example, they [students] may not understand the directions of the arrows in the food chain. One [organism] eats the other one [organism]. So, s/he draws an arrow from the grasshopper to the plant because the grasshopper eats grass. They [students] can reverse

the direction of the arrows. What else could it [ecological concepts that students experience more difficulty] be? I mean, as I said, I don't remember very well because [last semester, Novice 1 taught ecology] was the end of the semester and I just started teaching. [pre-interview]

Similar to the previous response, Novice 1 mentioned students' difficulties in the flow of energy in ecosystems. She indicated that students have difficulty drawing arrows to explain the energy flow between organisms in the food chain. Moreover, she expressed that she did not have enough experience to explain more about students' difficulties in ecology. Novice 1 also asked about the concepts students learn easily.

I: What are the concepts that students learn easily?

N1: The easiest... maybe they [students] can understand that the plants are producers but there is also a misconception about producers, we are also producers. when we say, producers... For example, we plant something in the fields, so they confuse being a producer with it [planting something in the field]. Yes, there is such a misconception among children. [pre-interview]

I: Then, I would like to ask you what is a misconception.

N1: What is a misconception...I may not be able to give a full definition, but we can say that the knowledge about a concept is not actually correct. [pre-interview]

I: What are the main misconceptions students possess you detected in ecological concepts?

N1: Frankly, I have been a teacher just for 11 months. I could not detect a certain misconception in my experience, to tell the truth. [pre-interview]

I: Okay, then, how do you understand that if your students have misconceptions?

N1: Firstly, as a teacher, we need to recognize them [misconceptions]. As a teacher, we need to have sound content knowledge... You have to know a concept accurately to recognize your students' wrong comprehension of the concept. When the misconception is recognized, you can direct questions to the students to remedy this wrong knowledge. [pre-interview]

I: Are there any methods to determine these misconceptions?

N1: Question and answer and also concept association techniques like concept map for instance. [pre-interview]

I: What are the sources of misconceptions then?

N1: Now the teacher is a very serious resource. Because what the teacher says, our teacher says it's true, isn't it? You know, the source of the primary misconception can be the teacher and its [misconceptions caused by teachers] effects can be very serious. The second can be family. That is the environment in which they [students] live. After all, if s/he learned something from her/his parents, it is difficult to change if we learn information as misconceptions, and if the information has come from the family since childhood... yes, it is difficult to change it [misconception] with this child. Because it [misconception] shows resistance to change. What else could this

misconception information be?... we said that it is affected by the family, we said, it is affected by the teacher, at work it may be affected by the environment, it may be affected by the environment of friends, or it is affected by the newspaper he reads at work, it is affected by the television he watches, after all... [pre-interview]

Novice 1 defined misconceptions as wrong understanding of students a concept. She seemed to not be able to detect students' misconceptions in ecology. However, Novice 1 seemed to have knowledge of misconceptions that influence students learning, that are pervasive and difficult to change. She related detecting students' misconceptions with teachers' professional development and having sound content knowledge. She figured out to have sound content knowledge in order to grasp students' misconceptions. Novice 1 indicated the methods to elicit students' misconceptions were questioning and concept maps. However, she did not mention quizzes, discussions, and short tests to identify misconceptions in ecology. As a way of remediation of students' misconceptions, Novice 1 mentioned the questioning method. However, the methods of conceptual change approach, analogy, and conceptual change texts to eliminate students' misconceptions were not mentioned. She identified the sources of the students' misconceptions as the first source, teachers. Other sources mentioned were students' families and environmental factors like media.

Before classroom observations, Novice 1 was asked to prepare a lesson plan. In her lesson plan within the summary section, she wrote in the end part that "Through question and answer, students' learning deficits and misconceptions will be tried to be determined" (see Appendix K for Turkish; see Appendix L for English). She seemed to deal with students' learning difficulties and misconceptions according to her lesson plan. In fact, in her lesson, she was observed to use questioning to understand students' prior knowledge and understanding regarding ecological

concepts and issues. On the contrary, there were observation notes that she ignored students' wrong answers those were the possible students' misconceptions. However, she seemed to ignore them. The related excerpt is provided below.

T: What are producers?

S1: Can we say egg?

T: Did you remember the producers, consumers and decomposers you learned last year? We talked about producers; do you remember what are the producers?

S1: Then, I suppose the producer is chicken; the consumer is egg.

T: We need to change our vision.

S2: Decomposers can be called soil.

T: We are not talking about decomposers now.

[classroom observation]

Besides, in the lesson, Novice 1 highlighted and provided explanations for some concepts and issues students have misconceptions about or experience difficulty in learning. The related excerpt is provided below.

T: After the discussion regarding producers let me briefly summarize. Producer means the organisms using the sunlight, taking in carbon dioxide from the air, plus having water to produce their own food themselves. [classroom observation]

T: In the food chain, producers produce energy. So, the food chain needs to start with producers. There should be a source of energy at

the beginning. Then, we draw consumers. After producers, we place herbivores. Then we can continue with carnivores, omnivores or vice versa. The arrows in the food chain represent the energy transfer.
[classroom observation]

Consistent with the classroom observation, Novice 1 stated several misconceptions she captured and students' difficulties in ecology during post-interviews conducted after classroom observation. The related post-interview excerpts are presented below.

I: What were the students' difficulties in ecological concepts?

N1: Photosynthesis and respiration are not very easy concepts for students to understand. They are very abstract concepts. They [students] have difficulties in understanding how a plant could be a producer. Pronouncing it as "producer" in the Turkish version may cause the problem as well. [post-interview]

I: What were the main misconceptions students possess you detected in ecological concepts?

N1: Let me give you an example, when we say ecosystem, I remember students suppose only living organisms. They did not include non-living things. If you talk about a mountain ecosystem, they tell you all about bugs and bushes on this mountain. Sometimes we can even exclude plants from the ecosystem.

There was also another misconception that I experienced which is plants respire in the morning, and photosynthesize at night. I taught students that plants respire both at night and daytime and

photosynthesize only daytime in each lesson. On the other hand, students insist on answering similarly.

There was a misconception of students related to the food chain. I taught the arrows even at 7th grade and I taught it [the arrows in food chain] this year [at 8th grade] again. They drew the directions of the arrows in reverse; in fact, they [the arrows in the food chain] indicate the flow of energy. Rather who eats whom?

The plants are getting their food from the soil, here is another misconception. This misconception was also included in the textbooks with the explanation that; if the plants are getting their food from the soil the mass of the soil should decrease. But when you grow plants in a flowerpot, the amount of soil is not reduced. I informed the students that these plants not causing a decrease in the soil. [post-interview]

I: So, how did you help students remedy students' misconceptions about ecology?

N1: What did I do? I tried to determine what I did first. So, whether there are misconceptions in that class or not. At least, I tried to identify the misconceptions that I knew and the misconceptions that I was aware of in students. Then, there's the soil example [provided in the guidance book]. For example... I tried to create an imbalance in children, whether the soil of the plants is decreasing or not. Yes, in this case, it doesn't happen that way... I told them to question themselves. [post-interview]

Novice 1 seemed to identify the sources of ecological concepts students have difficulty and misconceptions as the concepts which are abstract like energy, photosynthesis and respiration causing confusion because of the daily life language. Before classroom observation, Novice 1 provided the least students misconceptions and explanations for the strategies to identify and recover students' misconceptions. Conversely, during the post-interviews, she explained plenty of students' misconceptions and the ways of replacing the misconceptions with scientific conceptions. For example, she stated that students have difficulties in energy, production, photosynthesis and respiration and misconceptions about ecosystems when plants carry out photosynthesis and respiration, the arrows in the food chain and plants' food.

All in all, Novice 1 seemed to know students' difficulties regarding ecology. However, she appeared to have a partial understanding of misconceptions she defined misconceptions as students' wrong learnings. Novice 1 emphasized the impact of teachers' experience and content knowledge on detecting and recovering students' misconceptions. She provided students' misconceptions in ecology as ecosystem, respiration and photosynthesis, producers' food and the producers. She expressed questioning and concept mapping as the methods to eliminate students' misconceptions. Novice 1's knowledge of students' difficulties regarding ecology and stated elimination methods were presented in Table 4.4.

Table 4.4 Novice 1's Knowledge of Students' Difficulties regarding Ecology

Pre and Post Interviews		Lesson Plan	Classroom Observation	
Learning Difficulties	Elimination Methods	Trough question and answer, students' learning deficits and misconceptions will be tried to be determined (see Appendix K & L)	Learning Difficulties	Elimination Methods
Flow of energy in ecosystems	Question and answer		Not mentioned	Not mentioned
Arrows in food chain	Concept map		Not mentioned	Not mentioned
Producer			Not mentioned	Not mentioned
Photosynthesis and Respiration			Not mentioned	Not mentioned
Misconceptions	Elimination Methods		Misconceptions	Elimination Methods
Producer	Question and answer		Producer	questioning
Ecosystem	Concept map		Arrows in food chain	
Plants' food				
Photosynthesis and Respiration				
Arrows in food chain				

In the current section, Novice 1's knowledge of students' understanding of science was documented with the sub-components which are knowledge of requirements for learning regarding ecology and knowledge of students' difficulties regarding ecology. The next section presented Novice 1's knowledge of instructional strategies.

4.1.3.3 Novice 1's Knowledge of Instructional Strategies

Novice 1's knowledge of instructional strategies was reported in two parts. In the first part, Novice 1's subject-specific strategies were reported. Novice 1's topic-specific strategies were presented in the second part. Novice 1's knowledge of

instructional strategies was gathered through pre-post interviews, lesson plans and classroom observations.

According to collected data, Novice 1 preferred to use direct teaching, questioning and demonstration as the subject-specific instructional strategies. She used figures, daily-life examples and comparisons, analogies and metaphors for topic-specific representations. She was elicited to specify the topic-specific activities as experimentation, project-based learning, problem-based learning and simulations/animations. Novice 1's knowledge of subject-specific strategies presented in the next part.

4.1.3.3.1 Novice 1's Knowledge of Subject Specific Strategies

The collected data from pre- and post-interviews, lesson plans and classroom observation were for Novice 1's knowledge of subject-specific strategies. The findings revealed that Novice 1 was likely to use direct teaching and questioning in general. In fact, she used direct teaching and questioning in her lesson regarding ecology. Table 4.5 presents Novice 1's knowledge of subject-specific strategies.

Table 4.5 Novice 1's Knowledge of Subject Specific Strategies

Subject Specific strategies	Interview	Lesson plan	Classroom Observation
Direct teaching Questioning Demonstrations	<i>I prefer lecturing, I use question and answer, or I do demonstrations in general. [pre-interview]</i>	Teaching and learning strategies, methods: lecturing and question and answer (Appendix K & L)	She was observed to use <i>direct teaching and questioning</i> .
Project based learning	<i>Some projects can be developed actually, a project-based learning can be provided. [pre-interview]</i>	Not mentioned	Not mentioned
Problem-based learning	<i>You may provide a case and set a problem-based learning. [pre-interview]</i>		

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

N1: I am a very new teacher, I am very inexperienced, there are a couple of teaching techniques that I use in general, either I do lectures, I do questions and answers, or I do demonstrations. Apart from that, there are many methods and techniques that I do not know how to integrate them into the subjects. [pre-interview]

I: Apart from these instructional strategies, which types of instructional strategies do you think of to use? What kinds of teaching strategies can be used for ecology?

N1: Hmm, some projects can be developed actually, a project-based learning can be provided, for instance. Because there are lots of things to be done regarding photosynthesis. You may provide a case

and set a problem-based learning. You can give a case saying like "What if that was like this...". It [instructions] can be amplified with activities or different teaching methods. [pre-interview]

I: What is the applicability of these methods? Do you apply these methods in your lessons?

N1: I think they [project-based learning and problem-based learning methods] can be applied but only if you have enough time. We [teachers] have a very serious time problem. We are making the annual plan with assigned units to the last date of the school determined as the 18th of June [in 2010, the date which the schools are closed]. However, I needed to have two more weeks to finish all of the units on time. For example, the SBS [National Central Examination for transition to Secondary Education in Turkey] is a serious difficulty for us [teachers]. [pre-interview]

Novice 1 tended to prefer direct instructional strategies, questioning and demonstration methods to teach science. She prepared her lesson plan accordingly. She stated the instructional strategy and method in the part of teaching and learning strategies in the lesson plan as “lecturing and question and answer” (Table 4.5). In fact, during classroom observations, Novice 1 used direct instruction and questioning in accordance with her interview responses and lesson plan prepared regarding ecology. Novice 1 explained the reason for choosing those limited kinds of instructional strategies to be an inexperienced teacher and time constraints in interviews. She was likely to be aware of the fact that there are many kinds of instructional strategies that could be used in science teaching. However, as she mentioned in post-interviews, she preferred to use questioning. The related post-interview excerpt is provided below.

I: When you were planning a science lesson, what were the things you took into consideration?

N1: I considered the questions that I asked students to take their attention. Because you need to attract the students' attention, you start a new unit, and you need to raise curiosity with questions. You need to make them [students] have question marks in their minds. To be clear, I do not remember how I started the lesson [observed by the researcher] but the important thing here is if you attract the student's attention, the students will be more interested in the subject. Because the students can relate the issues to their lives. Students can associate the subjects with their lives better. Therefore, the questions are important, and drawing their [students'] attention is important. [post-interview]

4.1.3.3.2 Novice 1's Knowledge of Topic Specific Strategies

Novice 1's knowledge of topic-specific strategies was investigated in two sub-dimensions which are knowledge of representations and knowledge of activities. In the next part, Novice 1's knowledge of representations was presented.

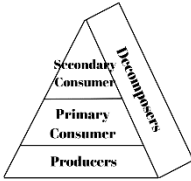
4.1.3.3.2.1 Novice 1's Knowledge of Representations

The findings about Novice 1's knowledge of representations were collected through pre-and post-interviews, Novice 1's lesson plan and classroom observations. Novice 1 was found to use drawing figures, examples, comparisons, analogies and metaphors as representations. During classroom observations, she asked students to draw a food chain and energy pyramid on the board. She provided daily examples to the students and asked students to give daily life examples in her lessons. To increase

students' understanding of ecological concepts, she used comparisons, analogies and metaphors. Table 4.6 presents Novice 1's knowledge of representations.



Table 4.6 Novice 1's Knowledge of Representations

Representations	Interviews	Lesson plan	Classroom Observation
Drawing figures	...we drew a food chain [on the board] while I teach to ecology to the 7th grade.	Students are asked to draw food chain on the board. (Appendix K & L) Students will be asked to draw the energy pyramid on the board. (Appendix K & L) The equation of photosynthesis is drawn on the board... (Appendix K & L)	Plant → Rabbit → Snake → Eagle Grasshopper Plant → Rabbit → Snake → Eagle Mouse  sun light chlorophyll carbon dioxide + water → glucose + oxygen
Daily life examples	I gave the students daily life examples... I told them about the energy resources, their usages, and their harmful effects on the environment.	Not mentioned	Chlorophyll is not only found in plants, but also in some bacteria, in algae. Cyanobacteria contain chlorophyll and photosynthesis takes place.
Comparisons / analogies	Not mentioned	Not mentioned	This energy flow between living organisms is not always unidirectional. It is not always linear, how is it actually in nature? Think of a spider web. It is like the shape of a tree. It is branching out from all sides. Same with the food web.

I: What are the representations you provide in your ecology lessons?

N1: For example, we drew a food chain [on the board] while I taught 7th grade. [pre-interview]

Related to the representations, Novice 1 stated to use drawings in ecology teaching, in pre-interviews. In her lesson plan, she stated that “Reminding the concept of “food chain” they learned in 7th grade, students will be asked to draw a food chain on the board.” (Table 4.6). Also related to drawing figures in the lesson plan she wrote “Students will be asked to draw a food pyramid in the light of the food chain on the board. The place of the decomposers will be indicated on this energy pyramid.” (Table 4.6). She drew the equation of photosynthesis on the board that was included in her lesson plan as well. The related statement in the lesson plan was “The equation of photosynthesis is written on the board and the materials that plants use and produce in photosynthesis are written.” (Table 4.6). These statements from Novice 1’s lesson plan exemplify that she used drawing figures on the board as representations in her ecology lesson.

Consistent with her lesson plan, Novice 1 drew food chain, food web and energy pyramid figures on the board during classroom observations (Table 4.6). She used analogies to make her students understand the food web and provided daily life examples related to the ecology in her lesson. The related following excerpts from classroom observations are provided below.

N1: This energy flow between living organisms is not always unidirectional, is it? They can receive energy from different living organisms. It is not always linear, how is it actually in nature? Think of a spider web in the shape of a tree. It is branching out from all sides, isn't it? Same with the food web.

N1: What is the main energy source of organisms? Sun. The producers produce food with the help of the sun. What are other energy sources we use in daily life?

S1: fossil fuels

N1: Then, what are the fossil fuels?

S2: oil, coal...

S3: For example, coal is more harmful than natural gas.

N1: Chlorophyll is not only found in plants but also in some bacteria, in algae. Cyanobacteria contain chlorophyll and photosynthesis takes place related following excerpts from classroom observations are provided below.

[classroom observation]

Novice 1 asked about the representation she used after classroom observation. She stated she used daily life examples in her ecology lesson during post-interviews.

I: What were the representations you provided in your ecology lessons?

N1: I gave students daily life examples. I told them what is edible and what is not edible, I told them about the energy resources, their usages, and their harmful effects on the environment. [post-interview]

As a result, Novice 1 seemed to prefer to use drawing figures, providing daily life examples and comparisons, metaphors and analogies as representations regarding ecology. In the next part, Novice 1's knowledge of activities will be documented.

4.1.3.3.2 Novice 1's Knowledge of Activities

The other dimension of Novice 1's knowledge of topic strategies is knowledge of activities. The pre- and post-interviews, lesson plans and classroom observations are the tools to collect data about Novice 1's knowledge of activities. Novice 1 stated that she used direct lecturing, questioning and demonstrations in her ecology lessons. On the contrary, she was not observed during conducting demonstration. She stated in the pre-interviews that she conducted demonstrations the previous year when she taught ecology at the 7th grade level. During interviews, she mentioned representations like daily life examples, apart from activities. Related pre-interview excerpts are provided below.

I: What kinds of activities are within the curriculum related to ecology?

N1: There is a fermentation experiment. The time is limited. I could not teach the last unit to the 8th grade. Before the High School Entrance Exam [SBS] exam, I did not have time for the activities. The fermentation experiment is an easy activity that I performed last year. I showed the preparation of the experiment at the beginning of the lesson to students. I put the balloon onto the bottle and hid it [the preparation] below the table. I continued to teach the lesson. When the balloon got bigger, I took it out and showed it [the preparation] to the students. Within ten minutes with the help of this activity, students learned anaerobic respiration. [pre-interview]

I: If you have enough time, are there any activities that you want to do?

N1: So, I wanted to do the thing [one experiment], do plants do photosynthesis or not? For this experiment, you cover the leaf. Here you are dripping iodine solution on the leaf. According to its colour, you understand that it [leaf] did photosynthesis or it [leaf] did not. I think it [the experiment] would be very effective. But this [the experiment] required some preparations. I didn't do it because of my laziness. Well, maybe I didn't do it because of the lab situation. But it could be nice. So, [students will be experience to] look, plants did photosynthesis and did not do it [photosynthesis] here. Because we could emphasize the importance of light for those who did not receive light. Here's a little bit of refinement on the activity in the book to show that plants respire day and night. Look, they're breathing during the day. Carbon dioxide gas is released during the day. We could show it. So, I think all these [experiments Novice 1 mentioned] would be more effective. Because it is not true to verbally say to children that photosynthesis performs during the day and respiration at night. So, we have the opportunity to show them [students], but they are not very simple experiments, they require preliminary preparation plus time. So, it has to go through a certain process. In that respect, I would like to do those activities. [pre-interview]

I: According to you, are these activities enough and suitable for elementary students?

N1: I think they are enough. However, because of the time, we could not do too many activities. According to me, some activities are

foolish. For instance, there is an activity namely the dance of photosynthesis. I did not do it and I do not think that this activity is effective in making students learn photosynthesis. It is better to make them perform the experiment of 'photosynthesis and light'. However, I could not do it. I did not have time to do it. There was also an activity that 'when plants' respire'. This activity also was very extensive and you had to allocate much time. [pre-interview]

I: So, what else can you do other than this?

N1: What can I do will be very utopian, I told you previously. You know, in such a room, I create a food chain with animals and observe them. Utopian... This would be very difficult to realize, maybe on a smaller scale than that, maybe it could be... It's not just about the food chain, of course, different activities can be thought of to make photosynthesis, aerobic and anaerobic respiration comprehend. Perhaps these are very long-term activities, that is, they can be project-based. Maybe when the semester's beginning to the end, there are things to be desired... or there is a water cycle... cycles ... nitrogen cycle, carbon, oxygen cycle here, I don't know how they are... how can it be explained simulations maybe animation can be. [pre-interview]

Novice 1 stated experiments, project-based learning, problem-based learning, simulations and animations as the activities for teaching ecology in pre-interviews. However, she used direct teaching and questioning in classroom observations. She explained the reasons for not being able to conduct experiments regarding photosynthesis and respiration. For example, not suitable laboratory conditions, time constraints, the activities necessitating preliminary works and high school entrance examinations were the reasons mentioned by Novice 1 during pre-interviews. The

classroom observation findings revealed that she made her students answer the questions she asked and allowed her students to answer the questions related to ecology in their science workbooks. She was found similarly in her lesson plan that she used direct teaching and questioning to discuss the issues in ecology. Besides, Novice 1 did not complete the part of her lesson plan related to activities (see Appendix K for the Turkish version, see Appendix L for the English version). Therefore, her lesson plan did not provide findings regarding her knowledge of activities. She left a note on her lesson plan in the “teaching and learning activities” part that was “what she was expected to write” (see Appendix K for Turkish version, see Appendix L for English version). Conversely, Novice 1 mentioned several activities in ecology during interviews. She stated experiments about photosynthesis that she would like to conduct. The collected data from interviews indicated the inconsistency of Novice 1’s enacted and reported PCK in knowledge of instructional strategies regarding activities.

I: Is there anything you plan to do next year that you did not do in class this year?

N1: Yes, I can do something next year... I'm going to close one side of that leaf in photosynthesis, I'll look. I will test whether it [the leaf] did photosynthesis or not... I can prepare such a setup a month before starting the unit. This is how I can make up for this year's shortcomings in the next year. Maybe I couldn't do that. Why because I didn't have time. But if I had done it beforehand, how many minutes would it take to drip the iodine solution on the leaf? It would have taken me one lesson, maybe I need to do the preliminary preparation beforehand, I can do these kinds of things next year by preparing beforehand. [post-interview]

To conclude, Novice 1 preferred to use direct teaching and questioning which are teacher-centered strategies. She stated that the reason to chose these methods was because of laboratory conditions, time constraints, the activities necessitated preliminary works, and high school entrance examinations which was SBS [National Central Examination for transition to secondary education in Türkiye]. Novice 1 was found to use figures, daily life examples, comparisons, analogies and metaphors as representations in ecology teaching. She stated the activities that can be done in ecology lessons like experiments for respiration and photosynthesis, simulations and animations for matter cycles. She also mentioned projects can be conducted in ecology and that problem-based learning can be effective for students' understanding of ecology.

The current section was for Novice 1's knowledge of instructional strategies documented in two sub-sections as knowledge of subject-specific strategies for presenting Novice 1's knowledge of instructional strategies in science. In the second sub-section, Novice 1's topic-specific strategies were presented in two sub-components which were knowledge of representations and knowledge of activities in ecology. The next section documented Novice 1's knowledge of the assessment.

4.1.3.4 Novice 1's Knowledge of Assessment

Teachers' knowledge of assessment includes the teachers' knowledge of assessing students' learning in a specific content area within a subject (Magnusson et al., 1999). Thereby, Novice 1's knowledge of assessment was investigated in terms of their knowledge to assess students' learning. Novice 1's knowledge of assessment was examined in terms of knowledge of what to assess, types of assessment, knowledge of assessment methods and sources of assessment. Novice 1 also examined in terms of which knowledge domains influence her choice of assessment strategies and methods regarding ecology. Novice 1's pre- and post-interview

responses, lesson plans and classroom observations were the sources to understand her knowledge of assessment regarding ecology. Novice 1 pointed out knowledge, skills and attitudes to assess in science. She stated that she used questioning for diagnostic, classroom observation for formative and open-ended questions, and multiple choice questions for summative assessment. Novice 1's knowledge of assessment presented in two dimensions which were knowledge of dimensions of science learning to assess and knowledge of methods of assessment.

4.1.3.4.1 Novice 1's Knowledge of Dimensions of Science Learning to Assess

Novice 1's knowledge of dimensions of science learning to assess was investigated through pre-interviews, lesson plans and classroom observations. Table 4.7 presented Novice 1's knowledge of dimensions of science learning to assess.

Table 4.7 Novice 1's Knowledge of Dimensions of Science Learning to Assess

Dimensions of Science Learning to Assess	Pre-Interviews	Post-interviews	Lesson Plan	Classroom Observation
What to assess	Knowledge Attitude Skills	Not mentioned	Knowledge Attitude	Knowledge Attitude

I: What is your aim to assess in students?

N1: Now not every subject may require skill. Maybe there are situations where you just need to measure knowledge. I think it's diverse... it can be only knowledge, it can be only skill, it can be both.

Let's see how their attitudes changed. But this is not an assessment. You just observe the situation in their attitudes. Or it could be

something like this: in the beginning, s/he had such an attitude towards this subject... but yes, her/his attitude has changed in this direction, you can say that it has improved or regressed. [pre-interview]

Novice 1's knowledge of dimensions of science learning to assess found in pre-interviews as students' knowledge, skills and attitude. She did not mention interdisciplinary themes, the nature of scientific knowledge, and problem-solving skills to assess ecology. In her lesson plan, she focused her assessment on two dimensions she mentioned which were knowledge and attitude. The statement of Novice 1 in her lesson plan in the part of 'Evaluation and Assessment' is provided below (see Appendix K for English version; see Appendix L for English version).

N1: During the course, the answers given by the students to the questions asked and their participation in the discussions are used for assessment purposes.

[Lesson Plan]

Consistent with the pre-interviews and her lesson plan, Novice 1 evaluated students' answers and forced them to participate in the lesson with directing questions. Approving their responses and facilitating their participation, Novice 1 aimed to assess students' knowledge and attitude in classroom observations as she stated in the lesson plan and pre-interviews. She seemed to ignore the students' skills as she mentioned in the interviews rather she focused on students' conceptual understanding. The related classroom observation notes are provided below.

N1: How do producers produce food?

S1: By photosynthesis

N1: Well done Sila, what do plants need for photosynthesis?

S1: Sunlight

N1: What else?

S1: Carbon dioxide

N1: What else?

S1: Water

N1: What else? It takes minerals from the soil. So, what was produced? What did these plants produce?

S1: Oxygen

N1: What else?

S1: Glycose

N1: They produce their own food. So, if we write the equation of photosynthesis.....

[Classroom Observation]

The following section presented Novice 1's knowledge of methods of assessment.

4.1.3.4.2 Novice 1's Knowledge of Methods of Assessment

Novice 1 appeared to have knowledge on types of assessment that she pointed out diagnostic, formative and summative assessments. To diagnose students' prior knowledge and misconceptions, she used the question-answer method. In her lesson plan, students' participation was stated to be evaluated in she appeared to use formative assessment. During interviews, she explained that she used summative assessment as well. Novice 1's knowledge of methods of assessment is presented in Table 4.8.

Table 4.8 Novice 1's Knowledge of Methods of Assessment

Methods of Assessment	Pre-Interviews	Post-interviews	Lesson Plan	Classroom Observation
How to assess	multiple choice questions open-ended questions	formative	formative summative	formative summative
When to assess	At the beginning, During the lesson, At the end of the lesson	Not mentioned	At the beginning During the lesson At the end of the lesson	At the beginning, During the lesson, At the end of the lesson
Knowledge domains influence assessment methods	Subject matter knowledge Knowledge of students	Subject matter knowledge Knowledge of students	Not mentioned	Not mentioned

I: Which assessment methods and techniques do you use to assess students in ecology?

N1: I can use classical assessment and evaluation techniques. The traditional exam can be with multiple choice or open-ended questions. But it [evaluation] seems like... it [evaluation] can be more effective in open-ended questions. Because it [evaluation] is a little bit more there that you can understand whether students understand or not. You know, I can ask a question that they can tell me about their [contents'] relationship or... that is not only with an exam but also with classroom observation in the process of learning. After all, questions are asked and various answers and reactions are received in the classroom. You can say that this child understands these reactions from the children. We can observe not only for the exam but

also for the class, we can also make a process evaluation. [pre-interview]

I: Which one of the assessment methods that you use is more effective in terms of understanding whether students learn the ecological concepts or not?

N1: I am thinking class observation is the most effective one [to understand the students learn the ecology]. Because it is very different than the examination. In the classroom, everything is arranged by you [teacher], you [teacher] have the chance and necessary facilities to understand completely whether the student has learned the subject or not. Well, let us not say completely but most probably. [pre-interview]

I: Apart from these assessment methods, what kinds of assessment methods can be used for ecology?

N1: There can be done process evaluation in the classroom, a written exam, and you may want students to talk about the pictures. Ecology is a subject more related to visuals. You can ask the students about the relations of the concepts in ecology by means of pictures, so different kinds of things may be used to assess. [pre-interview]

I: When do you assess students in ecology?

N1: Always. I make an assessment while teaching the subject, for example, at the beginning of the lesson. At the beginning, you can evaluate what the students know about the subject make a process evaluation and assess the learning outcomes. [pre-interview]

I: Which knowledge do you have effective in determining your assessment method?

N1: Subject may be effective. For instance, the students may go on field trips and observations. But it is not possible to make them [students] have field trips and observations in every subject... It may be depending on the subject and also the level of students. Maybe a student is very good at the subject, so it is not always true to make an assessment with a classical examination. It may be necessary to force the students a little bit more, you may want them [students] to have an experiment, for example. This situation [determining the assessment method] may depend on the subject, student or teacher.
[Pre-interview]

During pre-interviews, Novice 1 stated to use summative assessment methods in which she mentioned about traditional evaluation tools like tests with multiple choice questions and open-ended questions. Novice 1 also pointed out learning process can be evaluated by classroom observation which she pointed out as the most effective assessment method. She stated visuals can be used to assess students' concepts of interaction in ecology. However, in general, Novice 1 seemed to not be able to specify alternative assessment methods in ecology in pre-interviews.

The lesson plan of Novice 1 indicated that she used diagnostic assessment (see Appendix K for the Turkish version; Appendix L for the English version). The statement related to diagnostic assessment in Novice 1's lesson plan is provided below.

N1: At the beginning of the unit, interesting questions about the unit in general will be read and discussions will be held with the students... Students' readiness levels will also be evaluated during

this question-answer period, and the lesson will be organized according to the levels of the students in the development part of the course.

[Lesson plan]

It was understood from Novice 1's lesson plan's teaching process part that she used formative assessment in which students asked questions about ecological concepts that students expect to learn. The evaluation and assessment-related excerpts in the lesson plan were "By emphasizing the concept of producer, guiding questions will be asked to students that will enable students to find out the importance of producers." and "The first link of the chain (producer) will be deleted and the results will be asked. After the discussions, students are expected to make inferences about that the food chain will be completely destroyed." (see Appendix K for the English version; see Appendix L for the English version). The final part of the lesson plan was related to assessment and evaluation, Novice 1 mentioned students' answers to the questions and their participation would be evaluated.

During the lesson, the answers given by the students to the questions asked and their participation in the discussions are used for measurement and evaluation purposes.

[Lesson plan]

In classroom observation, she asked diagnostic questions to evaluate students' prior knowledge. Some examples of her diagnostic questions are "We learnt food chain and food web last year, what are the arrows in this food chain represent?", "what was producers?". Novice 1 asked open-ended questions to direct students to the process. "How do producers produce food?", "What causes the depletion of the ozone layer?" are the examples Novice 1 asked to students to enable students activate their higher

order thinking skills. She also asked closed ended questions to evaluate factual knowledge of students. In fact, Novice 1 commonly used closed ended questions some of the examples are “In the base of the energy pyramid do the producers placed?”, “what does the name of the matter provide plants green colour?”.

Different from pre-interview findings, Novice 1 seemed more certain about assessment methods with their specific aims after classroom observation.

I: How did you assess students in ecology?

*N1: It [assessment] was a formative assessment, that is to say, I am trying to evaluate the previous year at the beginning of the lesson to see whether students are ready for this year. I was asking them "We learned about this in the previous lesson, do you remember that?" I did not make examinations or quizzes in this unit for evaluation.
[Post-interview]*

I: Did you think that these assessment methods are sufficient in order to determine whether students understand the ecological concepts or not?

N1: Of course, they [assessment methods] could be diversified... A concept map can be drawn actually. In fact, I could ask them to draw the concept map at the beginning of the subject; in this way, we could discuss what they know about the subject and the related concepts. Because they [students] knew the definitions of concepts. At least they learned in the previous year. They knew what the food chain or photosynthesis is. [Post-interview]

I: Which knowledge did you have effective in determining your assessment method?

N1: My subject matter knowledge was effective...it [subject matter knowledge] changed the type of question that I asked. When I asked an open-ended question, students may have various answers to the open-ended question. So, I must have a grasp of the subject to decide whether their answer is correct or not. Also, you cannot ask about every subject with open-ended questions. Sometimes multiple-choice questions will be necessary to assess the subject very easily. So, the subject is also important in this meaning. [Post-interview]

To sum up, Novice 1 was likely to have knowledge of assessment in ecology. She mentioned two types of assessments which are formative and summative assessments in the findings of interviews, lesson plans and classroom observations. She said to assess her students at every stage of the lesson in ecology. But she focused on students' conceptual understanding of the concepts besides assessment of the nature of science, science process skills, ecological awareness and social skills. Her knowledge of methods of assessment pointed out her understanding of formative and summative assessment methods.

The following section reveals overall the summary of Novice 1's PCK.

4.1.3.5 Novice 1's PCK summary

Novice 1's pedagogical content knowledge with its aspects in teaching ecology was presented in this section in Table 4.9.

Table 4.9 Novice 1's Pedagogical Content Knowledge in Teaching Ecology

KoC	KoL			KoIS	KoA	
Goals and objectives	Materials	Requirements	Learning difficulties	Subject specific	Topic specific	What to assess
See Table 4.1	Teachers' guidebook Students' workbook notebook Anaerobic respiration experiment	Daily life examples Prior knowledge Presence of abstract concepts Students' learning style	Flow of energy in ecosystems Direction of arrows in energy flow	Direct teaching Questioning Demonstration	<i>Representations:</i> Figures Daily-life examples analogies metaphors <i>Activities:</i> Experiment PBL ProblemBL Simulation animations	Knowledge Skill Attitude <i>Methods of assessment:</i> <i>Formative assessment:</i> classroom observation <i>Summative assessment:</i> open-ended questions, multiple choice, questions
<i>Vertical/horizontal relations:</i> G-7 food chain food web energy pyramid G-8 aerobic respiration anaerobic respiration material cycles			<i>Misconceptions:</i> Producer, Ecosystem, Producers' nutrient Respiration and photosynthesis			

KoC: Knowledge of Curriculum

KoL: Knowledge of Students' Understanding of Science

KoIS: Knowledge of Instructional Strategies

KoA: Knowledge of Assessment

In this section, Novice 1's SMK and PCK was revealed. In the next section, Novice 2's SMK and PCK regarding teaching ecology documented.

4.2 Novice 2's Subject Matter Knowledge and Pedagogical Content Knowledge Regarding Teaching Ecology

4.2.1 Novice 2's Demographic Information

Novice 2 was also female and had one and a half years of teaching experience. She has a BS degree in elementary science education. She was continuing her education in the master's program in the Department of Educational Administration at Osman Gazi University (one of the universities in Türkiye). She mentioned her interest in ecological issues and found biology topics such as ecology easier especially for her students. She indicated that she did not enroll in any special course or training on ecology and ecology teaching. She attended inservice training about instructional techniques. She expressed that she used teachers' books as the main source for her ecology instruction. She had experience in teaching at 6th and 8th-grade levels in her one and half years teaching experience.

4.2.2 Novice 2's Subject Matter Knowledge on Ecology

To elicit Novice 2's subject matter knowledge in ecology she asked twenty-nine questions with sub-questions during the interviews, including figures, drawings, and concept map. Findings are reported under two main categories basic ecological concepts and energy flow in ecosystems. Within the basic ecological concepts category, basic ecological concepts' definitions which were ecosystem, species, population, community, habitat, ecological niche, biological diversity, producer,

consumer, and decomposer were presented. In the other category, the energy flow in ecosystems identified through chain, food web, and energy pyramid was documented.

Overall, her responses revealed her limited or no understanding of the majority of ecological concepts. Some excerpts are presented below.

4.2.2.1 Novice 2's Subject Matter Knowledge on Basic Ecological Concepts

Novice 2 was asked to define ten basic ecological concepts in the interviews. The first ecological concept to define was an ecosystem.

I: What is an ecosystem?

Novice2 (N2): I remember ecosystem as ...in fact, this [concept] is the content of 7th grade [here, she informed that she had not taught 7th-grade curriculum before]. Therefore, I do not remember the definition of it [ecosystem] much. Hmm...if I define ecosystem, it is the area where living and non-living organisms live. That is the definition of ecosystem that comes to my mind. [interview]

I: Can you give examples of the ecosystem, then?

N2: Well, the world we live in is an ecosystem, living and non-living things live in harmony inside. [interview]

To understand more about her ecosystem knowledge, especially the relationships btw ecological concepts, Novice 2 was asked to draw a concept map (see Figure 4.5 and Appendix C for original drawings of Novice 2). Before drawing her concept map, Novice 2 listed ecological concepts which are seen on the left side of the concept map (Figure 4.5). As seen in the list, all except material cycles, extinct

species, and natural disturbances were integrated into the concept map. Overall, her concept map consisted of fifteen ecological concepts which are ecosystem, living things, non-living things, habitat, species, population, community, producers, consumers, decomposers, food, solar energy, oxygen, carbon dioxide, and global warming.

Moreover, she drew a hierarchical concept map and determined the ecosystem as the most general concept. Then she directly connected the ecosystem with, living things, non-living, and habitat. However, she did not attend to link these components with each other to indicate their relations. In other words, she formed branches from central concepts. For example, the ecosystem branched into living things, non-living things, and habitats, and living things branched into producers, consumers, and decomposers. She added examples to some of the concepts in her concept map. For instance, related to ecosystems, Novice 2 gave examples such as lakes and forests. Related to species, she provided red pine tree and Van cat as examples. In addition, she drew an example of the food chain in relation to producers. She also used cross-links in her concept map. It was seen in her concept map that producers and consumers in different domains crosslinked with carbon dioxide. There are linking words that, though simple, form meaningful associations between ecological concepts. However, some statements were not meaningful, such as the ones that attempted to associate ecosystems with habitat. The other scientifically incorrect linkage is “producers are the example for - bird fed on with caterpillar, eagle fed on with bird - [a sample food chain]”. In addition, she linked producers with living things, food, oxygen, carbon dioxide, solar energy, mulberry leaf, and a sample food chain she formed. The resulting statements in her concept map were “producers are the member of living things”, “producers produce food”, “producers use carbon dioxide”, “producers produce oxygen”, “producers use solar energy”, and “producers are the example of the mulberry leaf” and “producers are the example of mulberry leaf-caterpillar-bird-eagle [sample food chain]”. Moreover, she linked

consumers with the concepts of living things, food, oxygen, and carbon dioxide. The statements identified in Novice 2's concept map in relation to consumers are "consumers are the members of living things", "food is used by consumers", "consumers produce carbon dioxide" and "consumers use oxygen". She did not identify the relationship of consumers with the sample food chain in her concept map and the organisms of this sample food chain with the consumers. But she related decomposers only with living things. "Decomposers are the members of living things" was found the only related statement with decomposers in Novice 2's concept map. The relation between producer and consumer seen in the concept map was an indirect relation resulting from feeding. In her concept map, she did not mention ecological niche, biological diversity, food chain, food web, and energy pyramid. Instead, she showed a simple food chain by giving examples.

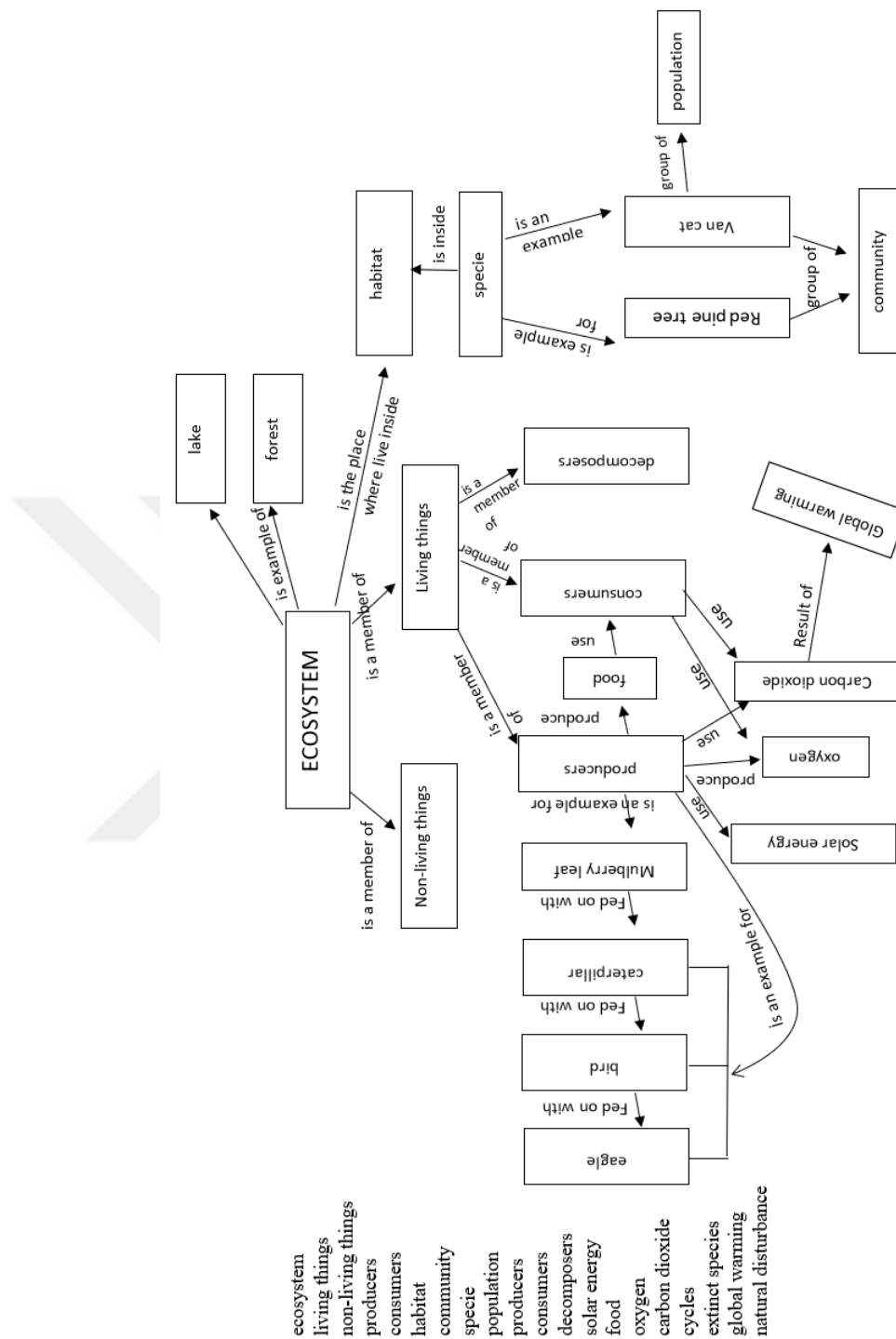


Figure 4.5 Novice 2 Concept Map (see Appendix C for original drawing)

To further reveal her knowledge of ecosystem, Novice 2 was provided a short script.

I: Assume that “You asked your class to construct a closed ecosystem as a homework assignment. Among your students, Ali and Ceren decided to prepare this homework together. They meet after school for this homework. Ali suggested to Ceren: ‘Let’s take three large glass containers. In one we will put all the non-living things like rocks, soil, water, and air and we will hang a light bulb over it to represent the sun. In another container, we will put just the plants and in the third container, we will put just the animals. It will be cleaner this way if we keep everything separate!’ How would you evaluate Ali’s ecosystem suggestion?”

N2: Related to the ecosystem, we said that all living and non-living things are with interaction. In this example [first container], there will not be interaction [between living and non-living things]. Non-living organisms continue to be non-living. Neither producers nor consumers can not live by themselves. Because they [producers and consumers] need each other. If there are no producers in the same area and if consumers cannot find food, they [consumers], cannot live. In fact, there cannot be any system like that. [interview]

I: Predict what would happen in the three jars over time. Explain your ideas.

N2: There were animals in the third container. There is limited oxygen there. As they [animals] continuously consume oxygen, they [animals] exhaust all of the oxygen [soon]. They [animals] could not find air anymore. Likewise, they [animals] do not have food anymore. [interview]

At this point, it is necessary to note that while talking about ecosystems, she pointed out the interaction between biotic and abiotic components. However, she failed to mention the ‘interaction’ neither in her concept map nor in her responses in interviews.

In her responses (both in the previous script and concept map), she talked about producers, consumers, and decomposers. Accordingly, she was asked a series of questions regarding those concepts.

I: You mentioned about producers. So, what are the producers?

N2: Producers are plants with green leaves...that is, [the things] producing their own food. [interview]

I: Then, what is the importance of producers in ecosystems?

N2: They [producers] are organisms that convert light energy to a usable form. For these reasons, their importance is huge. [interview]

I: What is the importance of consumers in the ecosystem, then?

N2: The importance of consumers... Well, like producers, consumers are also essential. They [consumers] provide carbon dioxide necessary for plants. Producers and consumers exist in a balance. In the end, if there are no consumers, there will not be producers. For this reason, they [producers and consumers] are in a balance together. [interview]

I: Okay, what is the importance of decomposers in the ecosystem?

N2: Um...Decomposers are even biotic components of ecosystems. They [decomposers] are tiny organisms within the soil facilitating the

breaking down of dead organisms into inorganic or organic matter. Decomposers provide both mineral and elimination of accumulated waste of organisms in the soil... If there were no decomposers, everywhere would be full of dead organisms. and become scarce of useful materials. Therefore, these organisms [decomposers] are very important. In fact, decomposers do something useful for nature, especially for producers. If decomposers do not exist, plants cannot get important materials from the soil. If decomposers do not exist, plants cannot feed on them. [interview]

I: How do you explain the relationship between producers, consumers, and decomposers?

N2: Hmm...Producers' roles can be understood from their names. They are things producing their own food. Consumers are organisms consuming what producers produce which are both food and oxygen. When these producers and consumers die and are buried in soil, decomposers break down organic or inorganic matters [found on dead bodies]... That is, if one of them [producers, consumers, and decomposers] disappears, the balance [of the ecosystem] will be entirely destroyed, and none of the organisms can survive [without the absence of others]. [interview]

As clearly shown, Novice 2 associated producers only with plants with green leaves although there are other organisms that are photosynthesized. While she explained the importance of producers by mentioning the production of their own food, converting light energy to a usable form of energy, she did not talk about their essential roles in material cycles and energy transfer in the ecosystem. Novice 2 did not explain the roles of the consumers in ecosystems in detail. She did not state the

roles of consumers in material cycles, the flow of energy in ecosystems, creating or modifying habitats, and forming relations with other organisms. Moreover, Novice 2 appeared to have an understanding of the decomposers. She expressed that decomposers break down organic materials into inorganic materials for producers' benefit. However, she did not provide any explanation of the decomposer's roles in the energy pyramid and the long-term survival of the ecosystem. In that respect, Novice 2 explained the relation between producers, consumers, and decomposers as a dependent relation. On the other hand, she did not mention the flow of energy relation between producers, consumers, and decomposers.

In her concept map, Novice 2 identified consumers' interaction with producers. Similar to her previous responses, Novice 2 pointed out the interaction between producers and consumers in relation to food in her concept map (Figure 4.5). However, the association of decomposers appeared too weak with the other ecological concepts in her concept map (Figure 4.5). The next ecological concepts found in Novice 2's concept map were species, population, community, habitat, ecological niche, and biological diversity. Thus, her knowledge of species were clarified, first.

I: What is species?

N2: Species produce fertile offspring. take cats... there are different types of cats. For instance, Ankara cat is a species. When they reproduce, they produce reproductive offspring. However, donkeys and horses are different [species]. [interview]

I: It was seen in your concept map you linked species with population and community. So, please define these concepts and link among them. For example, what is the population?

N2: As far as I remember, a population is a group of organisms that belong to the same species, living in a certain area. For example, Ankara cats live in Ankara. [interview]

I: Then, what about habitat?

N2: What is a habitat? Maybe, for instance, it [habitat] is the living and non-living things within the city of Ankara. It [habitat] can be certain communities living in the city of Ankara. [interview]

I: What about the community?

N2: Uh, what can be the difference between community and habitat? How can it be defined? Hmm, I do not know. [interview]

I: What is an ecological niche?

N2: Uh, I do not remember. [interview]

The overall finding revealed that although Novice 2 seemed to have an understanding of the concept of species (i.e., interbreeding and producing fertile offspring), she failed to provide species possessing and sharing certain characteristics in her definition. Similar to her concept map (Figure 4.5), Novice 2 included gave red pine tree and a Van cat as examples for species stating that “red pine tree and Van cat are the example for species”. The examples of species are further connected to the concepts of community and the population indirectly, yet it is linked to the one example which is ‘Van cat’ only. In her concept map (Figure 4.5), she also attempted to link species with the concept of habitat. For example, “species found in habitat” or “habitat consists of species”, remained to be a very general example. Besides, she defined habitat as the place of living and non-living things in a specific place and linked habitat with the concepts of ecosystem and species (Figure 4.5). The related

statements were “ecosystem is the living place of habitat” and. She did not provide; however, any other association of habitat with other ecological concepts.

Novice 2 was likely to possess some understanding of the population. She pointed out that populations formed from groups of organisms belong to the same species. However, in her concept map, the association of population with other ecological concepts seemed to be limited (Figure 4.5). In fact, the only statement identified in the concept map related to population was “Van cat is a group of the population”.

As far as her knowledge of the community was concerned, it was seen that Novice 2 did not develop a clear understanding of the community, even if she included the concept in her concept map and concept list as well as established meaningful, yet simple preposition: “red pine tree and Van cat are community” (Figure 4.5). She was found to possess no knowledge about ecological niches. She did not integrate it in her concept map drawing as well (Figure 4.5).

Novice 2’s knowledge of biological diversity was also explored.

I: What is biological diversity?

N2: Well, biological diversity... As an example, crossing over takes place during meiosis, and at the end, different organisms are produced. We can call this biological diversity. That is, it [biological diversity] is defined as an organism of the same species not being same, being various in some sort of their characteristics. For example, in human beings as a kind of species, there are verified qualifications like tall and short or blonds and darks. [interview]

I: Do you think that biological diversity is advantageous for organisms?

N2: Of course, biological diversity is an advantage...If all of the organisms are the same, for instance, if a disease emerges, if one of them [human beings] was affected, all of them [organisms] could be even affected. [interview]

Novice 2 tends to interpret biological diversity mainly in terms of genetic diversity. She did not mention ecological diversity, by mentioning the crossing-over process in meiosis. She underlined the advantages of biological diversity to make species resistant to diseases and pointed out that species would be more prone to be extinct if they share similar characteristics. On the other hand, species diversity was implicitly mentioned. However, she neither integrated biological diversity into her concept map nor wrote her concept list (Figure 4.5).

Since the concept list she developed included extinction-prone species as a last question of basic ecological concept, she asked about the characteristics of extinction-prone species.

I. Although the conceptual list you created includes extinct species, you did not integrate it into the concept map you created. What can you tell about the characteristics of extinction-prone species, then?

N2: I have never thought about it [extinction-prone species] previously, actually. For example, why did bald ibises become extinct? Maybe, their living area was limited. That is, they might live in a small area and the negative conditions in that area caused them to die. In addition, as they could not live in any other area, what did they do? They became extinct. For example, an organism living at the poles cannot survive with the increase in temperature there. As there cannot be another place for them to live, they will become extinct.

Initially, it [the characteristics of extinction-prone species] can be their limited living area, this comes to my mind. [interview]

Novice 2 identified the characteristics of extinction-prone species as being found in only one place or region and limited specialized resting or breeding areas. However, she did not mention their fixed migratory pattern, low reproduction rate, possession of specialized feeding habits, or feeding at high tropic levels.

The next sections report Novice 2's subject matter knowledge on energy flow in ecosystems including energy, photosynthesis, food chain, food web, and energy pyramid were documented.

4.2.2.2 Novice 2's Subject Matter Knowledge on Energy Flow in Ecosystems

The next sections reported Novice 2's SMK on energy flow in ecosystems gained through pre-interview questions, drawings, interpretation, and her concept map drawing. To better capture Novice 2's understanding regarding energy flow in the ecosystem, she was specifically asked about energy, photosynthesis, the food chain, the food web and the energy pyramid. First, she asked to define energy.

I: What is energy?

N2: Energy is...Energy is an abstract concept. So, I cannot define it. When we say energy, what comes to my mind is that it [energy] is needed to make an effect. That is, it can be said as the power, a thing.... [interview]

I: So, how can you explain the flow of energy in ecosystems?

N2: Of course, there is energy flow in ecosystems. The first, energy starts with the sun's energy. Then, this [solar] energy is converted

into chemical energy by plants; in turn, chemical energy is converted into electrical energy or kinetic energy. It [energy] is continuously transferred in this way. That is, energy is not destroyed. It [energy] can be converted into heat at most. [interview]

I: You said energy starts with the sun's energy and is converted into chemical energy, how does this energy conversion take place?

N2: By photosynthesis. [interview]

I: What is the aim of photosynthesis, then?

N2: Well, the aim of photosynthesis is food production; that is, [plants] produce food for themselves. In fact, we benefit from this event [food production]. At the end of photosynthesis, our food is produced. In fact, plants are food for other organisms. Indeed, plants produce kinds of proteins through photosynthesis and vitamins, and all of the carbohydrates are produced by photosynthesis. At the same time, they [plants] are the source of oxygen and they take in poisoned carbon dioxide from the air. [interview]

I: Can you explain the mechanism of photosynthesis?

N1: Here [in photosynthesis] light is important and the place of photosynthesis is the green parts of plants. That is, it takes place within the matter on green parts called chlorophyll which is located inside the chloroplast. [interview]

I: May I ask you what is the food of plants?

N2: Yes, plants produce their own food at the same time they take water and minerals from the soil. [interview]

I: Do you think that photosynthesis obeys the first and second laws of thermodynamics?

N2: Photosynthesis can obey the first law because light energy is transformed into chemical energy inside the plant. For instance, I take this chemical energy and transform it into motion energy.

During photosynthesis, two or three ATP are used for running of photosynthesis. Some amount of energy is lost. That is, it [photosynthesis] obeys; I mean the second law of thermodynamics. In this way, an energy pyramid is formed accordingly. That is, plants have a certain amount of energy, they [plants] transfer ten percent of this energy to the upper levels. But the remaining parts are lost as heat or plant makes it something by motion. That is, it [remaining energy] is lost. [interview]

I: Why would an increase in the atmospheric concentration of carbon dioxide not necessarily result in a corresponding increase in photosynthesis?

N2: Now, carbon dioxide is a factor necessary for photosynthesis. That is, if all the necessary materials exist in the environment for photosynthesis such as the number of stomata which are pores on the leaves and so on...when carbon dioxide increases in the environment, of course, photosynthesis increases too. However, until when? The increase continues up to the point when the other factors limit. [interview]

I: What are the other factors that limit the reaction then?

N2: It [the limiting factor] can be the size of the leaf; it can be the amount of water in the environment; it can be the amount of mineral; the size of stomata pores; the place of stomata- under or above; it [pre-interview] can be everything. Up to these factor limits, the increase in carbon dioxide corresponds to an increase in photosynthesis. Then, it [the rate of photosynthesis] becomes stable.
[interview]

To sum up, Novice 2 associated energy with power and effect and also photosynthesis with energy conversion, chloroplast, chlorophyll, and food production. However, she did not state glucose as the food produced by photosynthesis. She also indicated that plants take in inorganic materials from the soil. She mentioned reactants and the products of photosynthesis. She explained how photosynthesis obeys the thermodynamics first and second laws briefly. She stated energy conversion and transformation related to the first law of thermodynamics. Related to the second law of thermodynamics, she also addressed the efficiency of energy by referring to the energy pyramid. However, Novice 2 failed to include energy, photosynthesis, and energy pyramid in her concept map (Figure 4.5). Her understanding of the energy pyramid was reported later under a separate heading (see 4.2.2.3). Novice 2 also seemed to possess an understanding of possible limiting factors in photosynthesis.

However, she did not talk about the mechanism of the photosynthesis in detail. The next sub-sections presented Novice 2's SMK on the food chain, food web, and energy pyramid.

4.2.2.2.1 Novice 2's Subject Matter Knowledge on Food Chain

I: What is a food chain?

N2: It [food chain] is the same thing with food web. Well, I have trouble when I define it [food chain]. The food chain can be explained by organisms feeding on each other in the same area. That is, one [organism] eats another [organism] and keeps this [feeding] relation as a chain. [interview]

I: Can you draw and explain a food chain?

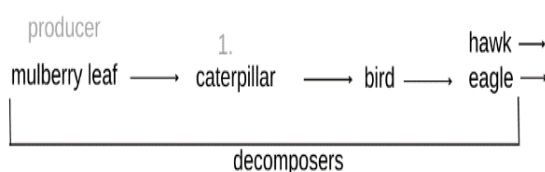


Figure 4.6 Novice 2 Food Chain Drawing (see Appendix C for original drawing)

N2: Mulberry leaf...um... the caterpillar eats the mulberry leaf... then the bird eats the caterpillar... the eagle is eating the bird. There can be more organisms after the hawk and eagle, and the food chain will continue. [interview]

I: Where are decomposers located in the food chain?

N2: I will also place the decomposers covering all of the [organisms in the food chain. [interview]

I: What do the arrows in the food chain represent? Please explain.

N2: These arrows indicate that the leaf is eaten by the caterpillar and the caterpillar is eaten by a bird. That is, this [food] chain formed from leaf to eagle. [interview]

I: Do you think that the length of a food chain is limited?

N2: It [the length of food chain] is not limited... we can extend this [food] chain...hmm... We can place another organism eating this eagle, for instance. [interview]

I: If so, if we can increase the length of the food chain, up to which trophic level can we continue?

N2: To which trophic level? Actually, primary consumer, secondary consumer...It [food chain] is not extended much. But if there are organisms eating these organisms in that chain, it [food chain] can be extended. On the other hand, presumably, it [food chain] is not extended much after eagle and hawk...hmm, if there is not any organism eating another organism...however, would it be? I am in a dilemma now. [interview]

I: Are the following elements -nectar, a butterfly, a bird, and decomposers- constituents of a food chain? (Reiner & Eilam, 2001)

N2: Now, immediately comes to my mind that decomposers will not be at the end of the food chain because decomposers are those who decompose all of the organisms when they die. For this reason, decomposers are in relation with all of them [organisms]. [interview]

I: Is a bacterium inside the human body a part of a food chain? (Reiner & Eilam, 2001)

N2: Are bacterium part of the food chain? Of course, they [bacteria] are part of it [food chain] ...That is, as in the soil, inside our body...In the end, they [bacteria] feed on something. [interview]

I: If so, what could be the other living things that make up this food chain?

N2: They [bacteria] feed on things inside my body; they [bacteria] feed on foods. Is there an organism feeding with them [bacteria]? There are not. [pre-interview]

To summarize, Novice 2 appeared to have limited knowledge about the food chain. She equated the food chain with the food web (see 4.2.2.2.3). What is more, she associated the food chain with ‘who eats whom’ stating that the food chain is a kind of eating relations between organisms. However, she identified the trophic levels and interpreted and drew the arrows consistent with the scientific explanation. In her concept map drawing, she placed a mulberry leaf (as a producer) and a caterpillar (as a consumer) and drew these concepts with the linking words “fed on with” (Figure 4.5). Consistently, she explained the direction of the relationship between organisms in a food chain in terms of feeding relations apart from energy transfer. In line with this idea, Novice 2 tended to explain the arrows in the food chain representing feeding relations between the organisms rather than energy transfer. Accordingly, she thought that the length of the food chain is unlimited and stated that the levels of the food chain can be increased with other organisms that can feed on the others.

As understood from her responses, Novice 2 seemed to be knowledgeable about decomposers. She correctly said that decomposers operate at each trophic level in the food chain, and added that decomposers should be placed everywhere [trophic levels], though did not place the decomposers into her food chain drawing. She also criticized the food chain that places the decomposers at the top. However, she failed

to provide an explanation about the roles of bacterium inside the human body. In fact, she seemed to hold the misconception that she considered bacterium inside the human body as part of the food chain with eating things inside the body.

The 8th-grade ecology unit in 2009 included a link between the material cycles and food chains [the related objective in the 2009 science curriculum: 1.19. Explains the material cycles in parallel with the energy flow in the food chain.]. In this respect, Novice 2 directed question about the relation between food chains and matter cycles.

I: Your concept list also included material cycles though you did not integrate it into the concept map. Is there any relationship between material cycles and food chains? Please explain.

N2: In fact, material cycles are naturally formed through the food chains...For example, the important element is producers in carbon and oxygen cycles. That is, the relationship between plants and animals is important. In fact, converting carbon dioxide to oxygen; and converting oxygen to carbon dioxide again forms a cycle. But there are other factors such as factories..., in the nitrogen cycle, again there is of plants and animals importance. Because nitrogen is inside [found in bodies of] plants... that is, it [nitrogen cycle] happens through decomposition of nitrogen inside organisms. Each of them [organisms] is important [in material cycles]. [interview]

Although she was aware of the relationship between matter cycles and food chains, she did not provide a detailed explanation of this relation. She simply expressed that the carbon, oxygen, and nitrogen cycles are in relation to food chains without emphasizing the role of producers, consumers, and decomposers in material cycles.

4.2.2.2.2 Novice 2's Subject Matter Knowledge on Food Web

Novice 2's SMK on the food web was documented in the light of interviews findings including the concept map (Figure 4.5).

I: What is a food web?

N2: For example, at the bottom of the food web are plants. Then, there is a grasshopper eating this plant for instance. There can be a bird-eating grasshopper, and there is an eagle eating the bird. [interview]

I: Then, what is the difference between the food chain and the food web?

N2: The difference between the food chain and food web is... I actually do not know any difference between them. When talking about the food web, organisms feed on each other in my opinion. On the other hand, when we talk about the food chain, it is formed from producers to consumers and again it is something that resulted from their eating relations. [interview]

To reveal her understanding of the food web in detail, in the next questions, Novice 2 was asked several questions according to the food web diagram given below (Webb & Bolt, 1990, p. 188). The letters in the food web diagram represent a population in the food web. The following questions are targeted to uncover teachers' knowledge of complex relations of the populations in the food web. The findings of the sample food web questions presented in relation to common related misconceptions in the groups of "A change in one population will only affect another population if the two populations are related as predator & prey."; "A population located higher on a food chain within a food web is a predator of the next adjacent populations located

below.”; “A change in the size of a prey population has no effect on its predator population”; “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” (Griffiths & Grant, 1985).

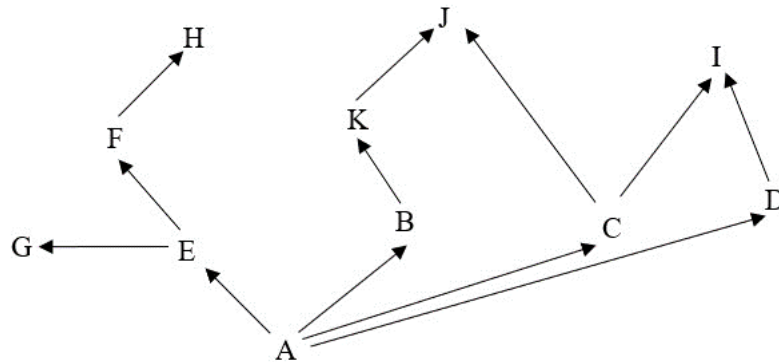


Figure 4.7 A sample of food web (Webb & Bolt, 1990, p. 188)

Group1. “A change in one population will only affect another population if the two populations are related as predator and prey” (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population H have on population E? Explain your answer.

N2: If population H decreases, then, the organisms eating population F decreases. Population F increases. If population F increases, then, they eat more population E. They [population E] increase, too. [interview]

I: What effect will a sudden decrease in population E have on the size of population H? Explain your answer.

N2: If population E decreases, population F decreases, too. Therefore, population H decreases. They [populations E, F, H] are

not in the same line. Because they [populations E, F, H] feed on each other. [interview]

The above questions targeted to reveal Novice 2's knowledge on change in one population will only affect another population if the two populations are related as predator and prey. In fact, Novice 2 appeared to have difficulties in the interaction between populations in the food web when the populations are not subsequent to each other. Novice 2 could not identify "the effect of a sudden size change in one population on a second non-adjacent population located lower on the same food chain" (Webb & Bolt, 1990). However, she could explain the influence of primary consumer effects in the tertiary consumers in the sample food web.

Group2. "A population located higher on a food chain within a food web is a predator of the next adjacent populations located below" (Griffiths & Grant, 1985).

I: What effect will a sudden increase in population H have on the size of population F? Explain your answer.

N2: As population H feeds on population F, an increase in population H will cause a decrease in population F. [interview]

I: What effect will a sudden decrease in population J have on B? Explain your answer.

N2: The sudden decrease in population J causes an increase in population K. If population K increases, it causes a decrease in population B. If I look at the other side; the sudden decrease in population J, increase in population C, and if population C increases, population A decreases. And if population A decreases, population B

decreases. That is, it [, population B] decreases on both sides.
[interview]

Novice 2 was likely to have an understanding of how change in one population causes a change in the other subsequent population in the food web. That is, she seemed to have knowledge of “the effect of a sudden size change in a prey population on its predator population and the ability to determine the effect of a sudden size change in a predator population on its prey population” (Webb & Bolt, 1990). Also, she seemed to be able to read the pathways in the food web in terms of populations’ interaction with their scientifically correct explanations. In fact, she explained decrease in one trophic level causes a decrease in subsequent other trophic levels. She was able to determine “the effect of a sudden size change in one population on a second population which is not on the same food chain, when the effect may be transmitted along more than one route” (Webb & Bolt, 1990). Novice 2 appeared to have knowledge that an increase in predator population causes a decrease in subsequent prey population.

Group3. “A change in the size of a prey population has no effect on its predator population.” (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population F have on the size of population H? Explain your answer.

N2: It decreases. As population H feeds on population F, its [population H] population decreases. [interview]

I: Which populations affected by an increase in population A is passed on to population J. Explain your answer.

N2: This is population J, and the last one is population A. An increase in population A affects all of the populations, in fact. Up to population

J; population C is affected, population B is affected, and population K is affected. If population A increases, population C increases, and population B increases. If population B increases, population K increases, too. Consequently, population J increases. [interview]

I: What effect will a sudden increase in population B have on population J? Explain your answer.

N2: When population B increases, as its [population B's] number increases, the food of population K increases. Then, population K increases, too. Population J increases. If population B increases, population A decreases. If population A decreases, population C decreases, too. Then, from the other side, population J should decrease. [interview]

The questions were aimed at understanding Novice 2's knowledge to determine "the effect of a sudden size change in a prey population on its predator population" (Webb & Bolt, 1990). In that respect, Novice 2 was likely to have knowledge of the relationships of populations identified as prey and predator. In fact, she could recognize all possible pathways through which "the effect of a sudden size change in one population on a second non-adjacent population located higher on the same food chain where the effect is transmitted along one than one route" (Webb & Bolt, 1990). It is inferred from Novice 2's responses that she had the knowledge on a change in the size of a prey population affects its predator population.

Group4. "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." (Griffiths & Grant, 1985).

I: What effect will a sudden increase in population G have on population F? Explain your answer.

N2: If population G increases, then, they [population G] will eat population E more. Then population E decreases. If population E decreases, population F decreases, too. If population F decreases, population H decreases. [interview]

I: What will affect a sudden increase in population I have on the size of population K? Explain your answer.

N2: If population I increases, population D decreases. If population D decreases, population A increases. If population A increases, population B increases, too. If population B increases, population K increases. Population A increases. Then, population C increases, and population J increases. Then, population K decreases a little. [interview]

Group 4 questions were to understand Novice 2's knowledge to determine "the effect of a sudden size change in a population on a second population not located on the same food chain when the effect is transmitted along one than one route" (Webb & Bolt, 1990). Novice 2's responses revealed that she had an understanding that a change in the size of one population in the food web will not correspond to the change in the other populations of the food web in the same way. In the food web diagram, G population is indirectly related to population F which is not located in the same food chain. Novice 2 could explain the interactions in populations within a convoluted food web diagram correctly.

To sum up, Novice 2 did not mention organisms' complex feeding relations, even though she expressed the existence of interconnecting food chains in the food web. She defined the food web just like the food chain. Novice 2 was likely to not know the difference between the food chain and the food web. Moreover, she did not mention the trophic levels with their scientific terms of producers, and consumers

like herbivores, omnivores, and carnivores in the food web. In addition, Novice 2 stated the effects of the size changes of the population on the other populations. She related the populations' interactions with feeding relations. From interview excerpts, Novice 2 was likely to have an understanding of the food web. But Novice 2 neither state energy transfer between populations nor identify consumers, herbivores, carnivores, or omnivores in the food web. However, Novice 2 could identify the consequences of the energy transfer between related but discrete two pathways in the food web diagram. She described the populations' interactions in terms of alternative pathways. Nevertheless, Novice 2 seemed to have difficulties with the effect of a sudden size change in one population on a second non-adjacent population, the effect is transmitted along more than one route. Novice 2 could explain the effect of a sudden size change in a population on a second non-adjacent population located higher on the same food chain where the effect is transmitted along one than one route.

4.2.2.2.3 Novice 2's Subject Matter Knowledge on Energy pyramid

*I: In the previous questions you mentioned about energy pyramid.
What is the energy pyramid?*

N2: The energy pyramid indicates an organism's transferring its energy to the other organisms., for instance, if plants' energy is a thousand, they [plants] cannot transfer their total energy to the organisms feeding on them [plants] That is, organisms either use some of the energy or give the energy off somehow, only ten percent could be transferred... as understood from the shape of the energy pyramid, the energy decreases to the upper levels. [interview]

I: Can you draw an energy pyramid?

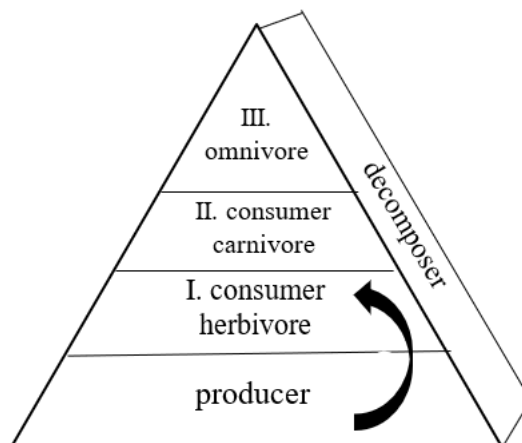


Figure 4.8 Novice 2 Energy Pyramid Drawing (see Appendix C for original drawing)

N2: In the first level, there are producers. In the second level, there are primary consumers which are herbivores I remember that there are secondary consumers followed by tertiary consumers. Last year I noticed that some of the textbooks mentioned tertiary consumers as feeding on both meat and vegetables but some of the sources did not. [interview]

I: So, at which level are decomposers placed in the energy pyramid?

N2: I should place decomposers at each level. Decomposers... all of these parts (pointing on her energy pyramid to each level) covering all of the organisms in the pyramid. [interview]

I: In fact, you touched upon the shape of the energy pyramid previously. Can you summarize why is it in the shape of a pyramid?

N2: Due to the [amount of] energy inside [found in] producers... They [producers] are high in number in the environment and the energy

stored inside them [producers] is the highest. So, they [producers] are placed at the bottom of the pyramid...As it is an energy pyramid, the amount of energy is important. The ten percent of energy is transferred to upper levels; then, a pyramid shape emerges.
[interview]

In the pre-interviews, Novice 2 explained the trophic levels of the energy pyramid, she pointed out producers, and consumers as herbivores [first consumers], carnivores [second consumers], omnivores [tertiary consumers], and decomposers in her energy pyramid drawing. That is, Novice 2 seemed to have knowledge of the energy pyramid in a scientifically correct explanation. She indicated ten percent energy decrease in each higher trophic level provides its pyramid shape. She related producers being at the bottom level with their numbers in the environment. Decomposers were explained to operate on each trophic level of the energy pyramid.

Overall, the findings of Novice 2's SMK reported in this section revealed she had difficulties in the ecosystem, energy flow in ecosystems, biological diversity, population, species, extinction-prone species, habitat, community, energy, material cycles, food chain, food web and additionally, she found to hold misconceptions in photosynthesis. She had no understanding of ecological niche.

In the next section, Novice 2's PCK on ecology was presented.

4.2.3 Novice 2's Pedagogical Content Knowledge on Ecology

In the light of Magnusson et al. (1999) PCK model, Novice 2's pedagogical content knowledge (PCK) was reported in the next section.

4.2.3.1 Novice 2's Knowledge of Curriculum

Two constituted components of knowledge of curriculum which are knowledge of goals and objectives, and knowledge of materials of Novice 2 was documented in this section under two separate sections. The data regarding Novice 2's knowledge of curriculum was gathered through pre-interviews, post-interviews, classroom observations and Novice 2's lesson plan. Novice 2's knowledge of goals and objectives on ecology was reported in the first section.

4.2.3.1.1 Novice 2's Knowledge of Goals and Objectives

This section presented Novice 2's findings gathered in interviews, lesson plans, and classroom observations regarding teaching ecology in 8th grade. The curricular objectives prescribed by MoNE and the related findings of Novice 2 are provided in Table 4.10.

Table 4.10 Novice 2's Knowledge of Goals and Objectives regarding G-8 ecology objectives in the Science and Technology Curriculum (MoNE, 2009)

Unit	Interviews	Classroom observations	Lesson plan
6: Living things and energy relations Content: Food chains			
1. Related to organisms in the food chains, students are able to; 1.1. Infer that producers are at the beginning of food chains.	Not mentioned	Teacher (T): We are talking about producers in the first link of the food chain that provides their own food.	Infer that producers are located at the beginning of food chains.

Table 4.10 Cont'd

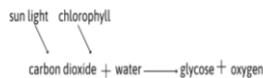
Unit	Interviews	Classroom observations	Lesson plan
1.2. List what is required for photosynthesis.	Not mentioned	Teacher (T): what is required for photosynthesis? Student1 (S1): light S2: sun T: yes, artificial or sun light need to be absorbed by chlorophyll. What is next required in photosynthesis? S3: water S4: carbon dioxide	List what is required for photosynthesis .
1.3. Observe the necessity of light in photosynthesis by experimenting.	Not mentioned	Not mentioned	Not mentioned
1.4. State that producers produce simple sugars and oxygen by photosynthesis.	Not mentioned	Teacher (T): What is produced by photosynthesis? What do plants produce? S3: Oxygen T: What is next? S4: Glucose T: The food is first produced in the form of simple sugar in photosynthesis that is glucose. This then converted into other nutrients.	State that producers produce simple sugars and oxygen by photosynthesis .
1.5. Express photosynthesis with an equation.	There is an equation of photosynthesis [within the objectives of ecology curriculum]. [pre-interview]	T: Let us write the formula of the photosynthesis. The equation of the photosynthesis... What are there in an equ 	Not mentioned
1.6. Discuss the importance of photosynthesis for living things.	They learn the importance of plants and trees... [pre-interview]	Not mentioned	Not mentioned

Table 4.10 Cont'd

Unit	Interviews	Classroom observations	Lesson plan
1.7. State that producers convert solar energy into usable energy by photosynthesis.	Not mentioned	Not mentioned	Not mentioned
1.8. Explain that living things need energy to survive.	Not mentioned	Not mentioned	Not mentioned
1.9. Explains that consumers in the food chain meet their energy needs from producers.	Not mentioned	Not mentioned	Not mentioned
1.10. Discuss the importance of respiration for living things.	Not mentioned	Not mentioned	Not mentioned
1.11. Define respiration.	Not mentioned	Not mentioned	Not mentioned
1.12. Lists what is required for respiration	Not mentioned	Not mentioned	Not mentioned
1.13. Indicate the products formed as a result of respiration with oxygen by experimenting.	Not mentioned	Not mentioned	Not mentioned
1.14. Estimate the equation of aerobic respiration as a result of his/her observations.	Not mentioned	Not mentioned	Not mentioned

Table 4.10 Cont'd

Unit	Interviews	Classroom observations	Lesson plan
1.15. Explain that some living things provide the necessary energy to survive without using oxygen.	Not mentioned	Not mentioned	Not mentioned
1.16. Gives examples of anaerobic respiration from daily life.	Not mentioned	Not mentioned	Not mentioned
1.17. Establish a relationship by comparing the aerobic respiration equation with the photosynthesis equation.	Not mentioned	Not mentioned	Not mentioned
1.18. Explain the relationship between producers and consumers in terms of nutrition and energy flow.	Not mentioned	Not mentioned	Not mentioned
1.19. Explains the material cycles in parallel with the energy flow in the food chain.	Not mentioned	Not mentioned	Not mentioned

The findings gathered in pre-interviews, Novice 2's lesson plan, and classroom observation revealed her knowledge of goals and objectives in ecology. Although in pre-interviews, she stated that she thought ecology goals and objectives were appropriate for 8th-grade students, she could not mention these goals and objectives

specifically. As seen in Table 4.10, Novice 2 mentioned the objectives regarding the food chain, food web, and photosynthesis, she did not provide any information related to respiration and material cycle objectives. The possible reason for this lack of findings was Novice 2's two-hour lesson plan prepared for the classroom observations that were conducted in line with the prepared lesson plan. However, she could explain the objectives of respiration and matter cycle objectives during pre-interviews.

In pre-interviews, Novice 2 was asked about the place of ecology in the elementary school curricular program.

I: Do you know the place of ecology in elementary school curricular programs?

N2: In 6th grade, ecology is not taught as a separate unit as I remember. In 6th grade, it [ecology] is associated with several units. That is, the questions of 'What is the importance of organic farming?' and 'how do plants and animals grow?' were tried to be answered [in 6th grade]. However, there is a unit related to ecology in 7th grade I guess. I have not taught in 7th grade yet within my two years of teaching experience. Hence, I have not taught ecological concepts in the 7th grade curriculum. Therefore, I do not know the content of this [ecology] unit in 7th grade. In fact, ecology is taught superficially at the 7th grade level as I know. In 8th grade, it [ecology] is the 6th unit. The unit is called 'the organisms and their energy relations'. Energy, the food chains, photosynthesis, respiration, and matter cycles are taught in this [ecology] unit. [pre-interview]

According to the 2009 curriculum prescribed by Türkiye MoNE, ecology units were included in the 4th, 5th, 7th, and 8th grade levels. The data regarding Novice 2's

knowledge of goals and objectives were collected in 2010. So, the 2009 curriculum was taken into account to analyze Novice 2's knowledge of curricular goals and objectives. Novice 2 was likely to know the place of the ecology in previous grades indicating her knowledge of vertical relations of ecology. In fact, she stated the place of the ecology in different grade levels correctly. She stated the place of the ecology unit at the 8th-grade level as the 6th unit correctly. She also mentioned the horizontal relation of ecology where she identified the ecology-related contents in the 8th grade level. The related pre-interview excerpt is provided below.

I: Is there any science unit taught in 8th grade associated with ecology?

N2: In the first unit, there are mitosis, meiosis, modification, and adaptation related to ecology. [pre-interview]

It was also aimed to reveal Novice 2's knowledge regarding the purpose of the ecology in science program. Moreover, she was asked about the specific objectives of the curricular program related to ecology.

I: What is the specified purpose of the ecology in the program?

N2: This unit [8th grade ecology unit] provides students to see organisms' relations or how organisms benefit from each other. That is, when one of the organisms becomes a predator, one of them eats the other. This provides them [students] to see the balance of nature. I teach is that the importance of photosynthesis and plants. They learn the importance of plants and trees in my lessons.

I: What is more about the purpose of the ecology in the program?

Here [the objectives] only there is a food chain; the food chain starts with whom; first of all, who eats whom. Here [the objectives] there are several common examples of the food chain. These examples are supposed to be answered by students. However, students did not find it. They see these examples from their textbook or there are cats and dogs around them. Hence, they [students] gave these examples. Therefore, related to food chains, more information can be taught. The influential factors in photosynthesis or graphics of them [photosynthesis] can be taught. I showed them [photosynthesis' graphics] to students, in fact. The effect of heat is not given, for example. It [the effect of heat on photosynthesis] was not in the book. But I taught. They [students] remembered photosynthesis as an equation only. In fact, how many students are able to remember the equation? Most of them [students] cannot remember. They [students] learn about photosynthesis where only carbon dioxide is taken in, and oxygen is given off. I could not teach anything more. Respiration is again similar. I included some more academic information related to matter cycles. Related to sources of energy, I mentioned contemporary issues. In this way, students became aware of the sources within Türkiye and the world. I gave more examples actually. [pre-interview]

Novice 2 appeared to have limited knowledge of the ecology objectives of the 8th-grade science program. Novice 2 did not mention specific skills students expected to gain specified in the program like experimenting with photosynthesis and respiration and interpreting the relation between producers, consumers, and decomposers. Indeed, the specified purpose of the ecology in the 8th-grade curriculum was “In this unit, students are aimed to understand photosynthesis, respiration, energy transformations, to explain the food chain and the elements that make up this chain,

to discover the relationship between the elements, to realize the matter cycles in life-related to environmental science, to know environmental problems and to offer solutions to environmental problems, to gain interest and skills in these.” (MoNE, 2009). Novice 2 neither stated the purpose of the ecology unit consistent with the prescribed program nor mentioned much of the related contents in the prescribed curriculum during pre-interviews. She taught prey-predator relations, food chain, and photosynthesis in 7th grade. She believed that there was a need to include more objectives to enhance students’ academic knowledge. She was asked whether the science curriculum offers possible misconceptions students may have about ecology. The related interview excerpt was presented below.

I: Is there any information provided in the curricular program to warn teachers about misconceptions?

N2: There is information about students’ misconceptions in the book [teachers’ guidebook]. There was related to plants’ food for instance. It [teachers’ guidebook] said that if they [plants] get food from the soil, there remains no food in the soil. The soil should decrease in amount. [pre-interview]

Novice 2 was likely to be aware of the teachers’ guidebook’s warnings about students’ misconceptions about ecology. She could follow the objectives, and explanations about the content they teach from these guidebooks (MoNE, 2009).

Novice 2 was also asked to prepare a lesson plan regarding ecology. She seemed to omit some objectives within the ecology unit at the 8th-grade level in her lesson plan’s objectives/goals and skills part. However, she observed teaching some of the objectives in her lesson although she did not include them in her lesson plan. In fact, it was seen in her lesson plan’s summary part that she covered the objectives of the

curriculum she did not list as well (Table 4.10 and Appendix M for the Turkish version; Appendix N for the English version).

In the classroom observations, Novice 2 tended to follow the prescribed curriculum with the help of teachers' guidebooks. She covered the offered objectives in the program regarding ecology. Therefore, she did not exceed the curricular objectives provided by MoNE. She taught the objectives related to the food chain and photosynthesis although she did not mention some of the curricular objectives, especially related to respiration (Table 4.10). One of the reasons for these missing objectives was Novice 2's lesson plan covering two hours of lessons. This could be the reason for missing objectives related to respiration. However, she neither included objectives related to energy flow in her lesson plan nor taught food chain and photosynthesis.

To sum up, Novice 2 had knowledge of the place of ecology in the 8th-grade science curriculum. Consistent with the prescribed curriculum, Novice 2 could state some of the objectives related to the food chain and photosynthesis; however, there were found deficiencies regarding curricular objectives. She taught food chain, food web, and photosynthesis in parallel to her lesson plan. However, Novice 2's lesson plan included fewer objectives than she covered during teaching. Moreover, she was more likely to indicate her inconsistent knowledge in terms of her beliefs and enacted PCK in the goals and objectives of ecology.

In the next section, Novice 2's knowledge of materials which is another sub-component of knowledge of the curriculum aspect of PCK.

4.2.3.1.2 Novice 2's Knowledge of Material

Novice 2 used a few instructional materials for teaching ecology. Indeed, she found using teachers' guidebooks, students' workbooks, and course books for science. Additionally, she believed that videos, posters, and 3D materials ensure effective ecology teaching. Table 4.12 presented Novice 2's knowledge of materials on ecology.



Table 4.11 Novice 2' Knowledge of Materials

Materials used	Interview questions	Lesson Plan	Classroom observations
Teachers' guidebook	<i>The materials suggested in the curriculum are appropriate. [pre-interview]</i>	Not mentioned	Followed the teachers' guidebook (MoNE, 2009).
Students' workbook, notebook	<i>I make students write the things on board onto their notebooks as a summary of what they learnt. [pre-interview]</i>	Materials and equipment used (students/teachers): textbook, notebook board, small piece of papers (see Appendix)	used to make students enroll to the lesson, to repeat and to evaluate the ecology content.
Board, chalk, eraser	<i>...to provide students with visual things with colorful chalks. These [chalks] are effective. [pre-interview]</i>	Materials and equipment used (students/teachers): textbook, board, small piece of papers (see Appendix)	used to make the content concrete with drawing figures and illustrations to make concepts better understood by students.
Exercise book	<i>Another alternative source of exercise book for SBS [High School Entrance Exam in Türkiye] is always with me. [pre-interview]</i>	Not mentioned	Not mentioned
Videos	<i>I use videos. [pre-interview]</i>	Not mentioned	Not mentioned
Photographs Posters, 3D models	<i>They [students] may asked to create an energy pyramid in three-dimensional shape or in a form of poster. [post-interview]</i>	Not mentioned	Not mentioned

Novice 2 was likely to use mainly students' textbooks, boards, and notebooks as the materials. She was asked about the materials she used in her ecology lessons and the aims for preferring these materials during pre-interviews as one of the components of knowledge of the curriculum.

I: What kinds of materials do you use for ecology teaching?

N2: I use videos. We can make field trips...as the material, um, ... I can use these materials for several activities. [pre-interview]

I: What was your aim to use these materials?

N2: I used usually the board in my lessons. It [the lesson] was effective. Explanations are not enough, in fact. You had to use a board at some points. You might draw something on the board in order to provide students with visual things with colorful chalk. These [chalks] are effective.

I make students write the things on the board onto their notebooks as a summary of what they learned. If there is a good activity in their workbooks, I also want students to do it. [pre-interview]

I: Are there any materials that you cannot reach for some reasons; however, you want to use?

N2: The materials suggested in the curriculum are appropriate. You can ask students to do a food chain by themselves by using some materials. They [students] can make it [food chain] with photographs, like a poster. They [students] may bring materials to do a pyramid or they [students] can illustrate the transformation of energy with some materials. [pre-interview]

Novice 2 thought board, textbook, and notebook were efficient instructional materials to promote students' learning in ecology. Novice 2 also stated students need visual materials apart from explanations, completing textbook activities, and taking notes. During pre-interviews, she expressed photographs could be used to illustrate food chains, and energy pyramids or by using some materials students could illustrate energy transfer. She did not explain those materials in detail.

Consistent with her pre-interview responses, Novice 2's lesson plan includes a textbook, board, and small piece of paper in the material part (see Appendix M for the Turkish version; see Appendix N for the English version). In fact, in the body part of the lesson plan, Novice 2 noted to use of these materials.

Parallel to the interviews and her lesson plan, Novice 2 used the board, textbook, and notebooks of the students in her ecology lesson. Novice 2 also asked students to draw a food chain on a piece of paper. Students wanted to do activities from their science textbooks and write notes on their notebooks.

Novice 2 asked questions after classroom observations to gain a deep understanding of her knowledge of the materials.

I: Which materials you used in your lesson?

*N2: I used the board. Another alternative source of exercise book for SBS [High School Entrance Exam in Türkiye] is always with me.
[post-interview]*

I: Were these materials you used effective?

N2: I try to make students understand the ecology concepts with providing examples, explanation, drawing figures and making them to take notes. The materials I used were effective, I believe. But other

materials could be used for more effective teaching like experimentation, 3D models, etc. [post-interview]

I: So, what would be more effective instead of this?

N2: Students might be asked to construct an artificial ecosystem to see food chain inside. They might be asked to create an energy pyramid in three-dimensional shape or in a form of poster. [post-interview]

Findings regarding knowledge of materials through pre- and post-interviews, lesson plans, and classroom observations revealed that Novice 2's believed and enacted PCK differ in terms of knowledge of materials. In fact, she was found to use textbooks, notebooks, and boards in her teaching practice in general; however, she expressed that visual materials and models would be more effective for teaching ecology. Moreover, she stated in the pre-interviews that she uses videos and materials for the activities in ecology, but she was not observed to use these materials in her lesson.

The next section presented the other PCK component which was Novice 2's knowledge of students' understanding of science.

4.2.3.2 Novice 2's Knowledge of Students' Understanding of Science

Novice 2's knowledge of students' understanding of science was examined within two categories which were knowledge of requirements for learning regarding ecology and knowledge of students' difficulties regarding ecology. The former category is explored in terms of teachers' knowledge of variations in approaches to ecology learning which include considering students' developmental levels, learning styles and abilities, and teachers' beliefs about prior knowledge that students possess

in a specific ecology concept. The latter category was investigated in terms of students’ difficulties, errors, and misconceptions with their reasons.

4.2.3.2.1 Novice 2’s Knowledge of Requirements for Learning regarding Ecology

Novice 2’s knowledge regarding students’ developmental levels, learning styles and abilities, and prior knowledge in ecology were presented in this section. The pre- and post-interviews, Novice 2’s lesson plan and classroom observations were the data source for Novice 2’s knowledge of requirements for learning ecology. Table 4.12 shows Novice 2’s knowledge of the requirements for learning regarding ecology.

Table 4.12 Novice 2’s Knowledge of Requirements for Learning regarding Ecology

Requirements for learning ecology	Pre-interviews	Lesson Plan	Classroom Observation
Prior knowledge	[Students’] prior knowledge and motivation influences my teaching much. [pre-interview]	At the beginning of the lesson, the teacher asks the students what they [students] know about the key concepts of producer, consumer, decomposer, photosynthesis, chlorophyll.	Yes, let's look at this side (in the workbook), it actually contains the topics you should have known in the past, let's see if you can fill in the side, there is a concept map there, you write the concepts of sun, food, artificial light source, plant cell, oxygen and carbon dioxide in the spaces above.

The following excerpts presented Novice 2’s related pre-interview responses.

I: In ecology teaching, what are the students' requirements?

N2: Firstly, I try to remind students of prior knowledge. If they [students] did not have knowledge of the concepts that they [students] should learn in the past, I start teaching from these concepts. [pre-interview]

I: Well, how does students' prior knowledge influence your teaching?

N2: Um...If students actively participate in the lesson, we continue with related activities. Hence, their [students'] prior knowledge and motivation influence my teaching much. [pre-interview]

Novice 2 emphasized the students' prior knowledge as the requirement for the students to learn ecology. Novice 2 also pointed out the importance of students' prior knowledge and motivation influencing her teaching.

In her lesson plan, Novice 2 stated the prior knowledge of the students as "Ecosystems, food chain, food webs" (see Appendix M for the Turkish version; see Appendix N for the English version). In line with this part of the lesson plan, she planned to initiate the lesson with the recall of students' prior knowledge. The related statement in the lesson plan is "At the beginning of the lesson, the teacher asks the students what they know about the key concepts of producer, consumer, decomposer, photosynthesis, and chlorophyll. Their thoughts were gathered without providing right answers immediately. If there are misconceptions, correct explanation is provided." see Appendix M for Turkish version; see Appendix N for English version).

During classroom observations, she started her lesson by asking questions to collect students' prior knowledge consistent with her lesson plan. According to the students' answers to these questions, she further asked probing questions or facilitated students

to remind the concepts they learned. In fact, if they provided the wrong answer, she provided the right definition of this concept. Some related excerpt from classroom observation was presented below.

I: Let's remember the key concepts. What were the producers?

S1: Producers are the one who produces its own food.

I: Yes, the thing that produces its own food is called the producer. Because plants produce their own food, they are called producers, not humans or animals. What does consumer mean?

S2: Those who consume the food produced by the producer.

I: The ones who use or consume a ready-made thing are called consumers. What does decomposer mean?

S3: It [decomposer] decomposes plants...

I: They [decomposers] are called single-celled organisms that allow plant or animal wastes to mix with the soil. What is photosynthesis?

S4: The work done by plants to produce food.

[classroom observation]

Novice 2 seemed to have limited knowledge of students' requirements for learning ecology. In fact, she provided students' prior knowledge as the requirement for students' learning ecology. However, she observed to detect students' prior knowledge in the lesson regarding producer, consumer, and decomposer. In fact, she stated students' prior knowledge in her lesson plan consistently producer, consumer, decomposer, photosynthesis, and chlorophyll. She did not mention other basic

ecological concepts students learned like ecosystem, habitat, species, population, food chain, and so on.

The next part presented the other category Novice 2's knowledge of students' understanding of science which was Novice 2's knowledge of students' difficulties regarding ecology.

4.2.3.2.2 Novice 2's Knowledge of Students' Difficulties regarding Ecology

Novice 2's knowledge of students' difficulties regarding ecology is documented in line with the findings from pre- and post-interviews and classroom observations. Table 4.13 presented Novice 2's students' learning difficulties in ecology and the elimination methods she used in her ecology lessons. Novice 2 did not mention students' learning difficulties, misconceptions, and the strategies to remedy these difficulties and misconceptions in her lesson plan. Therefore, there was no reported finding about Novice 2's lesson plan in this section.

Table 4.13 Novice 2's Knowledge of Students' Difficulties regarding Ecology

Pre and Post Interviews		Classroom Observation	
Learning Difficulties	Elimination Methods	Learning Difficulties	Elimination Methods
Material cycles	Question and answer	Food chain	Questioning
Photosynthesis and respiration		Photosynthesis	Question and answer
Producers			
Misconceptions	Elimination Methods	Misconceptions	Elimination Methods
Habitat	Question and answer Providing examples	Photosynthesis	Questioning
Community			
Plants' food			

I: Do your students have difficulty understanding ecological concepts?

N2: Students can confuse the ecological concepts. Do they [students] have difficulty? They [students] can have difficulty in the material cycles, because they [students] may not experience them [material cycles]. For instance, nitrogen cycles... they [students] have an idea about carbon, water, and oxygen cycles from their [students'] daily life. So, there are several cycles that students cannot understand. [pre-interview]

I: Are there any other ecological concepts that students experience difficulty with?

N2: Students did not have difficulty in general. However, they [students] had difficulty understanding photosynthesis and respiration. They [students] did not have difficulty in understanding daily life examples related to ecology. However, they [students] understood ecology better when compared with physics contents. [pre-interview]

I: What are the concepts that students learn easily?

N1: The concepts that students understand easily...the food chain and food web, then, the energy pyramid, for instance. However, they could not learn easily the cycles. They could give several examples and talk about environmental problems. [pre-interviews]

Novice 2 stated that students have difficulty in material cycles regarding ecology in pre-interviews. She explained the reason for their difficulty with their not having the chance to experience these cycles. Novice 2 expressed students learn ecological

concepts and issues easily when they can connect with their daily lives. Moreover, photosynthesis and respiration were the concepts Novice 2 stated that students experience difficulty comprehending because of these issues not being in relation to students' daily lives. Apart from students' difficulties, Novice 2 was asked about the ecological concepts students learn easily. She expressed students learn about food chains food webs, and energy pyramids easily and students provided several examples of environmental issues.

Although she did not mention misconceptions while talking about students' difficulties, Novice 2 asked about students' misconceptions. First of all, she asked to define the misconception.

I: I would like to ask you what is a misconception.

N2: Misconception... When we teach students a concept, he/she understands it differently. This is a misconception. [pre-interview]

I: How do you understand that if your students have misconceptions?

N2: When a child gives an answer to my question, s/he can talk about different things than their scientific meaning. I try to overcome this [misconception], then. There are several misconceptions students hold. Sometimes, I could recognize, sometimes I could not. Moreover, sometimes, I could not overcome. In fact, misconceptions are difficult to overcome. [pre-interview]

I: Then, what are the main misconceptions students possess you detected in ecological concepts?

N2: There are the concepts we do not use in our daily lives. So, students' conflict about these such as habitat and community concepts

even if they learn by rote learning they [students] forget the meanings and are confused. [pre-interviews]

I: How do you help students remedy students' misconceptions about ecology?

N2: What I have done is to give more examples regarding the concept [students have misconceptions]. When I give examples, students understand better. I try to explain the concept with examples. Then, misconceptions of the students decrease by some amount.

I try to make them [students] find the point they [students] confused. I try to make students recognize the point they [students] have misconceptions. Hence, I have to make them [students] recognize why their [students'] thoughts are wrong. [pre-interviews]

I: What are the sources of students' misconceptions according to you?

N2: What can be? If students cannot understand, the concept or their past learning may not be adequate. Therefore, s/he can have misconceptions. For instance, we give information related to a concept. Children may not have the capacity to learn this [students having misconception] concept. Therefore, s/he cannot understand the concept much. Then, this situation causes her/him to have misconceptions. [pre-interviews]

Novice 2 defined misconceptions as students' comprehension of concepts different than the teacher teaches that are apart from their scientifically correct meaning. During pre-interviews, Novice 2 stated students have misconceptions about habitat and community. She mentioned misconceptions of the students were hard to overcome. She did not talk about the methods of elimination apart from providing

examples. That is, she did not express any of the methods like conceptual change approach, analogy, and conceptual change texts to overcome students' misconceptions.

Parallel to pre-interviews, Novice 2 did not mention students' learning difficulties and misconceptions and the strategies to remedy these difficulties and misconceptions in her lesson plan (see Appendix M for the Turkish version; see Appendix N for the English version). However, within the summary section of the introduction part of her lesson plan, Novice 2 stated that students' conflicts in their prior knowledge were detected and these deficits were recovered. The related part of her lesson plan is presented below.

At the beginning of the lesson, the teacher individually asks the students what they know about the key concepts of this topic, such as 'producer,' 'consumer,' 'decomposer,' 'photosynthesis,' and 'chlorophyll.' Initially, their thoughts are collected without providing immediate answers. If there are any misconceptions, other students are also given a chance to speak, and correct explanations are encouraged to be provided.

[Lesson plan]

In classroom observations, one of the students seemed to have a misconception. The related excerpt is presented below.

S1: Teacher, is it because plants can't get sunlight, so they produce carbon dioxide at night? [classroom observation]

T: Since there is no sun at night, it cannot photosynthesize, so it only breathes. [classroom observation]

The student had a misconception about plants that s/he believed plants photosynthesize during the day and respire at night. Novice 2 provided the right answer; however, she seemed to not be aware of the student's misconception. Therefore, she continued with another concept and did anything more to overcome this misconception apart from giving the right answer. Moreover, in the lesson, one of the students asked to write decomposers to the food chain. The student said that decomposers were placed after consumers and wrote decomposers after consumers onto the food chain drawing on the board. On the contrary, Novice 2 tried to guide the student to reach the correct understanding through questioning and providing the student with the scientific explanation in her ecology lesson. The related classroom observation excerpt was as below.

T: Where did we place the decomposers on the food chain?

S2: After consumers.

T: Who were the organisms that decompose the wastes, dead of plants, herbivores, carnivores, and other consumers?

S3: Decomposers.

T: So, we have to place the decomposers affecting all.

[classroom observation]

Novice 2 was asked post-interview questions to gain understanding about her knowledge of areas that students experience difficulty.

I: What were the students' difficulties in ecological concepts?

N2: They [students] confuse producers with farmers. They [students] could not create a food chain example. Also, they [students]

experience difficulties in arrows in the food chain. They [students] have difficulty understanding the directions of arrows. Students had difficulties pronouncing even “photosynthesis”. [post-interview]

I: What were the main misconceptions students possess you detected in ecological concepts?

N2: There is one example in my mind that “whether plants get their nutrient from soil or not”. Students know that plants photosynthesize; however, they [students] cannot understand plants’ food. [post-interview]

I: How did you help students remedy students’ misconceptions about ecology?

N2: In order to diagnose students’ misconceptions, I give several related examples. If the explanation is found to be logical, s/he can solve this conflict. [post-interviews]

To sum up, Novice 2 appeared to have limited knowledge of students’ difficulties regarding ecology. However, compared to pre- and post-interviews, she seemed to provide more specific examples of students’ learning difficulties and misconceptions in ecology after classroom observation during post-interviews. Students stated to have learning difficulties in material cycles, photosynthesis and respiration, producers and food chain; and misconceptions in habitat, community, and plants’ food in ecology according to Novice 2’s findings. She stated to prefer questioning and providing examples to students to remedy students’ misconceptions although she did not notice her students’ misconceptions during her ecology lesson regarding photosynthesis.

The next section presented Novice 2’s knowledge of instructional strategies.

4.2.3.3 Novice 2's Knowledge of Instructional Strategies

Novice 2's knowledge of instructional strategies findings documented in this section within two sub-sections. In the first sub-section, Novice 2's subject-specific strategies will be presented. Novice 2's topic-specific strategies were presented in the second sub-section. Novice 2's knowledge of instructional strategies was collected through pre-and post-interviews, lesson plans and classroom observations.

Lecturing, questioning and demonstration were identified Novice 2 used subject-specific strategies. Besides, she used figures, examples, comparisons, analogies and metaphors as representations and made her students create a food chain as the activity that was explored in the subcomponents of Novice 2's knowledge of topic-specific strategies. The next part presented Novice 2's subject-specific strategies.

4.2.3.3.1 Novice 2's Knowledge of Subject Specific Strategies

Table 4.15 presented Novice 2's knowledge of subject specific strategies.

Table 4.14 Novice 2's Knowledge of Subject Specific Strategies

Subject Specific Strategies	Interview	Lesson plan	Classroom Observation
Lecturing	If the lessons are taught only through lecturing, students may not understand. There can be used several methods, in fact; however, I do not know.	Not mentioned	"An organism that produces its own food is called a producer. Because plants produce their own food, they are called producers, not humans or animals."
Questioning	Not mentioned	Teaching and learning strategies, methods: question and answer, creating food chain (Appendix)	"What are decomposers?" "What are consumers?" questions asked to students and asked students to create food chain on papers.
Demonstration	I have conducted experiments as demonstration	Not mentioned	Not mentioned

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

N2: As the aim of the science is recognition of the environment, with the help of daily life examples, students can recognize the environment easily. In fact, the science lessons are physics, chemistry or biology, they [science lessons] are all related to recognition of environment. When the rain falls; it [rain] is related to the environment or when the door opens, it [rain] is also related to the environment. There are simple machines. As it [science lesson] is the recognition of life, it is better to give examples to make them [students] understand. If the examples are abundant and if the students also provide examples, they [students] can understand the

concepts. If it is not, if the lessons are taught only through lecturing, students may not understand. There can be used several methods, in fact. Unfortunately, I do not know these methods. I have not seen the other teachers' lessons. I do not how they teach the science lessons. However, I need too much to enrol to observe other teachers' lessons to see what they use to teach. [pre-interview]

I: Apart from these instructional strategies, which types of instructional strategies do you know, or use in science?

N2: I have conducted experiments as a demonstration. To spend less time, I do not make students do experiments on their own. Instead, I perform in front of the class and show them [students] as a demonstration. Also, I make students watch videos related to the content they [students] learn. [pre-interview]

Novice 2 said to use direct instructional strategies were lecturing and questioning to teach science. In fact, parallel to pre-interview responses, she found in her lesson plan that she used these methods to teach ecology as well. She filled the part of the teaching and learning strategies in the lesson plan as “question and answer, creating food chain” (Table 4.15 and see Appendix M for the Turkish version; see Appendix N for the English version).

In classroom observations, she was observed to use direct instruction and questioning in accordance with her interview responses and lesson plan. Although Novice 2 used lecturing and questioning in her ecology lesson, she seemed to be aware of the existence of other various instructional strategies that can be used in science teaching. In fact, field trips and experimentation were some of these instructional techniques Novice 2 identified during post-interviews. In fact, she also explained and

admitted that she was an inexperienced teacher with poor knowledge of instructional methods and strategies. The related post-interview excerpt is provided below.

I: When you were planning a science lesson, what were the things you took into consideration?

N2: I think about the activities I will do before the lessons. In fact, I usually ask questions in my lessons. Therefore, I am planning the questions I will ask students. In this way, I inform them [students] about the lesson that I will teach. At the beginning of the lesson, I ask them to determine their prior knowledge and also, try to inform them about the further. As I am an inexperienced teacher, I have poor knowledge of preparing and conducting different kinds of methods. I hesitate to conduct field trips, and experimentation that I haven't used to do before. [post-interview]

Novice 2 pointed out the importance of providing daily life examples to the students to learn science. Although she mentioned there can be various teaching methods in science, she did not prefer to use other teaching methods apart from lecturing and questioning. On the contrary, she stated lecturing is one of the ineffective teaching methods in science. In classroom observations and in her lesson plan, Novice 2 used lecturing, questioning, and providing daily life examples, and illustrations for her ecology teaching (Table 4.14). Although she knew field trips and experimentation for science teaching, she said as she is a new teacher and never used these methods before and felt hesitant to use them. The next part documented Novice 2's topic-specific strategies.

4.2.3.3.2 Novice 2's Knowledge of Topic Specific Strategies

Novice 2's topic-specific strategies investigated in two dimensions which are knowledge of representations and knowledge of activities. In the next sub-section, Novice 2's knowledge of representations was presented.

4.2.3.3.2.1 Novice 2's Knowledge of Representations

Table 4.16 revealed the findings gathered regarding Novice 2's knowledge of representations in interviews, her lesson plan and classroom observations.



Table 4.15 Novice 2's Knowledge of Representations

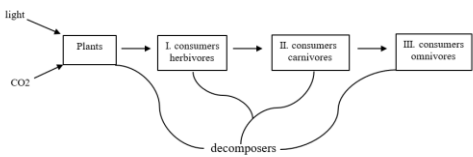
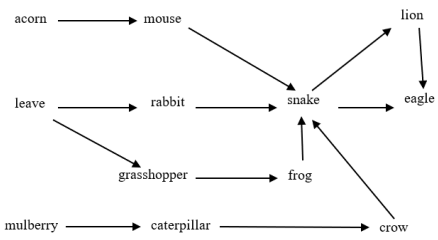
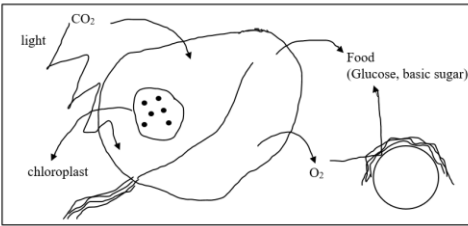
Representations	Interviews	Lesson plan	Classroom Observation
Drawing figures	If I draw a food chain to the board, then I ask students to create their own food chain. [pre-interview] To remind them [students], I asked to construct a sample food chain. [post-interview]	Students are asked to construct food chain The organisms are combined to form food web	 Novice 2's formed a food chain on the board  Novice 2's formed a food web on the board  [in this part, she explained photosynthesis] [in this part, she explained global warming. The figure represents the earth] Novice 2 draw a leaf to illustrate photosynthesis on the board <i>Human beings feed on both plants and meat. So, we can write them as the omnivores.</i>
Daily life examples	how much I give examples, they can comprehend the issue. [pre-interview] I provided examples to enable students to relate the issues with their life. [post-interview]	Students are informed about chlorophyll...it is shown the contents of the pistachio ice cream that the chlorophyll substance in the pistachio ice cream makes it green as an example for the chlorophyll.	

Table 4.15 Cont'd

Representations	Interviews	Lesson plan	Classroom Observation
Comparisons	I asked students whether the tree's barks could photosynthesize, or the tree's upper parts photosynthesize. [post-interview]	Not mentioned	It [plant] only photosynthesize with the upper green parts, but not the orange part of a carrot, so anything green does photosynthesis
Models/posters	3D model for the energy pyramid could be created. Posters could be prepared. [pre-interview]	Not mentioned	Not mentioned
Videos/documentaries	I can use videos about the ecology. I could make students to watch documentaries about photosynthesis. [post-interview]	Not mentioned	Not mentioned

I: What are the representations you provide in your ecology lessons?

N2: If I draw a food chain to the board, then I ask students to create their food chain. How much I give examples, they [students] could comprehend the issue, I think. I used general explanations to make them [students] aware of their environment. This [awareness of the environment] can be achieved with questions. It [representations] was always like that: lecturing and giving examples... [pre-interview]

I: What can be the other representations used in ecology lessons?

N2: A 3D [3 dimensional models] model for the energy pyramid could be created. Posters could be prepared. [pre-interview]

Novice 2 used to draw figures related to the food chain and food web. She provided daily life examples to enable students to relate the issues and concepts with their lives and to learn effectively. She also mentioned three-dimensional models and posters for the ecology lesson as the representations. Drawing figures and providing daily life examples were also in Novice 2's lesson plan (Table 4.15 and see Appendix M for the Turkish version; Appendix N for the English version). She stated in the lesson plan that she drew a sample food chain to ask students to create their own food chains that help to construct a food web. She also included her lesson plan providing daily life examples to students about chlorophyll.

Consistent with Novice 2's lesson plan, she was observed to draw figures of food chains, and food webs and to illustrate photosynthesis on leaf figures (Table 4.15). She made students construct a food chain on one of the pieces of paper and she formed a food web figure combining students' food chains. For photosynthesis, she drew a leaf on the board and made an illustration of the photosynthesis. Moreover, in her lesson, she used comparisons to make her students learn photosynthesis. The following excerpts from classroom observations are provided below.

N2: This process is called photosynthesis. Do only plants do this? Or do all plants do it?

S1: Those who have chloroplasts do.

N2: All plants with chloroplasts do, for example, a tree has chloroplasts, we all know this.

S2: But the tree, for example, not only constitutes leaves, but the brown colour is also not green.

N2: Yes, your friend said that since the colour of the chloroplast is green, it is made only in the green parts of the plant. If the plant is a herb, its stem is green and so does photosynthesis, but how about the bark of the trees?

I: No, it doesn't photosynthesize.

N2: It [plant] only photosynthesize with the upper green parts, but not the orange part of a carrot, so anything green does photosynthesis, so plants do. And of course, it [photosynthesis] is done by plants.

[classroom observation]

Novice 2 asked the representation in post-interviews she used after classroom observation. She stated she used daily life examples in her ecology lessons. The related interview excerpt was provided below.

I: What were the representations you provided in your ecology lessons?

N2: In the previous year, they [students] learnt food chain. So, to remind them [students], I asked them to construct a sample food chain. I provided examples to enable students to relate the issues to their lives. I reminded their prior knowledge with explanations. I tried to create confliction in students' minds. For example, I asked students whether the tree's bark could photosynthesize, or the tree's upper parts photosynthesize. Moreover, I like to give the example of

pistachio ice cream in which chlorophyll makes its colour green.
[post-interview]

I: What else could you use as the representations in your lesson?

N2: I can use videos about the ecology. We [all teachers in Novice 2 school] subscribe to Vitamin [an online platform that provides instructional videos in Türkiye] and I can make students watch videos. I could make students watch documentaries about photosynthesis. There are lots of documentaries. However, I did the ones if necessary.
[post-interview]

The figures, examples, comparisons, analogies and metaphors Novice 2 used were reported as knowledge of representations. Novice 2 was found to prefer representations such as drawing figures, daily-life examples and comparisons. During classroom observations, she asked students to draw a food chain and energy pyramid on the board. She also taught photosynthesis by drawing a leaf figure on the board and stating the reactants and products of the photosynthesis on the figure. She provided daily examples to the students and asked students to give daily life examples. To increase students' understanding of ecological concepts, she used comparisons. Moreover, she also mentioned models, posters, videos and documentaries that can be used as representations in ecology lessons.

The following section presented Novice 2's knowledge of activities.

4.2.3.3.2.2 Novice 2's Knowledge of Activities

Novice 2's knowledge of activities was the other sub-component of knowledge of topic-specific strategies. The pre- and post-interviews, lesson plan and classroom observations were the tools to gather data about Novice 2's knowledge of activities.

Novice 2 preferred to use lecturing and questioning and she stated that she used demonstrations in her ecology lessons the previous year that she taught at 8th grade level. In pre-and post-interviews, she commonly mentioned the representations like daily life examples, apart from activities. Related pre-interview excerpts are provided below.

I: What kinds of activities are within the curriculum related to ecology?

N2: There are suggested experiments within the curriculum. There are photosynthesis experiments and aerobic respiration experiments. Related to the food chain, there are not so many activities though. There are activities mostly related to respiration and photosynthesis. There are not many experiments, or activities about remaining concepts of ecology. They [activities] are related to making students aware of the environment. [pre-interview]

I: Are there any activities that you want to do?

N2: In chemistry, it is appropriate to conduct experiments to demonstrate to students. However, in ecology, it is more appropriate to provide examples to students from daily life to increase their [students] awareness of balance in the environment. [pre-interview]

I: According to you, are these activities enough and suitable for elementary students?

N2: I think the activities are enough and suitable. You can conduct photosynthesis experiments that how the chlorophyll works and to see which gas goes out in photosynthesis. [pre-interview]

I: Do you have any chance to conduct these activities?

N2: I had a chance to conduct an anaerobic respiration experiment last year. The time was limited, so I didn't want to do further activities, I even conducted it [anaerobic respiration experiment] very simply. Though, I didn't do the experiment about photosynthesis. [pre-interview]

I: So, what else can you do other than this?

N2: Students can be made to conduct campaigns related to environmental problems or to increase awareness about photosynthesis, and the importance of plants and forests.

In general, there are experiments that can be done. For example, you make plants to do photosynthesis in a container. The oxygen is collected in the container, and you hold the flame when you open the container's cap. You see the flame because oxygen goes out, but I did not dare to do it [experiment]. Because I don't know how much oxygen will be needed to make the shine. [pre-interview]

Although Novice 2 seemed to know about activities in ecology teaching and ecology curriculum, she used representations like drawings and direct teaching and questioning in her lesson. In Novice 2's lesson plan, the "teaching and learning activities" part filled with the statements of "creating food web, developing photosynthesis equation" (see Appendix M for the Turkish version; see Appendix N for the English version).

Parallel to her lesson plan, she gave students a piece of paper and asked them to draw a sample food chain in the lesson. Then, she asked students to draw their own food chain and combine these food chain drawings on the board to form a food web.

Therefore, the only activity she provided both in her lesson plan and classroom observation was to make students construct their food chains on a piece of paper. The related classroom observation notes are provided below.

T: Yes, “the food chain always starts with producers who produce their food, that is, photosynthesize.” Yes, I will give papers to you, everyone will write their name and surname and I want you to - construct a food chain.

T: Everyone will form their own food chain.

[classroom observation]

I: What were the activities you did in the ecology lesson?

N2: I want students to construct a food chain by themselves. Then, I asked them to write these food chains on their notebooks. Sometimes I want students to construct concept maps, however, I did not do it.
[post-interview]

I: What other activities could you do in your ecology lessons?

N2: I used lecturing to inform students about the concepts, and questioning to enable students to criticize the issues related to ecology and to provide daily life examples in general. I could do experiments related to photosynthesis and respiration. In fact, I did about anaerobic respiration last year. *[post-interview]*

To sum up, Novice 2 tended to use teacher-centred instructional strategies and methods like direct teaching and questioning. Although she had knowledge of student-centred teaching methods and strategies like experimentation, concept mapping, creating models, and posters, she did not prefer to use them in ecology.

She used direct teaching and questioning in common, used drawings, and comparisons, provided daily life examples and made students construct food chains and food webs in her ecology lessons.

The component of PCK which is Novice 2's knowledge of assessment presented in the next section.

4.2.3.4 Novice 2's Knowledge of Assessment

Novice 2's knowledge of assessment is presented in terms of knowledge of what to assess, types of assessment, knowledge of assessment methods and sources of assessment. Novice 2 also examined in terms of which knowledge domains influence her choice of assessment strategies and methods regarding ecology. Novice 2's pre- and post-interview responses, lesson plans and classroom observations were collected to understand her knowledge of assessment regarding ecology.

4.2.3.4.1 Novice 2's Knowledge of Dimensions of Science Learning to Assess

Novice 2's knowledge of dimensions of science learning to assess was gathered through pre-interviews, the lesson plan and classroom observations. Novice 2's knowledge of dimensions of science learning to assess was presented in Table 4.16.

Table 4.16 Novice 2's Knowledge of Dimensions of Science Learning to Assess

Dimensions of Science Learning to Assess	Pre-Interviews	Post-interviews	Lesson Plan	Classroom Observation
What to assess	Knowledge Attitude	Attitude	Knowledge Attitude	Knowledge Attitude

I: What is your aim to assess in students?

N2: My aim is to assess students' knowledge. We do not assess their attitudes. Whatever they do during exams is the criterion to understand their learning. [pre-interview]

Novice 2 was likely to focus on students' comprehension of ecology for assessment. On the contrary, in her lesson plan, she focused her assessment on attitude. The statement of Novice 1 in her lesson plan in the part of "Evaluation and Assessment" was provided below (see Appendix M for Turkish version; see Appendix N for English version).

Evaluation and Assessment: In the line with students' participation to the lesson, formative assessment will be done.

[Lesson Plan]

Parallel to the pre-interviews and lesson plan, Novice 2 focused on students' attitudes and conceptual understanding in her ecology lessons. She ignored the students' skills. Novice 2 directed questions to the students and used probing questions. Sometimes she gave answers when students could not find the right answer. That is, she focused on the assessment of students' understanding in the knowledge domain. A sample excerpt from classroom observation was provided below to illustrate students' participation in the lesson.

T: What is the colour that photosynthesis is done most efficiently?

S1: Yellow is the most efficient.

T: Then, why?

S2: We did not learn it.

T: Yes, I haven't taught it yet. But I want to guess the colour and the reason for it.

S3: I think orange because it is the sun's colour.,

T: What else?

S4: Teacher, I think it is green colour.

T: Why do you think so?

S4: Because the plants' colour is green.

T: Your friend said the efficient colour is green because it is the plants' colour. I am answering. The most effective take place under violet colour. I want you to search for the reason.

[classroom observation]

Novice 2 indicated that she aimed to assess students' knowledge and participation in the lesson through formative assessment. She asked about her aim to assess the students to understand her knowledge of dimensions of science learning. She appeared to focus on students' attitudes towards the lesson and evaluate their participation in the lesson.

I: What was your aim to assess in students?

N2: I assessed students' attitudes in my lessons. I do not like to assess students with performances and projects. For instance, in project homework, students work together. A student who does not participate in my lessons may get eighty or ninety from the project because of the group work. The student continues not to participate in the lessons. This is wrong when considering other students. I started to give a plus to each participation student. I gave a degree to three plus of the students. [post-interview]

Novice 2's knowledge of methods of assessment documented in the next section.

4.2.3.4.2 Novice 2's Knowledge of Methods of Assessment

Table 4.17 Novice 2's Knowledge of Methods of Assessment

Methods of Assessment	Pre-Interviews	Post-interviews	Lesson Plan	Classroom Observation
How to assess	Traditional exams	formative assessment through questions, activities	Diagnostic Formative	Formative Diagnostic
When to assess	End of the unit Within the unit	at the beginning Within the unit	At the beginning During the lesson	At the beginning During the lesson
Knowledge domains influence assessment methods	Content knowledge	Knowledge of assessment methods	Not mentioned	Not mentioned

I: Which assessment methods and techniques do you use to assess students in ecology?

N2: The traditional exams are not effective, in my opinion. However, what can be done apart from them [exams]? If the traditional exams are applied, the questions need to enable students to make interpretations. Apart from traditional exams, I do not know what we can do for assessment. [pre-interview]

I: Which one of the assessment methods that you use is more effective in terms of understanding whether students learn the ecological concepts or not?

N2: Related to ecology, there is not any other assessment method that comes into my mind. However, there should be different assessment methods apart from exams. [pre-interview]

I: When do you assess students in ecology?

N2: It [assessment] can be done at the end of the unit. Students can be assessed within the unit. The smallest parts of the unit can be assessed at this stage. Students can be assessed to understand how much they [students] learned in the end. The exams can be used for assessing students' level of learning...Those are more important for me. [pre-interview]

I: Which knowledge do you have effective in determining your assessment method?

N2: According to the content, the assessment methods I use vary. I usually use tests because of the SBS [High School Entrance Exam in

Türkiye] examination. Sometimes, I may ask what this figure represents. According to the content area, what I will use as the assessment method changes. [pre-interview]

Pre-interview findings revealed that Novice 2 seemed to use traditional assessment methods like exams at the end of the units. She mostly focused on students' conceptual learning to assess the level of the learning through exams.

In the lesson plan, Novice 2 stated related to evaluation and assessment that “In the line with students' participation to the lesson, formative assessment will be done.” (see Appendix M for Turkish version; see Appendix N for English version). She started to use formative assessment in her lesson plan. The statement related to formative assessment is “At the beginning of the lesson, the teacher asks the students what they know about the key concepts of producer, consumer, decomposer, photosynthesis, chlorophyll.” (see Appendix M for Turkish version; see Appendix N for English version). At the beginning of the lesson, to understand students' prior knowledge, she planned to ask questions about past learning.

In fact, in the classroom observation, Novice 2 started her lesson by asking about the concepts students learnt previously parallel to her lesson plan. The related classroom observation excerpts were as the follows.

T: We started a new unit. The key concepts. What were the producers?

S1: Producer, the thing producing its [producers'] own food.

T: Right. A thing that produces its [producers'] own food and carries out this activity is called a producer. Because plants produce their own food, they are called producers, not humans or animals. What did consumer mean?

S2: The thing that consumes the food producers produce.

T: Yes, the thing that consumes the produced food are called consumers. What were decomposers?

S3: Decomposing plants.

T: The organisms with single cells decompose the plants and animals' wastes into the soil.

[classroom observation]

Novice 2 assessed students' learning through students' answers in questioning and their participation in the food chain constructing activity. Therefore, the classroom observation notes supported the lesson plan findings that she used formative assessment methods in ecology. In fact, she generally used closed-ended questions to provide the right answer to the concept students expected to learn. Some of the questions Novice 2 asked in the lessons were like "What is the consumers?", "what are the things plants need for photosynthesis?" and "What are the products of photosynthesis?" It was likely that Novice 2 strictly followed the prescribed curriculum about ecology to enable students to learn the curricular concepts.

The post-interview findings about Novice 2's knowledge of methods of assessment are presented below.

I: Which assessment methods and techniques did you use to assess students in ecology?

N2: It [assessment] was a formative assessment, that is to say, I am trying to evaluate the previous learnings at the beginning. I asked them [students] "We learned about this concept in the previous year, do you remember?" I did not make examinations or quizzes for

ecology. We also did some activities, and I gave photocopies and handed out tests to them [students]. I was trying to understand whether they [students] learned the subject well enough. [post-interview]

I: Which one of the assessment methods that you use is more effective in terms of understanding whether students learn the ecological concepts or not?

N2: I would like to give an example for this question: I have a student named S1. I thought at the beginning of the semester that S1 was a lazy student from his/her exam results and that he participated most of the time in the lessons. Then, I changed my mind about him. That is to say, I prefer to assess students according to their participation. [post-interview]

I: Do you think that these assessment methods were enough?

N2: Most probably, the [assessment methods Novice 2 used] are not enough. In fact, the methods I used were efficient, I think. However, there can be other methods I need to use. [post-interview]

I: Which knowledge do you have effective in determining your assessment method?

N2: I used exams and sometimes I want students to do posters for the assessment. These are related to the knowledge I gained during my university education. I use a constructivist approach when deciding on assessment methods that I learned in my university years. I tried to use different methods apart from questioning. I make students do activities or want them to prepare posters.

The assessment method I used changed according to the subject matter. However, as I use generally exams as the assessment tool, they are much alike... I ask five types of questions in my exams; fill-in-the-blanks, matching, and multiple choices... if one of the exams includes a puzzle, the other has a question that requires interpretation.

Students' prior knowledge determines the difficulty of the questions I asked. If students do not understand the concepts, I ask simple questions. I ask questions parallel to the lessons taught. I prepare the questions myself in general. [post-interview]

Post-interview responses of Novice 2 revealed that she used formative and summative assessment methods. She stated that she assessed students' prior knowledge and their participation as a formative assessment and the level they learnt about the content as a summative assessment. Both in pre-interviews and in post-interviews, she mentioned tests as the assessment tool she used. On the other hand, she mentioned the different types of questions she used in post-interviews. Parallel to interview findings, Novice 2 assessed students' prior knowledge in her ecology lessons and encouraged students to participate in the lessons with the questions.

The following section presents the summary of Novice 2's PCK.

4.2.3.5 Novice 2's PCK Summary

Novice 2's pedagogical content knowledge with its components in teaching ecology was summarized in this section in Table 4.18.

Table 4.18 Novice 2's Pedagogical Content Knowledge in Teaching Ecology

Goals and objectives	KoC		KoL		KoIS		KoA
	Materials	Requirements	Learning difficulties	Subject specific	Topic specific	What to assess	
See Table 4.11	Teachers' guidebook Students' workbook, notebook Exercise book Board chalks	Prior knowledge	Producers Photosynthesis and respiration Material cycles	Lecturing Questioning Demonstration	<i>Representations:</i> Figures Daily-life examples Comparisons Models/Posters Videos/documentaries	<i>Activities:</i> Food chain construction <	

KoC: Knowledge of Curriculum

KoL: Knowledge of Students' Understanding of Science

KoIS: Knowledge of Instructional Strategies

KoA: Knowledge of Assessment

In this section, Novice 2's SMK and PCK was documented. In the next section, Expert 1's SMK and PCK regarding ecology presented.

4.3 Expert 1's Subject Matter Knowledge and Pedagogical Content Knowledge Regarding Teaching Ecology

4.3.1 Expert 1's Demographic Information

Expert 1 was a science teacher for twenty-eight years. She graduated from the Institute of Education in 1982 in Türkiye. Contrary to Novice1 and Novice2, she had a bachelor's degree from a three-year undergraduate education. During her three years of undergraduate education, she took courses such as education psychology, evaluation and measurement related to educational sciences and physics, chemistry, biology, botanic, zoology, and mathematics related to science content area. After graduation, she enrolled on the inservice training related to educational materials, educational guidance and counselling and the training related to computer-assisted instructions. She stated that she started her career by teaching biology to high school students. First years of her career, she taught agriculture, traffic and first aid lessons. She experienced teaching science at 6th, 7th and 8th grade levels. She had a willingness to improve her science teaching through reading several books, watching videos, attaining courses, and attending trainings and workshops. She also stated that she liked to discuss scientific issues and teaching approaches in science with her colleagues. Her school had the necessary equipment and facilities to provide students with different science learning environments.

In the following parts, Expert 1's SMK and PCK on presented. The first part put forward Expert 1's SMK in ecology.

4.3.2 Expert 1's Subject Matter Knowledge on Ecology

Expert 1's subject matter knowledge on ecology was investigated through pre-interview questions, figures, exemplifications, drawing related figures and their interpretations and concept map drawing. Through twenty-nine questions and sub-questions, subject matter knowledge regarding ecological concepts and principles was collected. Findings were reported under two main categories that are basic ecological concepts and energy flow in ecosystems.

The following parts presented Expert 1's SMK findings on basic ecological concepts.

4.3.2.1 Expert 1's Subject Matter Knowledge on Basic Ecological Concepts

First, Expert 1 asked to define ecosystem.

Expert1 (E1): Ecosystem...how can I define it? Living things in nature, in a certain area or the environment in which living and non-living things can exist. Briefly, we can define it [ecosystem] shortly as an environment. [interview]

I: Okay...Can you give examples to the ecosystem?

E1: Hmm... Lake ecosystem is an ecosystem, [there are also] terrestrial ecosystems... [interview]

I: Can you draw a concept map?

Figure 4.9 illustrated Expert 1's concept map related to basic ecological concepts.

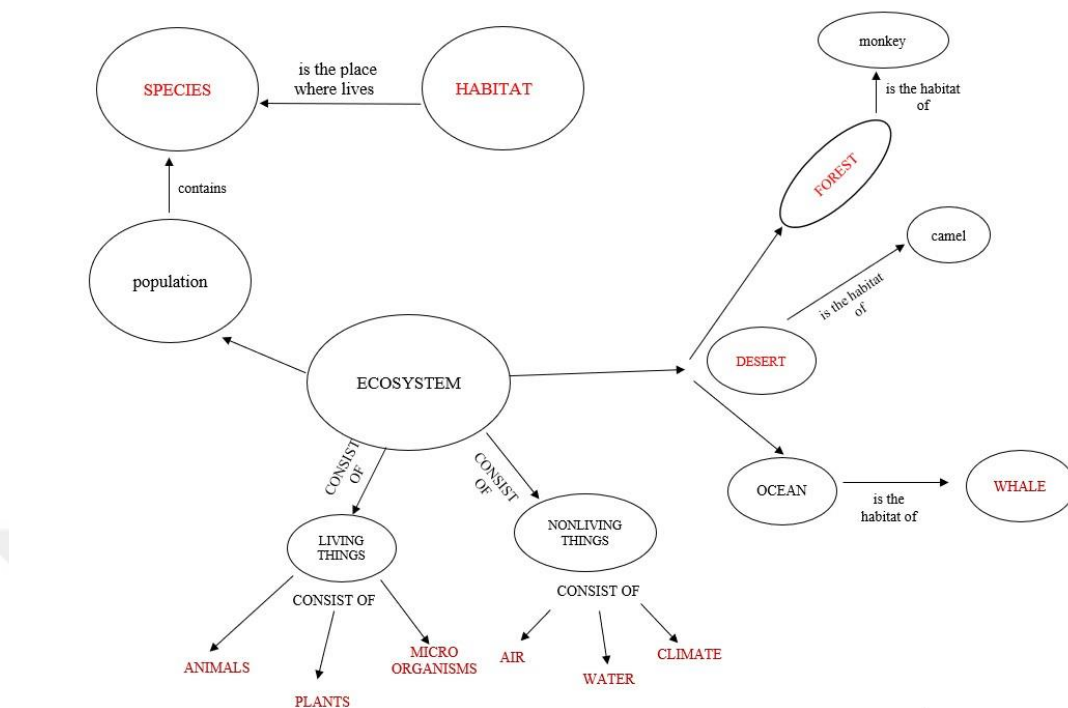


Figure 4.9 Expert 1' Concept Map (see Appendix D for original drawing)

Since she failed to mention the interactions between living and non-living things, she was asked a short script to reveal whether she was aware of the nature of those interactions:

I: Assume that you asked your class to construct a closed ecosystem as a homework assignment. Among your students, Ali and Ceren decided to prepare this homework together. They meet after school for this homework. Ali suggested that: 'Let's take three large glass containers. In one, we will put all the non-living things like rocks, soil, water and air and we will hang a light bulb over it to represent the sun. In another container, we will put just the plants and in the third container, we will put just the animals. It will be cleaner this way if

we keep everything separate!”. How would you evaluate Ali’s ecosystem suggestion?

E1: Yeap... There could not be an ecosystem like that [Ali’s ecosystem suggestion]. That is, three different kinds of things [animals, plants, non-living things] are placed in separate places. Non-livings another side. Ali’s ecosystem suggestion could not be an ecosystem. [interview]

I: Can you predict what would happen in the jars over time? Explain your ideas.

E1: They [living organisms] will disappear. All of these things [living organisms] will die. In fact, rock, soil, and water are already non-living, nothing will change about them [rock, soil, water]. Other organisms will die. For example, plants cannot take in carbon dioxide to photosynthesize. Animals cannot take in oxygen to respire. What will they [plants and animals] do? They [plants and animals] will die. [interview]

Expert 1’s responses consistent with her definition and concept map indicated that she had an understanding of ecosystems consisting of biotic and abiotic components. Although she did not mention the interaction of living and non-living things in her ecosystem definition in detail, she stated a brief relation of living and non-living things in the ecosystem in the previous script. She explained plants need carbon dioxide and animals need the oxygen in the air to respire. Moreover, she could provide examples of the ecosystem as a lake and terrestrial ecosystem. Expert 1 constructed a spider concept map and it consisted of six concepts that are ecosystem, living organism, non-living organism, population, species and habitat. She found it to not include some basic ecological concepts in her concept map like community,

ecological niche, biological diversity, producer, consumer, decomposer, food chain, food web and energy pyramid. She used linking words. However, there were some missing linking words between some concepts that are linked to each other with just arrows. For example, ecosystem and population; ecosystem and ocean; ecosystem and desert; and ecosystem and forest. Moreover, she was likely to use similar linking words. Expert 1 used linking words to form scientifically correct relationships of some of the ecological concepts. For instance, related to ecosystems she formed “ecosystem consists of living things” and “ecosystem consists of non-living things”. In fact, in her concept map, the ecosystem was a major central concept that branched into living, and non-living organisms and populations. She provided examples for the ecosystem, living things and non-living things. Related to the ecosystem, she gave examples such as ocean, desert and forest different from her interview responses. For the living things, she included animals, plants and microorganisms as the members. Similarly, air, water and climate were included as the members of non-living things in her concept map. However, her concept map did not consist of cross-links. In fact, it was a simple concept map that did not identify the holistic and complicated relations of ecological concepts with crosslinks and several branches terminated from each concept.

One of the basic ecological concepts Expert 1 identified in her concept map was species (Figure 4.9). However, in pre-interviews, she defined species without relating population and habitat. Expert 1’s definition of species is provided below.

I: So, what is species?

E1: The group of organisms possessing similar characteristics and arose from the same ancestors, maybe we can say this for species. For instance, I can give a horse and mule as an example. A mule is an offspring of a horse and donkey which is sterile. [interview]

In her concept map, Expert 1 connected species with habitat and population. Related statements were “population includes species” and “species’s living space is habitat” (Figure 4.9). Overall Expert 1 seemed to have an understanding of species. She defined species by focusing on both common characteristics and interbreeding. Related to species, Expert 1 asked about the characteristics of extinction-prone species.

I: What are the characteristics of extinction-prone species?

E1: I think, they are becoming extinct because of the competition... Can it be also because of the emergence of new species in the environment? Because of the process of adaptation, new species can exist... Moreover, the main reason can be our bad usage of natural sources... To increase some of the organism’s numbers; others need to be extinct. [interview]

The characteristics of extinction-prone species were explained in terms of species adaptation, competition, and the existence of new species in their environment. However, she did not identify several specialized characteristics of extinction-prone species such as habitat destruction, not finding food and shelter, decrease in reproduction rate, fixed migratory pattern, specialized feeding habits, to be found in only one place or region, limited specialized resting or breeding areas, feed at high tropic levels.

I: You included population in your concept map. What is the population?

E1: The group of organisms of the same species living in a certain area, we can define population like that. [interview]

I: You just said they should be the same species, why?

E1: Yes, [population is] a group of individuals of the same species living in an area. [interview]

I: You connected species with habitat in your concept map. What is a habitat?

E1: It [habitat] is the place where an organism lives. It [habitat] is the area. That is, when an organism is asked where it [organism] is, it [habitat] is the place where it [organism] can be most probably found. We can think like that, cannot we? [interview]

I: What about the community?

E1: Hmmm... It is not included in the curriculum. Therefore, I could not provide the definition. [interview]

I: What is the ecological niche?

E1: Well, these concepts [community and ecological niche] are not included in the curriculum. Therefore, I cannot give their definitions. [interview]

When Expert 1's knowledge of population, habitat, community and ecological niche was considered, it was found that she did have any knowledge (no understanding) of community and ecological niche. She explained the reason by stating that 'community and ecological niche are the concepts which are not found in the science curriculum. One can conclude that her knowledge was limited to the content of the curriculum. Her concept map neither included ecological niche nor community (Figure 4.9). Conversely, she defined habitat as a living space of organisms and consistently, in her concept map, she related habitat with species stating "habitat is the place where lives species"., she also used habitat as a linking word such as,

“desert is the habitat of camel”, “forest is the habitat of the monkey” and the ocean is the habitat of whale”. However, she did not specify the habitat where an organism sustains its growth and reproduction by meeting its necessary needs like proper climatic conditions, food, water, shelter.

I: What is biological diversity?

E1: The diversity of animals and plants in an area is called biological diversity, in my opinion. [interview]

I: Is biological diversity advantageous for organisms?

E1: It [biological diversity] is advantageous, of course. If there is a high diversity of organisms, it [biological diversity] is advantageous for the environment, too. Frankly, it [biological diversity] is advantageous for the groups of organisms, food chains and food webs. [interview]

Expert 1 seemed to have limited knowledge of biological diversity. She simply defined biological diversity focusing only on animals and plants, implying species diversity without referring to genetic and ecological diversity and associated the advantage of biological diversity with the food chains and food webs. Biological diversity was not included in her concept map (Figure 4.9).

Overall findings about basic ecological concepts suggest Expert 1's knowledge needs to be improved on some of the basic ecological concepts such as ecosystem, species, habitat, community, ecological niche, biological diversity, producer, consumer and decomposer in a way to construct interaction of these concepts.

Throughout the interviews, including the concept map, she did not mention about any concepts and processes referring to the energy flow in ecosystems such as

energy, photosynthesis, food chain, food web and energy pyramid. Accordingly, she was asked several questions to unveil her knowledge related to the energy flow in ecosystems. Her responses were reported below.

4.3.2.2 Expert 1's Subject Matter Knowledge on Energy Flow in Ecosystems

When asked to define energy, Expert 1's response was:

E1: Energy is the capacity to do work, it is the power... What we understand from energy is to be able to do or to achieve something. In fact, in our science lessons, it [energy] is defined as the capacity to do work. At the beginning [of the lesson teaching energy concept], I describe it [energy] as the capacity to do work. It [energy] is divided into two types potential energy and kinetic energy and explained them [potential energy and kinetic energy] in the lesson. We have also talked about mechanical energy and energy conversion. I suppose it [energy] is a word that originated from Greek. [interview]

I: How do you explain the flow of energy in ecosystems, then?

E1: Well, the flow of energy in the ecosystem can start in the terrestrial ecosystem can be the lake ecosystem, in the lake, for instance, there are mosses, and lichens. There is production there [in the lake]. There are blue-green algae in the lake, are not there? They [mosses, lichens, blue-green algae] may form a food chain. For instance, there are fishes that eat green algae [in the lake]. The fishes eat other small fishes. There [in the lake], for instance, frogs can eat tiny insects. That is, there is a cycle. We can say frogs eat the insects... [interview]

I: You said 'Production'. Do you remember how these organisms produce?

E1: Yes...well.... under the sunlight, water from soil, carbon dioxide from air is taken in. Hydrogen, oxygen and carbon are here [in the process of production] converted into glucose, basic sugar. It [glucose] is stored as food for both themselves [producers] and for other organisms. [interview]

I: What is the food of plants, then?

E1: Plants produce their own food. They [producers] are autotrophs. That is, autotrophs produce food at the end of photosynthesis. The organisms carrying chlorophyll produce their [producers] own food. [interview]

I: About photosynthesis, what is the purpose of it?

E1: The aim of photosynthesis is that; photo means light, synthesis means combination through light. Overall, it means the production of food under the sun light. That is, in order to survive, every organism needs food. Green plants produce their [producers] food with the help of these procedures, I think. [interview]

I: Okay, can you explain the mechanism of photosynthesis?

E1: Well. The sun's energy is stored inside the plant... that is to say, chemical energy is stored as food somewhere within the plant. This event causes the conversion of energy. In this way, the amount of carbon dioxide decreases, and the oxygen amount increases in the environment. [interview]

I: Do you think that photosynthesis obeys the first and second laws of thermodynamics?

E1: Now, it is related to energy. Sun's energy is used up to form a kind of energy. This occurs in the production of food for organisms. This energy is transferred to another organism in their eating relation.

In this way, happens energy conversion. I think, it [photosynthesis] also obeys the second law of thermodynamics. Actually, the total of the synthesized energy is not used as food by organisms. If we think that when a plant is decomposed, it is mixed with soil. In this case, some amount... a small amount of [energy] is lost, I think... Some part of the energy is lost in the soil. [interview]

I: Why would an increase in the atmospheric concentration of carbon dioxide not necessarily result in a corresponding increase in photosynthesis?

E1: Hmm, if we think according to poisoning... Of course, carbon dioxide is a poisonous gas. Frankly, I handle this issue from this point [carbon dioxide being poisonous gas]. However, carbon dioxide is effective in the rate of photosynthesis. If the amount of carbon dioxide is high, the rate of photosynthesis will be high accordingly. But if you look at the issue from this point, it [carbon dioxide] is poisonous for other organisms. But it [carbon dioxide] is necessary for photosynthesis and increases its [photosynthesis] rate. [interview]

Overall, Expert 1 seemed to have limited knowledge regarding most of the concepts and processes present in the flow of energy. She was the only one among the

participants who addressed the glucose, yet. Even though she did not provide detailed information about the converted form of energy through photosynthesis, she stated that chemical energy is stored as food in plants. However, she did not know the place where the food was stored in the plants. Although highlighted the CO₂, O₂ and water in the process of photosynthesis, she did not relate her knowledge to the material cycles. Indeed, she appeared to perceive the process of photosynthesis as somewhat simple and linear in which carbon dioxide and water are taken in and oxygen and glucose are produced. Even she did not integrate concepts and processes of energy into her concept map (Figure 4.9).

She failed to relate the questions of photosynthesis to the limiting factors implying her difficulties in understanding limiting factors. In fact, she did not relate food chain questions to the limiting factors as well (see section 4.3.2.2.1). She perceived a linear relationship. That is, she stated that the increase in carbon dioxide results in an increased rate of photosynthesis. Moreover, she explained the increase in the atmospheric concentration of carbon dioxide does not necessarily result in a corresponding increase in photosynthesis with carbon dioxide being poisonous.

Although she seemed to have difficulties in energy in ecosystems and limiting factors in photosynthesis, Expert 1 was likely to have some knowledge regarding energy flow in ecosystems. She explained solar energy is converted to chemical bond energy stored within glucose which is important for the energy flow in the ecosystem. She was aware of the flow of energy from producers to the consumers. To further understand Expert 1's knowledge of flow of energy, she asked questions regarding the food chain, food web and energy pyramid presented in the next parts.

4.3.2.2.1 Expert 1's Subject Matter Knowledge on Food Chain

Expert 1 answered the pre-interview questions regarding the food chain. She drew a sample food chain during pre-interviews as well. However, she did not include the food chain in her concept map (Figure 4.9).

I: What is the food chain?

E1: The food chain is the eating relation of organisms living together; we can describe the food chain like that. [interview]

Expert 1 described the food chain with the feeding relations of organisms. Expert 1 asked to draw a food chain presented in Figure 4.10.

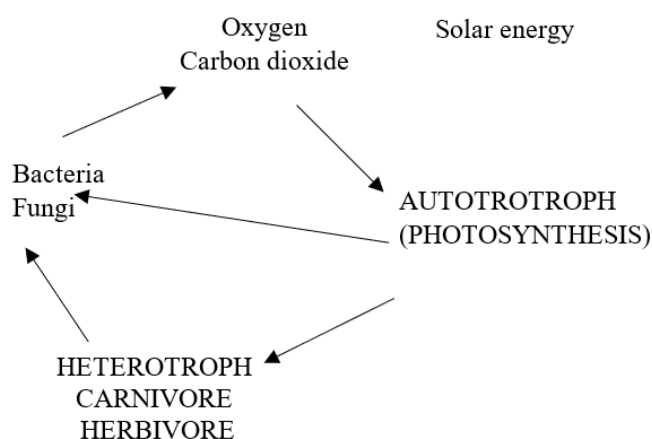


Figure 4.10 Expert 1 Food Chain Drawing (see Appendix D for original drawing)

I: Can you draw a food chain?

E1: What we have taught in the lessons so far, I think like this: for example, autotrophs. Now if we write autotrophs here (pointing to the food chain drawing) we need to write photosynthesis then who eats

them [autotrophs] that are heterotrophs, then hmmm... How do we say... there are carnivores and herbivores... then there are oxygen and carbon dioxide, can it [food chain] be like this? [interview]

I: Where are the decomposers? In which trophic level do decomposers operate?

E1: We can draw arrows to each organism in the chain; that is to say, from decomposers to the other organisms. [interview]

I: What do the arrows in the food chain represent? Please explain.

E1: It's [food chain's] direction...Related to organisms' feeding relation, they [arrows] show the direction. Or, can we think that: They [arrows] represent the energy transformation? We can also think in that way, in my opinion. [interview]

I: Is the length of a food chain limited?

E1: No, it is not. We cannot restrict the length of the food chain. [interview]

I: If we can increase the length of the food chain, up to which trophic level can we continue?

E1: I don't think so, if there is a number, we would have restricted it [length of food chain] actually. [length of the food chain] can be different for each food chain. So, if we made restrictions, we would break the food chain, I think. [interview]

I: Can you increase the levels of your food chain to 7-8-9 or 10?

E1: Yes, it can be. Now, for example, if we specify the plant names here [in the food chain] and by diversifying the names of living things, we could extend the chain more. [interview]

Overall, Expert 1 drew a cyclic food chain, having no starting and end points. Although mentioned in the following questions arrows represent the energy transformation. Her food chain emphasized organisms' feeding relations. Totally, her food chain consisted of concepts including processes namely solar energy, oxygen, carbon dioxide, autotroph, photosynthesis, heterotroph, carnivore, herbivore, bacteria, and fungi. In her food chain, she explained the trophic levels generally as autotrophs and heterotrophs and categorized them as carnivores, and herbivores. She did not give specific examples for each level of decomposers. Unexpectedly, she placed oxygen and carbon dioxide and associated these gases both with bacteria/fungi and autotrophs/photosynthesis. Additionally, Expert 1 found to perceive the food chain as unlimited in its length. Consistent with her cyclic food chain drawing (Figure 4.10), she believed "the number of organisms in nature is infinite" (Reiner, Eilam, 2001) implying the food web.

Related to the food chain, Expert 1 was asked follow-up questions to understand her knowledge further.

I: Consider the following example: Are the following elements - nectar, a butterfly, a bird and decomposers- constituents of a food chain?

E1: If we think of nectar as a part of a plant, a butterfly...After a bird, I have just seen the decomposers are placed. We can think that this [food chain example] is a food chain. That is, this group [of organisms in the food chain example] can form a food chain. Writing the name of the whole plant may be better...apart from that nectar,

that is, writing its [plants'] name as a plant is better. For me, nectar is a part of the plant, however, is it suitable or not, I do not know. [interview]

I: Hmm...Is there anything you would like to add?

E1: Actually, decomposers can be written between bird and nectar. When a bird dies, we need decomposers. When nectar gets into the soil, we can need decomposers. [interview]

I: Is a bacterium inside the human body a part of a food chain?

E1: The ones [bacterium] produce B and K vitamins. They [bacteria inside the human body] are part of the food chain; we can think like this. When they produce vitamins for humans, they [bacteria inside the human body] benefit from humans also. That is, they [bacteria inside the human body] make both food sources for themselves and produce beneficial things for humans. [interview]

I: If so, what could be the other living things that make up this food chain?

E1: Organic foods are the first link of this food chain, then. It [food chain] starts with organic foods as they [bacteria] are inside the human intestine. Organic food can be the source of food for the bacteria. Bacteria convert this [organic food] into inorganic matter. However, there is a conversion there. That is, inside the human intestine, all of the foods are converted into tiny molecules that humans benefit from them [converted tiny molecules]. [interview]

Expert 1 was likely to hesitate to relate nectar as a part of a plant which acts as a producer in the food chain. Similar to Reiner and Eilam (2001) found in their study that students believed that to be an element of a food chain, a full part of organisms should be consumed. Moreover, as Reiner and Eilam (2001) found in their study ‘bacterium is a part of the food chain because it creates important substances for the human body, without which we cannot survive . . . Vitamin B for instance is provided by bacterium’, Expert 1 perceived bacterium was a part of food chain acting as providing necessary factors to human body. She stated organic materials as the first link of the chain rather than producers. The other problem in Expert 1’s responses in this sample food chain was that she believed decomposers should be placed between bird and nectar to decompose their dead bodies disregarding other organisms and perceived cyclic relations in food chain. Besides, she recognized the role of the bacterium as decomposers as well. She was asked about the importance of decomposers to further gain her knowledge, additionally producers and consumer and their relations.

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

E1: Well, a decomposer is a kind of organism that convert waste products into a useful form. It [decomposer] is a kind of organism that can facilitate plants and animals to be more efficient. Bacteria... we can say bacteria. We can identify them [decomposers] as tiny bacteria in the soil, cannot we? [interview]

I: What about the producers?

E1: They [producers] are green plants. [interview]

I: What is the importance of producers in ecosystems?

E1: What is the importance of producers? Hmm, producers are the basis [of the energy pyramid], the food source of other organisms that take sunlight, combine it [sunlight] with water from the soil...Isn't it? That is, they [producers] are the basis [of the energy pyramid] that the other organisms feed on them. [interview]

I: Then, what is the importance of consumers in the ecosystem?

E1: Um...Consumers feed on producers. That is, they [consumers] are at the second level of the food chain and the second part of the energy pyramid. We can think like that. We can also think that their numbers are lower than that of producers. We can say consumers are heterotrophic organisms. We can categorize them [consumers] as omnivores and carnivores... Producers transfer [their produced] food to consumers. If producers do not produce, how will consumers get their food? That is, if the connection in the [food] chain is broken, other organisms cannot exist. Because they [heterotrophs] could not find food and as a result, they can not fulfil their vital functions. As this [food] web continues in dependence on each other, they [organisms apart from producers] will disappear because of the food, in my opinion. [interview]

I: Okay, how do you explain the relationship between producers, consumers and decomposers, if any?

E1: Now, how is the relationship between producers, consumers and decomposers? Well, these organisms [producers, consumers and decomposers] can survive with certain kinds of feeding relations. But if decomposers do not exist or if the producers' and consumers' waste products disappear, what happens? Here, there may occur loss; there

may occur pollution. Decomposers provide conversion of these wastes into usable form; transformation to nature, I think. [interview]

Expert 1 appeared to refer to producers only as green plants. She identified producers' importance because of their roles in food production in the ecosystem. She stated producers are the base of the energy pyramid; however, she did not associate this knowledge with the amount of energy producers' have. Additionally, she did not relate the producer's role in the food chain and food web. Although she did not mention producers produce food through photosynthesis, she stated the sunlight and water used in this process. About consumers' importance, she said that they are heterotroph organisms in the second level of the food chain and energy pyramid. She related the importance of decomposers with the food chain and energy pyramid. She provided examples of the decomposers as bacteria. Decomposer's importance was stated as converting waste products into usable form. She did not talk about breaking down of organic molecules into inorganic molecules and did not relate the cycling of materials. However, she did not explain the usable form decomposers provide to other organisms. Basically, she explained the importance of consumers with the feeding relationship. Expert 1 explained the producers, consumers and decomposers and their relations in interviews as a feeding relation. On the other hand, she did not include these concepts in her concept map.

To understand Expert 1's knowledge regarding the relation between food chains and matter cycles due to the curricular significance. Specifically, the 8th-grade ecology unit includes the link between the material cycles and food chains [the related objective in the 2009 science curriculum: 1.19. Explains the material cycles in parallel with the energy flow in the food chain].

*I: Is there any relationship between material cycles and food chains?
Why/Why not?*

E1: Of course, there is a relation between the food chain and material cycles. If there were no material cycles, the increase and decrease [in the amount] of materials would influence the food chains, are not? That is, the increase or decrease [in the concentration] of carbon dioxide or nitrogen, or water, will result in what? [as a result] Destruct the nature. If nature is damaged, the food chain will be damaged. The diversity of organisms will decrease, I think. This [decrease in diversity of organisms], producers will be affected first... That is because the main things in these cycles are water, carbon dioxide and oxygen. These factors also influence producers. Now, green plants have the role to convert six carbon, twelve hydrogens, and six oxygen into basic sugar and the other produced molecules are oxygen and water... Sorry, [not oxygen and water] food and oxygen are produced. The produced food as glucose... [related to] carbon cycles. For the others [other material cycles], for instance, in the water cycle; there is not too much relation between the water cycle and the food chain. In fact, through evaporation; water vapour forms clouds. Clouds play no role in the organisms. However, food chains are directly related to the carbon dioxide cycle. That is, with the conversion of the molecules [carbon dioxide and water], they converted into.... basic sugar. It is converted into glucose and oxygen is mixed into air. But when the carbon cycle is damaged, producers will disappear. Next, they [producers] could not produce food and then they will not exist anymore along with the other organisms feeding on them [producers]. [interview]

Expert 1 tried to explain the relation between matter cycles and food chains by focusing on carbon and water cycles. Initially, although she thought that there was a relationship between material cycles and food chains, she later, stated that food

chains are not linked with the water cycle. She failed to perceive the cycle holistically, and instead, focused on simple linear relations among the components of the water cycle. She, however, attempted to explain the relation between carbon cycles and food chains by implying the possible roles of producers and consumers in the carbon cycles. To deepen her knowledge about the complex relation of organisms in ecosystems further, Expert 1 asked questions about the food web presented in the next section.

4.3.2.2.2 Expert 1's Subject Matter Knowledge on Food Web

Expert 1's concept map did not include the concept of a food web (Figure 4.9). Therefore Expert 1's interview responses revealed her SMK on the food web. First, she was asked the definition of food web.

E1: The food web is formed by food chains. [That is] the food web is formed by organisms in the environment. We can say that it [food web] is a web system. It [food web] includes food chains, I suppose. [interview]

I: What is the difference between a food chain and a food web?

E1: Food chain and food web... Now, these organisms can be consumed by other different organisms. Then, what happens? Other different food chains can be formed. The total of these chains can form a food web. [interview]

Expert 1 described the food web as consisting of various food chains. However, Expert 1 neither mentions organisms' complicated feeding relations nor trophic levels, especially with their scientific concepts that are producers, and consumers like herbivores, omnivores, and carnivores. Responses of Expert 1 to each of the

questions of the sample food web below indicated her difficulties and even misconceptions related to complex relations of populations in the food web (Webb & Bolt, 1990, p.188). The following questions are targeted to uncover teachers' knowledge of complex relations of the populations in the food web. The questions probed the understanding at different levels of complexity and disclosed the possible misconceptions teachers have. The letters in the food web represented a population in the food web. The letters in the food web diagram represent a population in the food web. The following questions are targeted to uncover teachers' knowledge of complex relations of the populations in the food web. The findings of the sample food web questions presented in relation to common related misconceptions in the groups of "A change in one population will only affect another population if the two populations are related as predator & prey."; "A population located higher on a food chain within a food web is a predator of the next adjacent populations located below."; "A change in the size of a prey population has no effect on its predator population"; "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" (Griffiths & Grant, 1985).

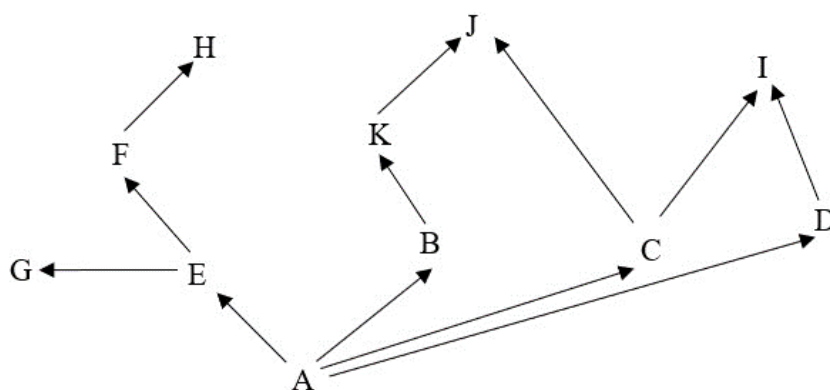


Figure 4.11 A Sample of Food Web (Webb & Bolt, 1990, p.188)

Group1. A change in one population will only affect another population if the two-populations are related as predator & prey (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population H have on population E? Explain your answer.

E1: Sudden decrease in population H results with an increase in population E. [interview]

I: What effect will a sudden decrease in population E have on the size of population H? Explain your answer.

E1: How does it affect the population H? It [population H] increases. [interview]

The above initial question was asked “to determine the effect of a sudden size change in one population on a second non-adjacent population located lower on the same food chain” (Webb & Bolt, 1990). In this respect, Expert 1 seemed to have difficulties in deciding the effect of a sudden size change in a population on a second non-adjacent population located lower on the same food chain. In fact, the sudden decrease in population H has increased population F. This increase in population F resulted in a decrease in population E. The second question was targeted to elicit “the effect of a sudden size change in one population on a second non-adjacent population located higher on the same food chain when the effect is transmitted along only one route” (Webb & Bolt, 1990). Expert 1 also seemed to have difficulties in deciding the effect of a sudden size change in a population on a second non-adjacent population located higher on the same food chain; the effect is transmitted only in one route. The decrease of E transmitted to the decrease of H population because H is the predator of the F and F is the predator of the E. The responses of Expert 1 are likely to indicate that she had misconceptions the one population will affect another

population not only if they are interrelated as predator and prey populations. If the populations are more distantly connected in the food web, Expert 1 was not able to identify interactions of populations correctly.

Group2. A population located higher on a food chain within a food web is a predator of the next adjacent populations located below (Griffiths & Grant, 1985).

I: What effect will a sudden increase in population H have on the size of population F? Explain your answer.

E1: Again decreases. [interview]

I: What effect will a sudden decrease in population J have on B? Explain your answer.

E1: If this [population J] decreases, that [population K] increases. In this case, these [population B] increases. I think population B increases. [interview]

Expert 1 seemed to have an understanding of “the effect of a sudden size change in a predator population on its prey population” (Webb & Bolt, 1990). That is, she could explain decrease in one trophic level causes a decrease in subsequent other trophic levels. However, she appeared to have difficulties “to determine the effect of a sudden size change in one population on a second population which is not on the same food chain, when the effect may be transmitted along more than one route” (Webb & Bolt, 1990). She was likely to have a common misconception of populations depicted high on the food chain of the food web will not always be predators of populations lower in the food chain.

Group3. A change in size of a prey population has no effect on its predator population (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population F have on the size of population H? Explain your answer.

E1: The sudden decrease in population F influences the decrease in population H. It [population H] decreases because of eating relations. As I said before I think that it [population H] is feeding on population F ... According to the direction of the arrow, I think like that. [interview]

I: Which populations are affected through an increase in population A is passed on to population J. Explain your answer.

E1: B, C, K, aren't they? Population A represents producers here. [interview]

I: What effect will a sudden increase in population B have on population J? Explain your answer.

E1: Population B is now taken by population K. If it [population B] increases, others increase. If it [population B] increases, the population J increases. [interview]

Expert 1 was likely to recognize all possible pathways through which “the effect of a sudden size change in a prey population on its predator population (Webb & Bolt, 1990). Expert 1 seemed to have the conception of a change in the size of a prey population affects its predator population. Moreover, Expert 1 could explain “the effect of a sudden size change in one population on a second non-adjacent population located higher on the same food chain where the effect is transmitted along one than one route” (Webb & Bolt, 1990).

Group4. 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 (Griffiths & Grant, 1985).

I: What effect will a sudden increase in population G have on population F? Explain your answer.

E1: Again, it [population F] decreases. Because population E is consumed by populations F and G. [interview]

I: What will affect a sudden increase in population I have on the size of population K? Explain your answer.

E1: Yes, it [a sudden increase in population I have on the size of population K] influences. Now, for instance, the population B feeds on the population A. Here, A transferred to D. Then its [population A's] increase influences population D, then population A. In terms of population B, it influences population K [interview]

Above food web questions targeted to reveal Expert 1's knowledge "to determine the effect of a sudden size change in one population on a second population not located on the same food chain, when the effect is transmitted along one than one route" (Webb & Bolt, 1990). Population G in the food web diagram is indirectly related to population F that are not located in the same food chain. Expert 1 could identify the interactions in populations within convoluted food web diagrams. Indeed, she could be able "to determine the effect of a sudden size change in one population on a second population which is not on the same food chain, when the effect may be transmitted along more than one route" (Webb & Bolt, 1990).

To sum up, related to the food web, Expert 1 appeared to explain some of the relations of organisms based on their feeding relations. She was not able to interpret the arrows in the food web in their scientifically correct explanation of energy

transfer rather she referred to eating relations. She did not mention the roles of populations as consumers, herbivores, carnivores, or omnivores. However, she identified producers. Expert 1 also delineated the energy transfer between related but discrete two pathways in the food web diagram. But she was likely to have difficulties in the populations' interactions in terms of alternative pathways. In other words, Expert 1 appeared to have difficulties in the effect of a sudden size change in one population on a second non-adjacent population; the effect is transmitted along more than one route.

4.3.2.2.3 Expert 1's Subject Matter Knowledge on Energy pyramid

Expert 1's concept map did not consist of an energy pyramid (Figure 4.9). Therefore, interview responses were sources for her SMK on the energy pyramid. First, she was asked to define the energy pyramid.

I: What is the energy pyramid?

E1: Now, organisms feed on each other. This kind of feeding relation is called the energy pyramid. That is, moving from the bottom level to the upper level, it is called the energy pyramid. [interview]

Expert 1's definition indicated that she explained the energy pyramid with organisms feeding relations. Although she did not specify the trophic levels during previous interview responses, she could identify these levels in her energy pyramid drawing (Figure 4.12). She explained the decrease of energy level to the upper levels. She placed the decomposers operating on each trophic level by its scientific explanation. Figure 4.12 presents Expert 1's energy pyramid drawing.

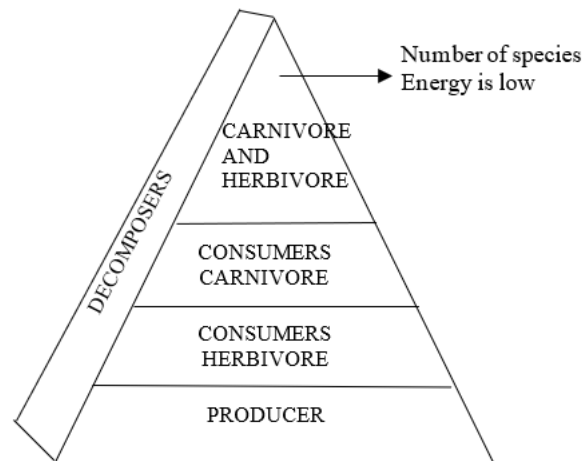


Figure 4.12 Expert 1 Energy Pyramid Drawing (see Appendix D for original drawing)

I: Can you draw an energy pyramid?

E1: Now, should we place the first, the producers... the second, the consumers, the decomposers here [where she identified in the drawing]? Now, again [as food chain and food web] the first one is producers. The second one is consumers here...decomposers... primary consumers are here; we can categorize them [consumers] as herbivores and carnivores. Here [indicating from her energy pyramid to the third level] carnivores... sorry, herbivores initially. After carnivores, here [indicating from her energy pyramid to the fourth level] are omnivores. Then, we can write here [indicating from her energy pyramid to the fourth level] the omnivores. [interview]

I: Why is the energy pyramid in shape?

E1: Now, here [in the energy pyramid] their number decreases. Their energy level [organisms in the energy pyramid] also decreases to the upper levels. Hence, the peak of the pyramid is sharp. [interview]

Expert 1 placed producers, consumers and decomposers on her energy pyramid and explained the trophic levels with their roles of producers, consumers and decomposers and identified their feeding types as herbivores, carnivores and omnivores. From a scientific point of view, Expert 1's energy pyramid appeared to be correct. Moreover, Expert 1 seemed to have knowledge of the energy pyramid's shape representing the energy rate of trophic levels. Although she did not explain the loss of energy between trophic levels, her answer about the possibility of reversing the energy pyramid was scientifically correct.

Briefly, Expert 1 was found to have limited knowledge of the basic ecological concepts and processes like ecosystem, species, producer, consumer, decomposer, species, habitat, biological diversity, energy, photosynthesis, food chain, food web and energy pyramid. She could not define community or ecological niche. She reasoned her no response with these concepts not being included in the science curriculum.

In this section Expert 1's subject matter, knowledge was documented. In the next section, Expert 1's pedagogical content knowledge on ecosystems was reported.

4.3.3 Expert 1's Pedagogical Content Knowledge on Ecology

Expert 1's pedagogical content knowledge (PCK) was investigated in the light of Magnusson et al. (1999) PCK model. PCK pre-interviews, PCK post-interviews, the lesson plan and classroom observations were used to set forth Expert 1's PCK.

4.3.3.1 Expert 1's Knowledge of Curriculum

Knowledge of the curriculum consisted of two components that were knowledge of the goals objectives and materials. Goals and objectives included Expert 1's

knowledge of goals and objectives and vertical and horizontal curricula outlined within the national documents. In the present study, the data related to knowledge of curriculum was collected in 2010. Hence, Expert 1's knowledge of curriculum findings was gathered in line with the prescribed ecology curriculum in 2009 by the Türkiye Ministry of National Education (MoNE, 2009). Expert 1's knowledge of curriculum materials offered for a specific topic presented in the next section.

4.3.3.1.1 Expert 1's Knowledge of Goals and Objectives

According to the Türkiye national science curriculum in 2009, ecology units were included in 4th grade as the 2nd unit name was "World of Life". The specified objectives in 4th grade level were "as a result of the observations, students provide daily life examples to living and non-living things", "living and non-living things decided through questioning", "discovering that there are different types of habitats around", "predicting the living things that can be found in a living space.", and "observing and recording living things in a living space around". Moreover, in the 5th grade, ecology was included in the 6th unit named as "identifying the world of life and natural life in our country and in the world". The objectives of 5th grade ecology unit were "As a result of the observations, students give examples of various living things living in their surroundings.", "providing examples to living and non-living things unique to their country", "comparing the similarities and differences in the nutrition of living things in a habitat students observe.", "constructing a sample food chain illustrating feeding relations of organism", "discuss the consequences that may arise with the disappearance of a link in the food chain." and "searching for endangered species and to create projects to protect these species". In the 6th grade level, there was not included a unit related to ecology. In the 7th grade level, in the 6th unit of "organisms and life" consist of ecology objectives which were "explains the concepts of species, habitat, population and ecosystem and the relations of these

concepts.”, “explains the relations of living organisms with each other and non-living factors in an ecosystem, defines food chain and food web and gives examples.”, “make predictions about living things that can be found in different ecosystems (lake, sea, forest, etc.)”, “recognize and emphasize the importance of biodiversity in the ecosystem.”, “give examples of extinction-prone species in the country and in the world.” and “offer suggestions to protect extinction-prone species.”. Expert 1 was interviewed and observed in the light of the 8th-grade ecology unit. The curricular objectives prescribed by Türkiye MoNE and Expert 1’s collected data regarding 8th grade level 6th unit of ecology “Organisms and their energy relations” objectives were presented in Table 4.19.

Table 4.19 Expert 1’s Knowledge of Goals and Objectives regarding G-8 ecology objectives in the Science and Technology Curriculum (MoNE, 2009)

Unit	Interviews	Classroom observations	Lesson plan
6: Living things and energy relations			
Content: Food chains			
6: Organisms and their energy relations			
Content: Food chains			
1. Related to organisms in the food chains, students are able to;	<i>It will be beneficial to learn about the food web and the food chain...</i>	Student1 (S1): Food chain, yes, but you notice those in the food chain who eat whom.	Infer that producers are located at the beginning of food chains.
1.1. Infer that producers are at the beginning of food chains.			
1.2. List what is required for photosynthesis.	Not mentioned	Teacher (T): By taking carbon dioxide from the air and water from the soil, the process of producing food by green plants is called photosynthesis... The leaves of the plants are green, is it effective for photosynthesis?	List what is required for photosynthesis.

Table 4.19 Cont'd

Unit	Interviews	Classroom observations	Lesson plan
1.3. Observe the necessity of light in photosynthesis by experimenting.	Not mentioned	Not mentioned	Not mentioned
1.4. State that producers produce simple sugars and oxygen by photosynthesis.	Not mentioned	S7: After combining with sunlight, the plant photosynthesizes in the chloroplast. Then, as a result of photosynthesis, oxygen and the simple sugar we call food is produced. T: Simple sugar, which we call food, is glucose..	State that producers produce simple sugars and oxygen by photosynthesis
1.5. Express photosynthesis with an equation.	Not mentioned	T: You need to learn photosynthesis with its equation.	Express photosynthesis with an equation.
1.6. Discuss the importance of photosynthesis for living things.	Not mentioned	T: Living organisms need food to survive, why do they need to feed? You said, they need energy. Which kind of energy is converted into what kind of energy in photosynthesis?	
1.7. State that producers convert solar energy into usable energy by photosynthesis.	Not mentioned	S8: Solar energy is converted into chemical energy.	State that producers convert solar energy into usable energy by photosynthesis.
1.8. Explain that living things need energy to survive.	Not mentioned	T: Living organisms need food to survive...	Not mentioned
1.9. Explains that consumers in the food chain meet their energy needs from producers.	Not mentioned	T: Okay, we take in food as a result of eating plants.	Not mentioned

Table 4.19 Cont'd

Unit	Interviews	Classroom observations	Lesson plan
1.10. Discuss the importance of respiration for living things.	Not mentioned	S9: Every organism respire. The aim of respiration is to be able to do daily physical activities like to walk and move by the help of ATP.	Not mentioned
1.11. Define respiration.	Not mentioned	Aerobic respiration is to produce energy through foods by using oxygen.	Not mentioned
1.12. Lists what is required for respiration	Not mentioned	S10: during respiration, organisms take in oxygen and give off carbon dioxide.	Not mentioned
1.13. Indicate the products formed as a result of respiration with oxygen by experimenting.	Not mentioned	Not mentioned	Not mentioned
1.14. Estimate the equation of aerobic respiration as a result of his/her observations.	Not mentioned	Not mentioned	Not mentioned
1.15. Explain that some living things provide the necessary energy to survive without using oxygen.	Not mentioned	S11: Anaerobic respiration is the breaking down of foods with the help of enzymes in absence of oxygen in the environment. And with the help of this process, the energy ATP is produced.	Not mentioned
1.16. Gives examples of anaerobic respiration from daily life.	Not mentioned	S12: one [example to anaerobic respiration] is alcoholic respiration and lactic acid fermentation.	Not mentioned

Table 4.19 Cont'd

Unit	Interviews	Classroom observations	Lesson plan
1.17. Explain the relationship between producers and consumers in terms of nutrition and energy flow.	Not mentioned	Energy flow in the food chain, we can think of the food chain as a string consisting of a plant, a herbivore and a carnivorous animal in its simplest form...	Not mentioned
1.18. Explains the material cycles in parallel with the energy flow in the food chain.	<i>explaining the matter cycles. Grouping the organism, stating their interaction.</i>	T: the oxygen cycle, the carbon dioxide cycle, the water cycle, but all of them are either used or produced in photosynthesis. ...what would happen if they broke down? S: For example, the water cycle happens. it [water] evaporates, creates clouds, rain happens, such a cycle happens.	Not mentioned

The collected findings revealed that Expert 1 was likely to have an understanding of most of the goals and objectives of the ecology curriculum. Although she did not mention the curricular objectives of 8th-grade level ecology during pre-interviews, Expert 1 taught each of the determined objectives (Table 4.19). Moreover, she did not include some of the objectives in her lesson plan (Table 4.19 & see Appendix O for the Turkish version, see Appendix P for the English version). However, she seemed to have an understanding of both vertical and horizontal relations.

I: Do you know the place of ecology in elementary school curricular programs?

E1: Yes, I know. Ecology concepts are introduced in 4th and 5th grades. In 6th, 7th and 8th grades, the concepts are taught in detail.

That is, concepts inside the ecology curriculum are basic in the initial grade levels to become advanced in the higher grade levels. In fact, ecology starts to be taught in 4th grade and to the 8th grade. [pre-interview]

I: In 8th grade, in which unit, ecology is taught?

E1: I think it was the 7th unit, I can't remember exactly, but it was the 7th unit as I remember. [pre-interview]

I: Is there any science unit taught associated with ecology?

E1: In order to teach the benefits of and harm to that living species, it will be beneficial to learn the food web and the food chain, in my opinion. [pre-interview]

I: What is the specified purpose of the ecology in the program?

E1: It is the student's recognition of the environment, learning protections of the environment and learning the interaction of organisms. [pre-interview]

I: I want to ask whether you find these aims appropriate.

E1: For me, the basic principle is the protection of nature, recognition of it [nature] and protecting it [nature]. The main objectives should be those. We try to teach in that sense. We both introduced the content of the unit and mentioned what should be done to protect and we talked about if it [nature] is not protected what it [nature] will be? [pre-interview]

In Expert 1's lesson plan (see Appendix O for the Turkish version; Appendix P for the English version), she stated the objectives which were "Related to organisms in the food chains, students are able to infer that producers are located at the beginning of food chains.", "Related to organisms in the food chains students are able to list what is required for photosynthesis", and "Related to organisms in the food chains students are able to state that producers produce simple sugars and oxygen by photosynthesis.", "Related to organisms in the food chains, students are able to discuss the importance of photosynthesis for living things.", "Related to organisms in the food chains, students are able to express photosynthesis with an equation.", and "Related to organisms in the food chains, students are able to state that producers convert solar energy into usable energy by photosynthesis." (Table 4.19)

In classroom observations, Expert 1 seemed to strictly follow the prescribed curricular ecology objectives (MoNE, 2009). In line with her lesson plan, Expert 1 observed teaching ecology depends on the prescribed objectives in the teachers' guidebook and her lesson plan. Expert 1 tended to not exceed the degree of curricular knowledge regarding goals and objectives of ecology while preparing her lesson plan and teaching in the class. Because Expert 1 could be observed for two lesson hours, she prepared her lesson plan accordingly and stated the objectives that could be accomplished in two lesson hours. She asked her students to prepare a presentation and demonstration to meet the curricular objectives. The students presented their presentations and did the demonstrations that addressed the curricular objectives of the 8th-grade ecology curriculum.

To sum up, related to Expert 1's knowledge of goals and objectives, she was likely to know the place of ecology in the curriculum in 8th grade and its vertical relations. But she seemed to have difficulties in the horizontal relations of the ecology. Although she did not state some ecology objectives in pre-interviews and the lesson plan she prepared, she was observed to teach the curricular objectives consistent with

the curricular program prescribed by MoNE (2009). She seemed to follow the prescribed program by MoNE strictly she found to prepare her lesson plan and teach ecology lessons accordingly.

In the next part, Expert 1's knowledge of materials, another sub-component of knowledge of curriculum presented.

4.3.3.1.2 Expert 1's Knowledge of Materials

Expert 1 used some instructional materials in her ecology teaching. She mainly used the teachers' guidebook, students' textbook, board, projection, brochures and science journals in her lesson. Expert 1's knowledge of materials was documented with the line with the pre-and post-interviews, lesson plan and classroom observations. The Table 4.20 summarized the Expert 1's knowledge of materials to teach ecology.

Table 4.20 Expert 1's knowledge of materials

Materials used	Interview questions	Lesson Plan	Classroom observations
Teachers' guidebook	Not mentioned	Not mentioned	used to follow the prescribed content of ecology by the help of teachers' guidebooks.
Students' textbook	I used posters, presentations, and textbooks. [post-interview]	textbook, various brochures, science journals (see Appendix O & P)	used to make students enrol to the lesson, to repeat and to evaluate the learned content.
Board	I evaluated the content of the unit to be learnt on board ... [post-interview]	Not mentioned	used to make the content concrete with drawing figures and writing concepts to make concepts better understood by students.
Projection	I used posters, presentations, and textbooks. [post-interview]	Not mentioned	Students perform presentations.

Table 4.19 Cont'd

Materials used	Interview questions	Lesson Plan	Classroom observations
Materials for role playing	When preparing food chains, we use their toy animals. [pre-interview]	Not mentioned	Not mentioned
Materials for experiments	Experiments are more effective for ecology lessons... [pre-interview]	Not mentioned	Not mentioned
periodicals, journals	I used some kinds of periodicals, publications of TÜBİTAK [national science journal in Türkiye] and so on. [pre-interview]	Not mentioned	Not mentioned
Computer	It is better to teach ecological concepts to the students by making them see and do things themselves. [post-interview]	Not mentioned	Not mentioned

Expert 1 asked questions to understand her knowledge of materials before classroom observations. The excerpts from pre-interviews were presented below.

I: What kinds of materials do you use for ecology teaching?

E1: In general, when preparing food chains, we use toy animals. I make them [students] prepare posters and presentations. These are the materials. In addition, board, eraser, and pencil. These are the primary tools actually. Some kinds of periodicals, publications of

TÜBİTAK [national science journal in Türkiye] and so on. [pre-interview]

I: Do you think the materials you used in your ecology lesson were effective?

E1: The materials I use, generally visual materials...For instance, experiments are more effective. When you perform an experiment, when you make them [students] observe something, the learning becomes more effective because they [visuals, experiments] can experience it. On the other hand, if we use lecturing, they [the information taught] may be forgotten easily. They [students] can learn better when they [students] are asked to write a story related to the concept. Students have to search and think for it [the learning content] ... These kinds of things [materials and activities] can make learning permanent. [pre-interview]

I: Are there any materials that you cannot reach for some reasons; however, you want to use?

E1: While teaching, the school administration should prepare the environment well for you. You need to prepare your lesson well enough. You need to prepare it [lesson plan] at home. When you come to lessons with your flash disk including how you will teach at school, right, they [materials] are very effective. [pre-interview]

Expert 1 stated that visuals are more effective in teaching ecology enabling the learning to be permanent. She stated to use posters, presentations, toys, teachers' guidebooks, textbooks, and boards in her ecology lessons during pre-interviews. She mentioned experimental materials as well.

Expert 1 found to write the part of the instructional materials in her lesson as “textbook, kinds of brochures, science journals” (see Appendix O for the Turkish version; Appendix P for the English version). Conversely, in the classroom observations, Expert 1 stated that she used the teacher’ guidebook (MoNE, 2009), board, students’ textbook and the materials for students’ role-playing and projection for the students’ presentation in her lesson. In the lesson, in line with the prescribed curricular program, Expert 1 made her students prepare a presentation related to ecology topics and a role-playing activity related to photosynthesis. She also guided students in their presentations, and asked students questions on board to facilitate their learning. She also used the textbook activities in the lesson. After classroom observations, Expert 1 asked questions about the materials she used in her lessons.

I: Which materials did you use in your lesson?

E1: I used posters, presentations, and textbooks. [post-interview]

I: What were your purposes in using these materials in your lesson?

E1: Now, I gave students an assignment to prepare a poster and a presentation. I guided students in their [students’] preparation process. In other words, the main goal is to give an assignment to the students that will be evaluated as the project and performance homework. I evaluated the content of the unit to be learnt on board in order to ensure it cover all the objectives in the curriculum. [post-interview]

I: Are there any materials that you cannot reach for some reasons; however, you want to use?

E1: It is better to teach ecological concepts to the students by making them see and do things themselves. In fact, our school does not have

too many facilities to do something on the computer. Computers are out of work most of the time. In terms of ecology, it is more suitable to make students learn visually; especially by investigating. I tried to teach these [ecology] concepts through both investigating and field-tripping. [post-interview]

Expert 1's knowledge of curriculum findings is documented in this section. The findings revealed Expert 1 knew the goals objectives; and materials related to ecology. The next section presented Expert 1's knowledge of students' understanding of science.

4.3.3.2 Expert 1's Knowledge of Students' Understanding of Science

This section presented two sub-components of Expert 1's knowledge of students' understanding of science which were knowledge of requirements for learning and knowledge of areas that students experience difficulty. Expert 1's knowledge of requirements for learning was investigated in terms of her knowledge of variations in approaches to ecology learning which include considering students' developmental levels, learning styles and abilities and teachers' beliefs about prior knowledge that students possess in a specific ecology concept (Magnusson et al., 1999). Knowledge of areas of students' difficulty in ecology concepts and issues investigated in terms of students' difficulties, errors and misconceptions with their reasons (Magnusson et al., 1999).

The findings revealed that Expert 1 pointed out students' prior knowledge and daily life in relation to students' requirements. Expert 1 stated a few students' learning difficulties and misconceptions about ecology. She mentioned population, habitat, and plant nutrients for students' learning difficulties and misconceptions. She believed ecology could be learned easily by memorization of the concepts. To

overcome the learning difficulties, Expert 1 provided methods such as searching, investigating and brainstorming and she mentioned investigation, experimentation and observation to remedy misconceptions. Yet, she did not talk about the conceptual change approach, analogy, conceptual change texts, or concepts to overcome students' misconceptions.

The first section documented Expert 1's knowledge of students' requirements for learning ecology.

4.3.3.2.1 Expert 1's Knowledge of Requirements for Learning Ecology

Expert 1's knowledge of students' requirements for learning ecology is documented in line with the findings gathered in pre- and post-interview questions, lesson plans and classroom observations in this section.

Expert 1 stated regarding the students' requirements for learning ecology that their prior knowledge and relating to their daily life is important. She provided daily life examples to the students in her lessons and she included daily life examples in her lesson plan, too. She also mentioned the requisite daily life examples in the pre-interviews. Moreover, Expert 1 mentioned the students' prior knowledge as the requirement for students' learning of ecology. She planned to remind students prior knowledge about ecological concepts which were producers, consumers, decomposers, photosynthesis, chlorophyll, and energy they learnt previous years in her lesson plan. She observed asking students these concepts to remind their prior knowledge.

Table 4.21 Expert 1's Knowledge of Requirements For Learning Ecology

Requirements for learning ecology	Interviews	Lesson Plan	Classroom Observation
Relating with daily life	We need to teach the food chain the food web [to children] in order to show [them] the different animal or living species they encounter in their [students'] daily life...[pre-interview]	Result: the necessity of photosynthesis (producers), the importance of it [photosynthesis], the necessities to conduct photosynthesis and the products. The importance of it [photosynthesis] repeated.	T: What do the earth's surface and underground waters do, Eda? It [water] evaporates, when it [water] evaporates, where does that evaporated water go, what does it [water] form in the sky? We call it [water]the water cycle. You know, there is cactus...
Prior knowledge	I take into account students' prior knowledge while I am teaching. [pre-interview]	Students' prior knowledge: organisms learnt in previous years related to photosynthesis, the interaction between living and non-living things, food chain. (see Appendix)	T: You have learnt the food chain in the previous lessons, at which step of the food chain do the organisms photosynthesize take place? S1: They [organisms photosynthesize] take place at the first level.

I: What are your goals and purposes in teaching ecology?

E1: We need to teach the food chain the food web [to students] in order to increase awareness [of students]to the different animals or living species they [students] encounter in their [students'] daily life... to see various feeding [of species'] and to enable them [to students] to see certain species consume each other. Now, there is a flow in the food chain from basic to more complex. We cannot say that the cats are fed on plants. They [students] need to recognize the organisms that feed on vegetables and the ones that feed on meat.

They [students] will be aware of divergence among organisms. [pre-interview]

I: In ecology teaching, what do you think about students' requirements?

E1: I take into account students' prior knowledge while I am teaching. Students are asked to investigate the issues after giving related information or I benefit from their [students'] previous knowledge they [students] gained with watched, heard or read materials. We adjust lessons according to students' difficulties and the concepts that they [students] could not understand. [pre-interview]

Expert 1's knowledge of requirements for learning ecology was gained in pre-interviews. She mentioned students' prior knowledge and the concepts students have difficulties as the requirements to learn ecology. She stated the goals and purposes of teaching ecology to make students aware of the issues in their environment.

Consistent with the pre-interviews, Expert 1 stated in the relevant part of her lesson plan that “organisms learnt in previous years related to photosynthesis, the interaction between living and non-living things, food chain” (see Appendix O for Turkish version; see Appendix P for English version). She believed that students need to learn photosynthesis, the interaction between living and non-living things, and the food chain in ecology as prior knowledge. In the lesson plan, she included that at the beginning of the lesson: “The key words are asked to the students. They want to answer (producers, consumers, decomposers, photosynthesis, chlorophyll, energy). The concepts are reinforced through necessary explanations” (see Appendix O for Turkish version; see Appendix P for English version). She planned to remind students of prior knowledge at the beginning of the lesson.

In the classroom observation, she was observed to remind students of prior knowledge related to ecosystems, the types of ecosystems, biological diversity, the energy flow in food chains, photosynthesis and respiration consistent with her lesson plan. The related classroom observation excerpt is provided below.

T: You have learnt the food chain in the previous lessons, at which step of the food chain do the organisms photosynthesize take place?

S1: They take place at the first level.

[classroom observation]

As Expert 1 taught that students are required to relate ecology with their daily lives, she provided daily life examples to the students in her lessons. The excerpts in the below exemplify the daily life relations mentioned in Expert 1's ecology lessons.

T: If I ask you what is the stored form of glucose in potatoes, you will say starch. In sunflower seeds, can we store it as starch? What about animal cells?

T: You know, there are cacti, what do the earth's surface and underground waters do, Eda? It evaporates, and when it evaporates, where does that evaporated water go, what does it form in the sky? It forms clouds and condenses again and descends to the earth. What do we call this? We call it the water cycle.

[classroom observation]

Expert 1 asked post-interview questions about the students' requirements for learning ecology after classroom observation. In fact, Expert 1 pointed out that students have difficulties in ecology because of the language. That is, most of the scientifically correct concepts as well as ecology concepts are in Latin language, and

students have difficulties learning because of the language issues according to Expert 1. The post-interview excerpts are provided below.

E1: I have recognized that students have limited vocabulary. Even hardworking students have a limited vocabulary. This is the result of learning a few concepts. We try to teach scientific words derived from Latin; even though the students do not know the Turkish meaning of them [concepts]. Students need to learn habitat concepts, for instance. In fact, they can learn it [habitat]. I believe all of the students need to learn scientific words properly. [post-interview]

Expert 1 explained some of the requirements of students for learning ecology, one of which was related to the language of the ecological concepts mostly related to students' difficulties. In fact, in the next part, Expert 1's knowledge of areas where students experience difficulties is documented as the other sub-component.

4.3.3.2.2 Expert 1's Knowledge of Areas That Students Experience Difficulty

Expert 1's pre- and post-interviews and classroom observations were presented in this section to reveal Expert 1's knowledge of areas in which students experience difficulty.

The findings regarding Expert 1's knowledge of areas where students experience difficulty revealed that Expert 1 thought students learn ecology easily. That is, she believed that students did not experience difficulty in learning ecology in general. However, there were some ecology concepts stated by Expert 1 such as population and habitat students experienced difficulty in. She reasoned students learn ecology easily with the concepts being at the knowledge level that students can easily memorize. Expert 1 was also likely to think of misconceptions as the possession of

different opinions related to concepts. She mentioned students' misconceptions in ecology which were related to organisms like lions, fishes, carp and caterpillars during pre-interviews. She stated students' misconceptions in post-interviews as plants' nutrients. Table 4.22 summarises the Expert 1's knowledge of areas in that students experience difficulty.

Table 4.22 Expert 1's Knowledge of Areas That Students Experience Difficulty

Interviews		Classroom Observation	
Learning Difficulties	Elimination Methods	Learning Difficulties	Elimination Methods
Population	search-	Not mentioned	Not mentioned
Habitat	investigation	Not mentioned	Not mentioned
	brainstorming	Not mentioned	Not mentioned
Misconceptions	Elimination Methods	Misconceptions	Elimination Methods
Organisms	investigation	photosynthesis and	questioning
Plants' nutrient	experimentation	respiration	
	observations		

I: Do your students have difficulty understanding ecological concepts?

E1: No, they [students] do not have difficulty. [pre-interview]

I: Compared with the other topics, do students find ecology concepts easy?

E1: No, they [ecology concepts] are at medium level. Students do not find ecological concepts easier at all. According to students' interest, this situation [being easier, or not] changes. I believe seventy-five-sixty per cent of the students do not have difficulty [in ecology]. Some

students do not like biology as they [students] express this explicitly. They [students] s that they [students] confuse some concepts a lot. Therefore, they [students] cannot make an interpretation about them [confused concepts]. [pre-interview]

I: Hmm, what are the ecological concepts those students experience more difficulty with?

E1: Maybe students can experience difficulty while learning about population, and habitat. However, they [students] most probably learned all of these concepts in the end. [pre-interview]

I: How do you help students with their learning difficulties?

E1: Now, according to the teaching method used in the lesson, I prefer to introduce the concepts initially. The concepts are explained. Students provide their explanations. For example, when the concept is an ecosystem, students provide its definition and then deepen his/her knowledge of it in the lesson. [pre-interview]

I: So, you make students investigate the concepts they have difficulties in the lesson, right?

E1: Yes, maybe... They [students] search for the concepts and investigate them [students]. In the lesson, we can make students brainstorm to understand the concepts and find their truths. [pre-interview]

Expert 1 stated that students learn ecology easily. She thought that students do not experience difficulty in learning ecological concepts and issues. When she asked further, she answered that some of the students may have difficulty learning about

habitat and population. She stated that students can learn these concepts by searching and investigating. She mentioned brain-storming could be used to help students solve their learning difficulties. Expert 1 also asked to define misconceptions in pre-interviews.

I: What is a misconception?

E1: Related to a concept, possession of different opinions, true or not true opinions. The misconception is this, I think. [pre-interview]

I: What are the main misconceptions students possess about ecological concepts?

E1: I did not confront with students' misconceptions. There were no misconceptions students had up to now. For instance, I did a test in 7th-grade classes. I asked a question that had the correct answer as "Lions do not live in Türkiye". Students answered that "lions live in Türkiye" by referring to the lions in the zoo. Also, they [students] may not know the types of fish. They may have misconceptions like these... for instance; they may not know carp are found in freshwater. I asked another question related to an activity that we did in class. In this question, it is found that students did not know the caterpillars. [pre-interview]

I: How do you understand that if your students have misconceptions?

E1: When I want an explanation related to a concept, and when they [students] give an irrelevant explanation regarding that concept, I understand that they [students] think wrong. [pre-interview]

I: Are there any methods to remedy these misconceptions?

E1: Some of them [misconceptions] are difficult to remedy if they [misconceptions] exist in students' minds. On the other hand, through giving evidence, I try to change them [misconceptions]... I suggest students make more investigations, read more, experiment and share their [students] findings with the others. Through experimentation, investigation, and observation. If they [misconceptions] are provided with evidence, their misconceptions decrease. [pre-interview]

I: What are the sources of misconceptions then?

E1: They can be media, television, and programs prepared with wrong information. [pre-interview]

Expert 1 defined misconceptions as students' possession of different thoughts apart from commonly accepted meanings. She mentioned students' misconceptions related to the kinds of organisms in ecology in pre-interviews. Expert 1 stated the methods for overcoming the students' misconceptions as investigation, experimentation and observations. The sources for misconceptions were the media, and television programs including incorrect information.

Although she perceived that students did not have misconceptions and possessed few difficulties in ecology, in her lesson, a common misconception of the students in photosynthesis was detected. She explained the difference between photosynthesis and respiration according to the time the events take place in a day. The following was the related excerpt that occurred during the classroom observation.

E1: Alright, are their times the same, I wonder? When photosynthesis occurs under sunlight – let's explain without considering artificial conditions – if we compare in terms of time, would you think of one as morning and the other as evening? Or perhaps one as always and

the other only in daylight? Yes, indeed, photosynthesis is carried out only by green plants, but respiration is performed by all living organisms. Such a comparison can be drawn: photosynthesis produces energy, right? And the energy produced in oxygen is released by burning. Alright then, what else can you think of or say about this topic?

[classroom observation]

Consistent with the classroom observation, Expert 1 did not identify students' difficulties and misconceptions in her lesson plan. The post-interview excerpts are provided below.

I: Do the students have any difficulties in learning ecological concepts?

E1: No, they [students] did not have difficulty in understanding because the concepts are at knowledge level. That is, students can memorize easily, they [ecology concepts] are related with their [students] daily life. Even students can see the [ecological] issues on television. Therefore, students are successful in these units [ecology unit]. [post-interview]

I: What were the main misconceptions students possess that you detected in ecological concepts?

E1: They [students] did not know how plants get their [plants] nutrients. [post-interview]

I: How did you help students to remedy students' misconceptions in ecology?

E1: I corrected words that students used in the wrong manner. Hence, they [students] changed their [students'] mind resulting in wrong knowledge. I said to students that "You should use these words like that" [post-interviews]

In the next section, Expert 1's knowledge of instructional strategies, which is another PCK component, was presented.

4.3.3.3 Expert 1's Knowledge of Instructional Strategies

Expert 1's knowledge of instructional strategies was documented in two parts. In the first part, Expert 1's subject-specific strategies; in the second part, Expert 1's topic-specific strategies were presented. Expert 1's knowledge of instructional strategies findings was collected through pre- and post-interviews, lesson plans and classroom observations.

In general, Expert 1 preferred to use direct teaching, questioning and demonstration as the subject-specific instructional strategies. She used figures, daily-life examples, comparisons, visuals, and posters for topic-specific strategies. She appeared to believe field trips and experimentation as effective strategies for teaching ecology. Expert 1's knowledge of subject-specific strategies presented in the next part.

4.3.3.3.1 Expert 1's Knowledge of Subject Specific Strategies

The findings gathered through pre- and post-interviews, lesson plans and classroom observations were likely to indicate that Expert 1 used direct teaching, questioning and demonstrations. She also mentioned experiments as an effective teaching method in science teaching. Table 4.23 presents Expert 1's knowledge of subject-specific strategies.

Table 4.23 Expert 1's Knowledge of Subject Specific Strategies

Expert 1's subject specific strategies	Interview	Lesson plan	Classroom Observation
Direct teaching Questioning Demonstrations Experiments	I make my students prepare posters related to content. I ask my students to watch documentaries and I make them share the examples. Visual sources and experiments provide permanent learning.	Teaching and learning strategies, methods: lecturing, question and answer, brainstorming, group work, demonstration (Appendix O & P)	A group of students prepared a presentation before the lessons and presented it [presentation] as a group. Another group of students demonstrated a role-playing activity. Expert 1 used direct teaching, questioning and enabled students to discuss.

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

E1: I follow the teachers' guidebook in my lessons. There are several activities inside the guidebook, and I try to do them [activities in teachers' guidebooks] in my lessons. Frankly, I cannot do the experiments because of the time issues. In fact, there is not much time to do all of the activities. [pre-interview]

I: Okay. What do you do to enable your students to understand ecology better?

E1: To make the issues visual is important in ecology. I make my students prepare posters related to content. We keep these posters and use them when they are necessary. Also, I stick them on the wall in class so they [students] could see them [posters] all the time and they [students] could remember the things they [students] learnt. In this way, the learning can be permanent. I ask my students to watch documentaries and I make them [students] share the examples from these documentaries [documentaries students are asked to watch]. If there are students in the class who go to cram school, I make them [students] share the information they [students] learnt with their friends. [pre-interview]

I: Apart from these instructional strategies, which types of instructional strategies do you think of to use? What kinds of teaching strategies can be used for ecology?

E1: In fact, the visual... If they [students] could see the food pyramid visually for instance.... For instance, in a faculty's biology department zoology department or botany department...They [students] could not forget this experience and the content at any time. We draw the producers here [at the bottom of the energy pyramid], consumers we said herbivores, and carnivores are there [in the energy pyramid]. This is just a scenario in their minds. But if there is a concrete food pyramid in the schools... or if you ask students to create one [energy pyramid], they [students] will place plants below, they [students] will place a cow above. By placing toy animals, they [students] will form a food pyramid... [pre-interview]

I: What is the applicability of these methods? Do you apply it in your lessons?

E1: Visual sources and experiments provide permanent learning. If they [students] conduct an experiment or if they [students] observe the issues, they [students] can learn effectively. When they [students] can observe, hear, touch... these all activate their [students'] sensory senses. However, when we conduct direct teaching, they [students] forget immediately. The learning becomes temporary. Moreover, it is also effective to make students write a story with their own words after they [students] do related activities. They [students] need to do searching and need to think further in this way. [pre-interview]

Expert 1 was likely to make the learning content concrete with the help of activities to enable her students to learn ecology effectively. To do so, she used visual sources, posters, presentations, and daily life examples. Although she mentioned the effectiveness of experiments, she did not conduct experiments because of time constraints. However, she said that she makes her students do activities. Therefore, she tended to use demonstrations apart from direct teaching and questioning.

In the lesson plan, Expert 1 stated, “lecturing, question and answer, brainstorming, group work, demonstration” (Table 4.23 & see Appendix O for the Turkish version; Appendix P for the English version). Moreover, she stated students role-playing about photosynthesis in her lesson plan.

Consistent with her lesson plan, Expert 1 observed to use of direct teaching and questioning. She directed the students to discuss the issues with questioning and students conducted this role-playing in the lesson. Students prepared the role-playing activity and presentation as a group work before the lessons. During students' presentations, Expert 1 asked related questions to force students to discuss the issues.

Expert 1 also asked about the methods and strategies she used to make her students learn ecology better after classroom observation. She was also asked to compare the other subjects in terms of methods and strategies she used. The related excerpts are provided below.

I: What did you do to make your students understand ecology better?

E1: In the lesson, I tend to guide them [students] by asking what their [students'] opinions are in order to see their insights. Then I try to teach them [students] to enhance their [students'] understanding. In terms of teaching methods and strategies in the lesson, with the question-answer, I aimed to make them [students] relate their previous knowledge with the content they need to learn. Then, I made an explanation. Afterwards, students made their [students] presentations, at the same time students' questions were answered to ensure their [students'] understanding or I directed questions to students to understand whether they [students] understood or not. [post-interview]

I: Are the teaching methods and strategies you used the same for the other subject areas?

E1: If the content is more related to mathematical calculations, that is, if it is not related to ecology, for example, if it is Archimedes or if it is pressure, I used examples and problem-solving. I prepared handouts and photocopies to distribute to the students. [post-interview]

Gaining insight about Expert 1's knowledge of subject-specific strategies, the next section presented Expert 1's topic-specific strategies.

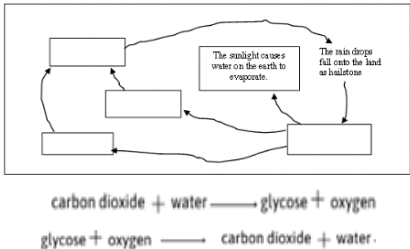
4.3.3.3.2 Expert 1's Knowledge of Topic Specific Strategies

Expert 1's topic-specific strategies were investigated in two sub-dimensions which were knowledge of representations and knowledge of activities. In the next part, Expert 1's knowledge of representations documented.

4.3.3.3.2.1 Expert 1's Knowledge of Representations

Expert 1's knowledge of representations was collected through pre- and post-interviews, lesson plans and classroom observations. Expert 1 was found to prefer representations such as drawing figures, examples, comparisons, and visuals. Before the ecology lessons, Expert 1 assigned groups of her students' homework. One of the groups was asked to prepare a presentation covering ecology concepts and issues. The other group was assigned to prepare posters about material cycles. Another group was assigned to role-play photosynthesis. She stated that she assigned such homework in ecology lessons each year. During classroom observations, she made her students present their presentations, posters and role-playing. She reinforced students' understanding with questioning and discussions. During these times, Expert 1 and her students provided daily life examples, and comparisons. Table 4.24 revealed Expert 1's knowledge of representations regarding ecology.

Table 4.24 Expert 1's Knowledge of Representations

Representations	Interviews	Lesson plan	Classroom Observation
Drawing figures	<i>I drew puzzles to assess their learning.</i>	to provide the requirements and the products of the photosynthesis through writing the equation... (Appendix O & P)	
Daily life examples	<i>I share daily life examples and news with students. [pre-interview]</i>	Not mentioned	S1: Human beings, animals, mushrooms and microorganisms are the living organisms' components of the ecosystem; air, water, soil, wind and sunlight are the non-living components.
Visuals (presentations, posters)	<i>I asked students to make PowerPoint presentations, posters... [pre-interview]</i>	Not mentioned	Not mentioned
Comparison	Not mentioned	Not mentioned	If you compare them [photosynthesis and respiration] in terms of time, one is always and the other only in daylight...

I: What are the representations you use in your ecology lessons?

E1: I am in favour of teaching visually, indeed. I share daily life examples and news with students. I prefer to teach ecology through field trips, investigations and demonstrations that students can search, and experience themselves although we have limited facilities.

Our school's computers do not work properly, for instance. [pre-interview]

Expert 1 stated she used visuals, demonstrations, and presentations as representation in her ecology teaching. Although Expert 1 did not include representations in her lesson plan (see Appendix O for the Turkish version; Appendix P for the English version), she was observed to use daily life examples, drawing figures and visuals in her ecology lessons. The daily life examples in the lesson are presented below. One of the daily life examples given in her lesson was related to living and non-living components of ecosystems.

S1: Human beings, animals, mushrooms and microorganisms are the living organisms' components of the ecosystem; air, water, soil, wind and sunlight are the non-living components.

[classroom observation]

Expert 1 provided examples of the organisms in a sample food chain.

T: Fox is eating a snake. How does fox feed on? Is it carnivore or herbivore??

S2: Both.

T: It is omnivore, then.

[classroom observation]

Students also gave examples of the organisms in ecosystems during the presentation as:

S3: The organisms feeding on the producers are called primary consumers. They are like sheep, rabbits and cows. Animals such as lions, tigers and eagles are the secondary consumers. Living things that use secondary consumers as food are called tertiary consumers, hawks are an example of a third consumer. Decomposers decompose dead animals and plants, and some fungi and bacteria are in this group.

[classroom observation]

Moreover, students gave daily life examples to the organisms that conduct aerobic and anaerobic respiration.

S4: Living things that do aerobic respiration are humans, animals, plants and some bacteria. Anaerobic respiration is the breakdown of nutrients with the help of enzymes in an anaerobic environment. There are two types of anaerobic respiration, fermentation: alcoholic fermentation and lactic acid fermentation.

[classroom observation]

Apart from daily life examples, Expert 1 asked students to compare photosynthesis and respiration.

T: How do you compare photosynthesis with respiration?

S5: In respiration, living things take in oxygen and give out carbon dioxide; photosynthesis is the opposite, the living thing takes carbon dioxide for itself and gives out oxygen.

T: So, are they [photosynthesis and respiration] both at the same time? When photosynthesis was under sunlight, now if we explain without thinking about artificial conditions, if you compare them [photosynthesis and respiration] in terms of time, one is always and the other only in daylight. Yes well, only green plants do photosynthesis, but respiration is all living things make. You can make such a comparison. Photosynthesis produces energy, isn't it, the energy produced in oxygen is burned and released.

[classroom observation]

Related to the comparison of photosynthesis and respiration, Expert 1 also wanted students to draw their equations on the board (Figure 4.13). In fact, in the lesson plan's result part, the Expert stated “to provide the requirements and the products of the photosynthesis through writing the equation of the photosynthesis and to ensure their learning.” (see Appendix O for Turkish version; Appendix P for English version). She included the equation of photosynthesis in her lesson plan she stated to be written on the board to teach in the lesson as:

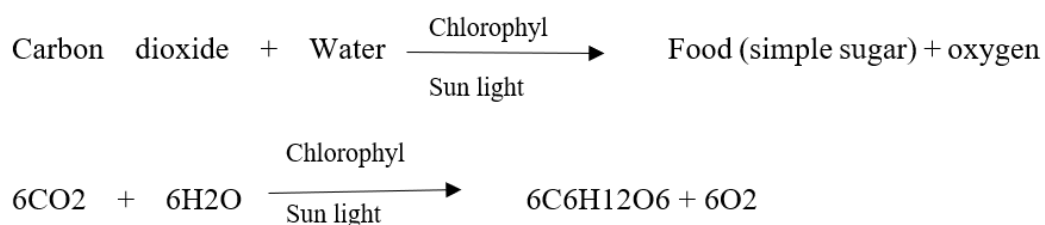


Figure 4.13 Expert 1's Photosynthesis Equation Figures in Her Lesson Plan

Before introducing the material cycles, Expert 1 asked students about the matter to see what they knew. Students answered by giving examples such as: “water”, “oxygen”, “carbon”. Students could not explain the material cycle and Expert 1

asked further questions to make students understand. During the explanations of the material cycles, Expert 1 drew figures to illustrate the water and oxygen cycles on board (Table 4.14). Moreover, she drew puzzles related to matter cycles to assess students' understanding.

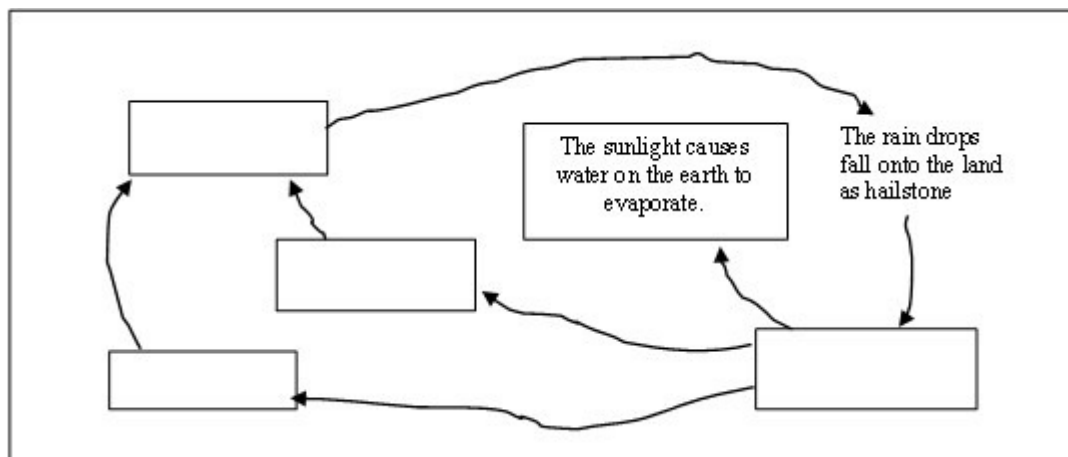


Figure 4.14 Expert 1's Matter Cycle Puzzle on Board

Expert 1 was also asked the representation she used after classroom observation.

I: What were the representations you provided in your ecology lessons?

E1: I asked students to make PowerPoint presentations and posters... I drew puzzles to assess their learning. I used these representations each year periodically. In fact, I used prepared presentations in different consents as well. Students performed role-playing to illustrate photosynthesis. [post-interview]

Expert 1 used drawing figures, providing daily life examples, comparisons, and visuals as the representations in her ecology lesson. In the next part, as the other sub-

component of knowledge of topic-specific strategies, Expert 1's knowledge of activities documented.

4.3.3.3.2 Expert 1's Knowledge of Activities

Expert 1's other dimension of knowledge of topic strategies was knowledge of activities. The pre- and post-interviews, the lesson plan and classroom observations were the tools to collect data. Expert 1 stated that she used posters, presentations and a role-playing activity in her ecology lessons. Table 4.25 revealed Expert 1's knowledge of activities.

Table 4.25 Expert 1's Knowledge of Activities

Activities	Interviews	Lesson Plan	Classroom Observation
Role playing	Students did PowerPoint presentations; they prepared posters and showed them in the lesson. Also, I gave students homework to prepare a role-playing activity to illustrate photosynthesis. [post-interview]	teaching and learning activities: group work, role playing	Students performed a role-playing activity regarding photosynthesis as a group.
Experiments	Visual sources and experiments provide permanent learning. [pre-interview]	Not mentioned	Not mentioned

I: What kinds of activities are there within the curriculum related to ecology?

E1: I do not remember [the activities within the curriculum] exactly. However, I suppose, there are activities related to drawing the levels of the energy pyramid. In material cycles, there are activities related to asking students about missing points or drawing these points and so on. I could not remember each of the activities. [pre-interview]

I: So, do you do any activities in ecology lessons?

E1: I teach ecology units by asking students to search or use presentations. Instead of these, I haven't done anything different. We have used presentations on computers, textbooks, and workbooks; however, all of these could not be used in each of the classes. [pre-interview]

Expert 1 mentioned the ecology unit in the curriculum including drawings and she used presentations as the activity. In fact, she used drawings and presentations in her ecology lessons (see section 4.3.3.3.2.1 Expert 1's knowledge of representations).

In the lesson plan of Expert 1, she wrote that “group work” and “role-playing” in the “teaching and learning activities” part (Table 4.25 & see Appendix O for Turkish version; Appendix P for English version). In fact, she made her students perform a role-playing activity about photosynthesis in her lesson. She introduced the students' roles in the activity to the class. The students in this role-playing activity represented the factors needed in photosynthesis and products of photosynthesis like sun, oxygen, water, plants and food. During the students' role-playing activity, Expert 1 directed questions like “Your friends' leaves are green. Do these leaves being green

have an influence on photosynthesis?” and she continually guided the students. Moreover, she gave explanations regarding photosynthesis like “plants’ green parts contain chlorophylls that are essential for photosynthesis...” to reinforce the effects of the role-playing activity.

I: What were the activities you did in ecology lessons?

E1: Students did PowerPoint presentations, they [students] prepared posters and showed them [students] in the lesson. Also, I gave students homework to prepare a role-playing activity to illustrate photosynthesis. [post-interview]

I: Which activities could be more effective instead of the activities you used?

E1: I believe field trips provide students with learning through experience that facilitates life-long learning. In this way, for instance, students can observe animals, and plants within a forest. There can be presentations or illustrations regarding the feeding relations of organisms within ecosystems and the levels of the energy pyramid. Whether these kinds of activities can be done somewhere or not, I do not know actually. However, these things help students to learn the issues effectively. Besides, according to the content, I used several different activities. [post-interview]

To conclude, Expert 1 preferred to use direct teaching, questioning and some student-centred activities like making students work in groups to prepare posters and presentations and role-playing activities. Expert 1 drew figures on the board, provided daily life examples, comparison as the representations in ecology teaching.

She also mentioned field trips and experimentation could be used to teach ecology more effectively.

4.3.3.4 Expert 1's Knowledge of Assessment

Teachers' knowledge of assessment includes the teachers' knowledge of assessing students' learning in a specific content area within a subject (Magnusson et al., 1999). Thereby, Expert 1's knowledge of assessment was investigated in terms of their knowledge to assess students' learning in ecology. In this respect, Expert 1's knowledge of assessment was examined in two parts knowledge of the dimension of science learning to assess and knowledge of methods of assessment. In the part of the knowledge of dimension of science learning to assess, Expert 1 knowledge was presented in terms of what to assess, types of assessment, knowledge of assessment methods and sources of assessment. Expert 1 also examined in terms of which knowledge domains influence her choice of assessment strategies and methods regarding ecology in the part of knowledge of methods of assessment. Expert 1's pre- and post-interview responses, lesson plans and classroom observations were the sources to understand her knowledge of assessment regarding ecology.

Expert 1 was found to assess students' knowledge, skills and attitudes in science. She used traditional assessment techniques like tests with multiple choice, fill-in-the-blanks and short answered questions. She preferred to assess students with the formative and summative assessment approaches.

The next subsection revealed Expert 1's knowledge dimensions of science learning to assess.

4.3.3.4.1 Expert 1's Knowledge of Dimensions of Science Learning to Assess

Table 4.26 presented Expert 1's knowledge of dimensions of science learning to assess.



Table 4.26 Expert 1's Knowledge of Dimensions of Science Learning to Assess

Dimensions of Science Learning to Assess	Interviews	Lesson Plan	Classroom Observation
What to assess	Knowledge	Knowledge	Knowledge
	Attitude		Attitude
	Skills		Skills

I: What is your aim to assess students?

E1: First of all, I aim to assess their [students] attitudes. Hence, nowadays, the attitudes and behaviours of students are problematic... After knowledge, I consider assessing their skills because each of them cannot be skilful. Maybe, they [students] can be knowledgeable; however, being skilful is related more to personal characteristics. The third one is a skill for my lesson. Being skilful is more important. Detecting a skill is more important. Knowledge can be gained afterwards. However, in school, we assess their knowledge initially; then, we assess their skills. [pre-interview]

Expert 1 was likely to assess students' attitudes, knowledge and skills. She pointed out students' attitudes in assessment. However, she mainly found to assess students' knowledge. In fact, in her lesson plan, she wrote the questions to assess students' knowledge that they were expected to learn in ecology lessons. The statement of Expert 1 in her lesson plan in the part of "Evaluation and Assessment" is provided below (see Appendix O for Turkish version; Appendix P for English version).

1. What are the inorganic matter they need to photosynthesize?

2. What is photosynthesis?

3. *What is the meaning of autotroph and heterotrophs?*

4. *Which one of the items that plants do not use during photosynthesis?*

a) O₂ b) CO₂ c) H₂O d) chlorophyll

5. *Please write the equation of photosynthesis.*

[Lesson Plan]

Expert 1 evaluated students' participation in the lesson and their answers to the questions in the lesson. Therefore, Expert 1 seemed to assess students' knowledge and attitudes in general. She also assessed the students' performing presentations, posters and role-playing. She provided feedback to students to improve their presentations. Expert 1 appeared to assess students' skills as well. The related classroom observation excerpt is as follows.

T: You prepared a good presentation. However, you need to include the equation of photosynthesis in the place where you explained the photosynthesis. Also, in the place where you divide respiration into two, you need to write the equation of aerobic and anaerobic respiration... These are not just deficiencies; you did a great job... but in order to improve yourself these are the feedbacks you need to take into account.

[classroom observation]

Expert 1 asked about how she assessed students after classroom observation. She stated that she made classroom observations. She seemed to assess their participation and knowledge when students provided answers to the questions in the lesson. In

fact, she was not observed to apply a test to evaluate students' learning. The post-interview response of Expert 1 related to the assessment provided below.

I: How did you assess students?

E1: I did not assess students directly. I assess students' answers to the questions. I made observations during lessons. Then, I apply a test to evaluate how much they [students] learnt...[post-interview]

In the next section, Expert 1's knowledge of methods of assessment presented.

4.3.3.4.2 Expert 1's Knowledge of Methods of Assessment

Expert 1 seemed to know the types of assessment that she mentioned formative and summative assessments. She mentioned that she used traditional assessment techniques like exams. However, she appeared to have knowledge of some of the alternative assessment techniques like presentations, figures, concept maps, and assessment of the process of the experiments. In fact, she said during interviews that she attended an inservice training about assessment techniques. However, she identified neither portfolios, projects related to alternative assessment methods nor rubrics to evaluate students' performances. She mentioned assessing students' prior knowledge and assessing their answers to the questions during the lesson. Moreover, she stated that she evaluated students' learning by exams at the end of each unit which was not observed in classroom observations. She explained her assessment methods in detail during pre- and post-interviews. However, Expert 1's lesson plan did not include the assessment methods she mentioned in interviews. She wrote assessment questions to the part of the lesson plan related to the assessment provided in the previous section of "Expert 1's Knowledge of Dimensions of Science Learning to Assess" (see section 4.3.3.4.1). Parallel to her lesson plan, Expert 1 was observed to

ask students questions related to ecology at the beginning of the lesson and during the lesson. Expert 1's knowledge of methods of assessment is presented in Table 4.27.

Table 4.27 Expert 1's Knowledge of Methods of Assessment

Methods of Assessment	Interviews	Lesson Plan	Classroom Observation
How to assess	We generally use traditional techniques. For instance, multiple choice, matching, filling in the blanks, short answers... [pre-interview] I can do assessment by showing different kinds of things, in the aim of demonstration, by directing student related questions and collecting their answers. [pre-interview]	See Appendix O & P	formative summative
When to assess	During the lesson, I asked questions and I collected students' answers. I gained insight about what students learned from their answers. [post-interview] We assess students at the beginning of the lesson and at the end of the lesson. [pre-interview]	At the beginning At the end	At the beginning, During the lesson, At the end of the lesson
Knowledge domains influence assessment methods	<i>Content knowledge</i> It [assessment] is more related with the content knowledge... [pre-interview] <i>Knowledge of students</i> Students' knowledge is also important while deciding on assessment. [post-interview] <i>Pedagogical knowledge</i> There are so many methods you can use. [post-interview]		

I: Which assessment methods and techniques do you use to assess students in ecology?

E1: Within the class, while teaching the content, I assess what they [students] know previously by questioning; after that, when they [students] learn the content, I evaluate their [students'] answers. ...that is, I ask them [students] to search for the concepts before the lesson. After they [students] searched the concepts, during the lesson, I asked them [students] to explain these [the concepts students searched before the lesson] concepts. I direct related questions. Then, I move to the activities within the workbook. I assess students in terms of whether they can do it or not. However, we generally use traditional techniques. For instance, multiple choice, matching, filling in the blanks, short answers... [pre-interview]

I: Then, do you think that these methods are sufficient in order to determine whether students understand the ecological concepts or not?

E1: They [methods for assessment] can be improved. I do not believe that they [methods for assessment] are enough because teachers should improve themselves continually. [pre-interview]

I: Apart from these assessment methods, what kinds of assessment methods can be used for ecology?

E1: Hmm...For instance, after teaching every part of the content, students can be assessed how much they [students] learned related to the concepts. However, we do not have the necessary time to do this [assessing each part of the content]. If I have the necessary sources,

I could do assessments by showing different kinds of things... such as in the aim of demonstration, by directing students related questions and collecting their[students] answers. For instance, by observing a photosynthesis process within different conditions or by doing experiments, I could provide students with a learning environment to reach their [students] own solutions. I want them [students] to determine which factors influence photosynthesis, for instance. According to the curriculum, assessment should be done with exams. For me, for instance, students should be assessed by experimenting, in preparing setups of experiments; I would like to evaluate their [students] decisions on the factors required or not required during the process. With preparing equal conditions, students decide on heat or something else, by testing themselves. We can assess through these ways; that is, we can decide on how much they [students] learned. [pre-interview]

I: When do you assess students in ecology?

E1: We assess students at the beginning of the lesson and at the end of the lesson. In addition, we can assess with traditional exams in order to assess how much they [students] have learned. [pre-interview]

I: You just said you assess students at the beginning of the lesson...how do you assess their previous learning apart from your mentioned methods then?

E1: I have not used them at all; however, the figures can be shown to students. In this way, assessment can be done. Assessment can be done by making students do concept maps, and by making students fill

in the blanks. I start to write the sentences and I want them [students] to continue where I stopped. I want them [students] to draw diagrams. For instance, it can be like that; what factors are necessary for photosynthesis; what is respiration; how many types of respiration are there; giving examples related to aerobic respiration and anaerobic respiration; where the respiration takes place; the necessity for energy and so on... [pre-interview]

I: Which knowledge do you have effective in determining your assessment method?

E1: It [assessment] is more related to the content knowledge, in fact. If you do not know the content, you will not know what you will ask. If you know the content, your chance of asking a question increases. You know what type of question you can ask at this time. They are related to each other. [pre-interview]

In the part of the lesson plan which was “Evaluation and Assessment”, Expert 1 wrote five assessment questions which were provided in the previous section of “Expert 1’s Knowledge of Dimensions of Science Learning to Assess” (see Appendix O for Turkish version; Appendix P for English version). She did not specify when she asked these questions. The statement in Expert 1’s lesson plan related to formative assessment is provided below (see Appendix O for the Turkish version; Appendix P for the English version).

“The keywords are asked of the students. They want to answer. (Producers, consumers, decomposers, photosynthesis, chlorophyll, energy). The concepts are reinforced through necessary explanations.” [Lesson plan]

Consistent with her lesson plan in classroom observation, Expert 1 asked questions to evaluate students' prior knowledge. Some examples of her questions were "Now, the organisms can photosynthesize...you learnt the food chain last year. At which trophic level these organisms are placed?", "in the food chain on the screen, which organism eats which one, who can respond?". In addition, Expert 1 asked open-ended questions to students like "How can you compare photosynthesis and respiration?", "If the rate of carbon dioxide increases in the environment, photosynthesis takes place, what can happen?" to enable students to activate their higher-order thinking skills. She also asked closed-ended questions to evaluate the factual knowledge of students. Some of the examples were "What factors influence the rate of photosynthesis?", "What is the equation of aerobic respiration?". Although the findings gathered from the lesson plan and classroom observations were consistent, her pre-interview responses related to assessment methods had contradictions, especially her beliefs on assessment methods. She said that if she had the necessary conditions, she preferred to apply alternative assessment techniques that she believed their effective.

Apart from pre-interview findings, Expert 1 asked questions after classroom observations. The following interview excerpts revealed her answers.

I: How did you assess students in ecology?

E1: I did not assess students on the day you observed. I asked questions and I collected students' answers. I gained insight into what students learned from their answers. I assessed students with exams. I did it [assessment] at the end of the unit. However, it would be better if I could do mini-tests after each section of the unit. But the time was limited. Hence, I could not do it. After the exams, I looked at what students could do and what they [students] could not do. In terms of

their [students] answers to the questions, I gave feedback that said “Turn back to this subject again and study these parts.” [Post-interview]

I: Did you think that these methods are sufficient in order to determine whether students understand the ecological concepts or not?

E1: Yes. I also used the questions at the end of each unit inside the students’ books. According to students’ answers to these questions...that I specified a percentage... if fifty per cent and above of the students can give answers to these questions, I understand that students learn the concepts. I also give notes on students’ performances in the lessons. [Post-interview]

I: Which knowledge did you have effective in determining your assessment method?

E1: Initially, I should say that previously, we assessed students with traditional exams. I took an inservice training related to concept maps. Apart from this, I find multiple-choice, fill-in-the-blanks questions more beneficial. I did my last exam with multiple-choice questions. Previously, the exams were more traditional. We asked questions like “Write what you know about this.” I participated in programs related to evaluation and assessment. I found these programs beneficial. There are so many methods you can use.

Students’ knowledge is also important when deciding on an assessment. If students know many things, you can ask various questions. If they do not know so many things, you ask simple

questions. According to the level of the class, you should choose question types. [Post-interview]

To summarize, Expert 1 was likely to have knowledge of assessment in ecology. She mentioned formative and summative assessment in the findings of interviews, lesson plans and classroom observations. She assessed students at every stage of the lesson in ecology. She preferred to use alternative assessment techniques in that she could assess students' performances in various ways like concept maps, figures, experiments, and diagrams. In fact, she mentioned several types of questions like multiple choice, fill in the blanks, matching and so on.

The following section presents the summary of Expert 1's PCK.

4.3.3.5 Expert 1's PCK Summary

Expert1's pedagogical content knowledge with its aspects in teaching ecology was presented in this section in Table 4.28.

Table 4.28 Expert 1's Pedagogical Content Knowledge in Teaching Ecology

KoC			KoL		KoIS		KoA
Goals and objectives	Materials	Requirements	Learning difficulties:	Subject specific	Topic specific	What to assess	
See Table 4.20 <i>Vertical/horizontal relations:</i>	Teachers' guidebook Students' textbook	Daily life examples Prior knowledge	Population Habitat <i>Misconceptions:</i>	Direct teaching Questioning Demonstration	<i>Representations:</i> Figures Daily-life examples	Knowledge Skill Attitude	
G-7 food chain, food web	Board Projection		Organisms Producers' nutrient	Experiments	Visuals (presentations, posters) Comparisons	<i>Methods of assessment:</i> Exams, concept maps, diagrams, figures, experiments, performances	
G-8 Food chain, photosynthesis, respiration, material cycles	Materials for role playing Materials for experiments periodicals, journals computer		Respiration and photosynthesis			<i>Formative assessment:</i> classroom observation <i>Summative assessment:</i> multiple choice, matching, filling in the blanks, short answers.	

KoC: Knowledge of Curriculum
 KoL: Knowledge of Students' Understanding of Science
 KoIS: Knowledge of Instructional Strategies
 KoA: Knowledge of Assessment

Expert 1's SMK and PCK were presented in this section. In the next section, Expert 2's SMK and PCK regarding ecology documented.

4.4 Expert 2's Subject Matter Knowledge and Pedagogical Content Knowledge Regarding Teaching Ecology

4.4.1 Expert 2's Demographic Information

Expert 2 was an experienced science teacher for thirty years. He graduated from the Institute of Education in 1978. Like Expert 1, he had a bachelor's degree from a three-year undergraduate education. During his three years of undergraduate education, he took courses in education psychology and evaluation and measurement related to educational sciences and physics, chemistry and biology, botanic, zoology, and mathematics related to the content area. After graduation, he enrolled in several inservice pieces of training that he said not to remember their exact topics. He said to participate in some particular courses and training regarding ecology. He mentioned that he was one of the participants in a non-governmental organization related to ecology and wildlife. He expressed that he took several biology courses in his undergraduate education and taught biology to high school students early in his career. He used several sources for his science lessons, like books, magazines, videos, and documentaries. Especially for his ecology teaching, he mentioned nature as his primary source. He had a laboratory in the school he launched himself and used the laboratory in his science lessons.

Expert 2's SMK and PCK on ecology are documented in the following parts. The first part presented Expert 2's SMK on ecology.

4.4.2 Expert 2's Subject Matter Knowledge on Ecology

Expert 2's SMK on ecology was investigated through pre-interview questions, concept map drawing, exemplifications, interpretations, and drawing figures. Through twenty-nine questions with sub-questions, SMK regarding ecological concepts and principles was collected. The SMK findings were divided into two main categories that are basic ecological concepts and energy flow in ecosystems. The basic ecological concepts category includes the findings about the ecosystem, species, population, community, habitat, ecological niche, biological diversity, producer, consumer, and decomposer. In the energy flow in ecosystems category, there were questions about energy, photosynthesis, food chain, food web, and energy pyramid.

Interview responses, his concept map drawing, and figures drawn by Expert 2 revealed that he had limited knowledge of the majority of basic ecological concepts like ecosystem, producers, consumers, species, extinction-prone species, habitat, community, and biological diversity. In addition, Expert 2 was found not to have knowledge in ecological niches. Besides, he was likely to have an understanding of energy and energy flow in ecosystems, and he was the only one among the participants in the study who explained energy in terms of an ecological perspective. Expert 2 could also explain the trophic levels of organisms in food chains, food webs, and energy pyramids. Although Expert 2 did not state the arrows represent the flow of energy between organisms, he could explain the complex relations of populations in the food web.

The following parts presented the details about Expert 2's SMK findings on ecology. The next part was related to Expert 2's SMK on basic ecological concepts.

4.4.2.1 Expert 2's Subject Matter Knowledge on Basic Ecological Concepts

In order to discover Expert 2's understanding of basic ecological concepts, he was interviewed and asked to define an ecosystem.

I: What is an ecosystem?

Expert2 (E2): Ecosystem...hmmm... it is the area, either large or small in which living and non-living things exist together. All of these things [living and non-living things] interact with each other inside it [ecosystem]. For example, no one of the organisms wants the other organisms to disappear. I saw this event in real life when one of the foxes closed the door of the mice's cave intentionally. When the mice ran out, the fox forced the mice to turn into its cave. However, the fox did not kill the mice, even if it [fox] had the capacity to kill it [the mice]. I interpreted this situation that if the fox killed the mice there immediately, the mice could not reproduce. As a result, foxes could not find food anymore. Therefore, from my point of view, the fox allowed the mice to live to reproduce more offspring, and in this way, it [the fox] could find more food and could continue to survive. [interview]

I: Are the non-living things included in this interaction?

E2: Of course, non-living things are included in the ecosystem. For example, the fur of the animals should be adapted to the environment in which they live. If they were not able to adapt to the environment, they would not continue to survive anymore... [interview]

I: Okay, can you give examples of the ecosystem?

E2: Forest ecosystem, lake ecosystem, pool ecosystem, desert ecosystem, and so on... [interview]

To gather further understanding about his SMK on ecosystems and the relationship between other ecological concepts, Expert 2 asked to construct a concept map. Figure 4.15 revealed Expert 2's concept map.

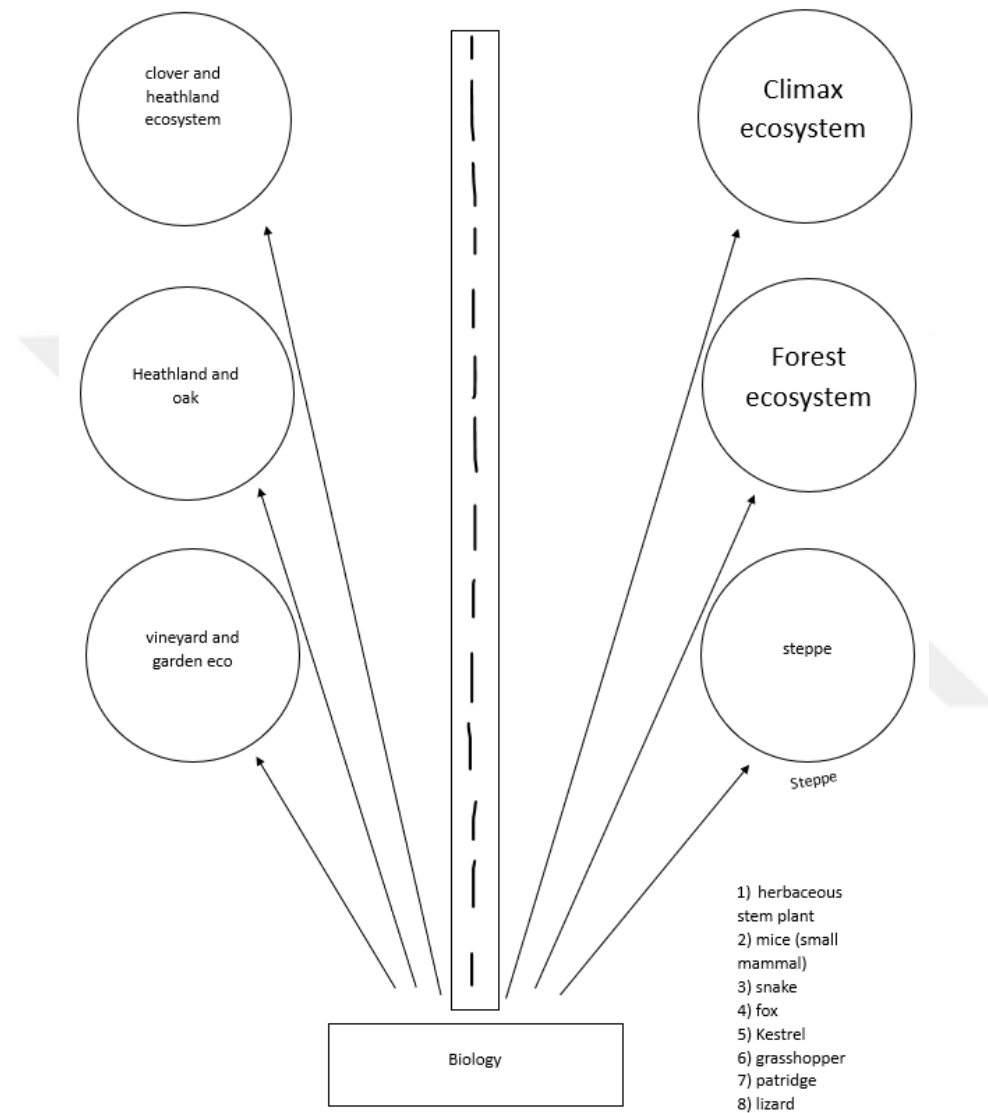


Figure 4.15 Expert 2' Concept Map (see Appendix E for original drawing)

Expert 2's hierarchal concept map consisted of a central concept which is biology, and six concepts, which are vineyard and garden ecosystem, health and oak, clover

and heather ecosystem, lime ecosystem, forest ecosystem, and steppe. He listed several concepts on the outer side of the concept map. These concepts were hawthorn herbaceous stem plants, mice (small mammals), snakes, foxes, kestrels, grasshoppers, partridge, and lizards. There are not any linking words. He also listed organisms found in each ecosystem. There are not any basic ecological concepts, and there is not any association between these concepts. There are neither crosslinks between concepts nor linking words. He explained his concept map that there are so many ecosystems on the earth that are the main issues of biology. Moreover, he mentioned that these kinds of ecosystems included in his concepts map interacted with others in an open system in which so many organisms live.

Although Expert 2 did not integrate other ecological concepts in his concept map, he defined an ecosystem as an environment in which living and non-living things and highlighted their interaction. As his concept map did not reveal his knowledge about the association of ecological concepts and ecosystems as well, he asked further questions about ecosystems.

I: Assume that “You asked your class to construct a closed ecosystem as a homework assignment. Among your students, Ali and Ceren decided to prepare this homework together. They meet after school for this homework. Ali suggested that: ‘Let’s take three large glass containers. In one, we will put all the non-living things like rocks, soil, water, and air, and we will hang a light bulb over it to represent the sun. In another container, we will put just the plants, and in the third container, we will put just the animals. It will be cleaner this way if we keep everything separate!’”. How would you evaluate Ali’s ecosystem suggestion?

E2: The ecosystem is the area in which living and non-living things are together, as I said previously. In ecosystems, there should be species and populations. In an ecosystem, it is not true to place only living things or non-living things separately. There needs to be sunlight also, producers, and non-living things in the ecosystem. This [Ali's ecosystem suggestions] cannot be an ecosystem because there are no consumers inside it [Ali's ecosystem suggestions]. You said that in one of the ecosystems [Ali's ecosystem suggestion for the third container], children placed consumers only. This is not an ecosystem, though. In order to form an ecosystem, there should be a huge container in which the rocks, soil, water and air, sunlight, producers, and consumers are inside... In order to form a sustainable, surviving ecosystem, there should be biological diversity inside this container as well. Actually, in order to form an ecosystem, these children should learn the concept of the ecosystem properly. [interview]

Although he did not identify the basic ecological concepts other than ecosystem in his concept map, Expert 2 mentioned and related species, populations, living and non-living things, producers, consumers and biological diversity with the ecosystem in his explanation of the sample ecosystems in the previous script. As he emphasized the species and populations at first in the previous explanation, he asked about these concepts.

I: What is species?

E2: Species are...um... For example, in a lake ecosystem, there are organisms living inside it [lake]. If it [ecosystem] is a pool, there are organisms living inside this pool different from the lake ecosystem.

Fox is a species, for instance. If the foxes come together, they form a population. [interview]

I: Can you explain the population?

E2: It [population] is a life form in which a group of organisms live together. Inside the ecosystem, these [organisms] groups are not separate from each other. Inside the ecosystem, even some of the populations live together; however, some of the populations live separately. For example, fox populations, do not live separately from each other. [interview]

I: Can you tell me the characteristics of extinction-prone species?

E2: Human beings kill these organisms [extinction-prone species] for their own benefit. If we remove humans from ecosystems, there remains no problem. From snake's poison, we make medicine; from snake's leather, we make bags, belts, and wallets. For example, rhinos are prone to extinction because they have been killed only for their thirty centimetres horns. Another reason [for extinction-prone species] is to apply medicine to animals for neutering. No kind of species causes another species to disappear in nature. However, human beings cause species to be extinct... [interview]

Expert 2 seemed to have an understanding of species and population concepts, in which he provided an example for the species and also the population. However, he did not express the characteristics of species, like sharing common characteristics and interbreeding. Besides, he did not include both species and population in her concept map (Figure 4.15), although he could associate these concepts in the interviews. Expert 2 also appeared to have a comprehension of extinction-prone

species as well. In fact, the characteristics of extinction-prone species were explained with over-exploitation by people providing examples like rhinos being killed for their horns, snakes' poisons for medicine, and snakes' leather for bags, belts, and wallets. However, he did not mention fixed migratory patterns of organisms, possession of specialized feeding habits to be found in only one place or region, limited specialized resting or breeding areas, and feeding at high tropic levels, which are the extinction-prone species' other characteristics. The next questions were to understand Expert 2's knowledge of community, habitat, and ecological niche.

I: How can you define community?

E2: I watched an amazing documentary previously. In this documentary, a crocodile ate one of the animals moving into the pond. The important thing that caught my attention was that there were tiny birds around there [pond], and these birds immediately moved to the mouth of the crocodile. They [birds] did not hesitate to get into the mouth of the crocodile and ate the pieces of remaining food in the teeth of the crocodile. I interpreted the reason that birds and crocodiles need to live as a community. In fact, organisms need to live within a community to survive. [interview]

I: What about habitat?

E2: According to their anatomies, animals like deer, bears, and pigs live in a certain area. The characteristics of the areas where these animals live differ. That is, these animals do not live in the same area. Habitat is a certain area where species can survive. For instance, the goat can find food from the steepness of the mountains because of protection from other organisms. [interview]

I: Then, what is the ecological niche?

E2: I have not heard of this concept before. So, I cannot define it [ecologic niche]. [interview]

Expert 2 seemed to have an understanding of community and habitat. Although he did not provide a certain scientifically accepted definition of community, he explained it by providing examples inferring that the populations living together form the community. Indeed, Expert 2 defined habitat with a scientifically correct explanation. In fact, he explained habitat is the certain place where organisms live and can survive to meet their needs, shelter, and feed. He seemed to know the components of habitat, like food, shelter, and space to reproduce and survive. Expert 2 did define the ecological niche. Biological diversity was the next ecological concept Expert 2 was asked to define.

I: What is biological diversity?

E2: Biological diversity is the diversity of species. If the plants living inside a pool are various, the species being able to live inside of this pool also vary. Konya Plain is a large area in which there is not plenty of food and water. That is, it is covered with barren soil. If biological diversity increases there, the number of species will also increase too. In addition, species should adapt to the place they live. Although Ankara foxes and Urfa foxes come from the same ancestor, their fur color differs. If they [species] do not have these adaptations, they [species] can be easily found by their [species'] predators. [interview]

To deepen her knowledge on biological diversity, Expert 2 asked “*is biological diversity advantageous for organisms?*”

E2: Yes, biological diversity is advantageous for organisms because of the reasons I mentioned previously. [interview]

Expert 2 explained the biological diversity in terms of species diversity in a certain area having different characteristics to be able to adapt to the place they live. He explained the advantages of biological diversity in terms of advantages of increased number of species. He also talked about species' adaptation to the place they live, causing a variety of characteristics. Therefore, he seemed to explain biological diversity in terms of species diversity and genetic diversity. He did not mention ecological diversity.

Expert 2's SMK on energy flow in ecosystems, including energy, photosynthesis, food chain, food web, and energy pyramid presented in the next section.

4.4.2.2 Expert 2's Subject Matter Knowledge on Energy Flow in Ecosystems

The interview questions, drawing figures, exemplifications and interpretations were documented to understand Expert 2's knowledge of energy, photosynthesis, the food chain, the food web and the energy pyramid. Expert 2's concept map did not consist of energy, photosynthesis and respiration, food chain, food web and energy pyramid (Figure 4.15). First, he asked to define energy.

I: What is energy?

E2: Energy is a transformation... How? First of all, the source of energy is the sun. All kinds of energy emerge from the sun. This energy is initially transformed by producers. That is, producers who can photosynthesize are the first energy source. Then, this energy is transferred to the first consumers. If we think about this situation in the energy pyramid, we can explain that energy is decreased to the upper levels. [interview]

I: You mentioned producers and consumers. Can you tell me, first, what is the importance of producers in the ecosystem?

E2: Well... Plants are producers that photosynthesize. In this way, they [producers] produce their own food... They [producers] take in carbon dioxide from the air and water from the soil for the process of photosynthesis. If there is light, plants produce their [plants'] own food. Some of these foods are used for the growth, reproduction, and metabolic activities of their [plants'] own. The remaining part is stored within roots, stems, or leaves. The produced oxygen provides animals with respiration. They can conduct aerobic respiration in this way. [interview]

I: Then, what is the importance of consumers in the ecosystem?

E2: Consumers produce carbon dioxide for producers to conduct photosynthesis. They [consumers] take in oxygen and give off carbon dioxide...[interview]

I: You said, 'Producers photosynthesize'. Do you remember how they [producers] photosynthesize?

E2: Green plants should have solar energy so that they can make their [green plants'] own food. Water is necessary; they [plants] must also take in carbon dioxide from the air. The food synthesized in the process is used in growth and development, and some of it [food] is stored. The primary consumers are herbivores, which comes then. Of course, other living things give off carbon dioxide and take in oxygen through breathing. Plants will use this carbon dioxide for photosynthesis, indeed... Plants, which are attached to the soil with

their roots, make the nitrogen in the air usable thanks to nitrogen-fixing bacteria. So, the more diverse the producers in an environment, the more species there will be. [interview]

I: So, what is the food of plants?

E2: Glucose. [interview]

I: What is the purpose of photosynthesis?

E2: The aim of photosynthesis is to survive. If a plant with green leaves cannot produce its own food, it [plant] cannot survive. In fact, nutrition is a common characteristic of organisms. [interview]

I: Do you think that photosynthesis obeys the first and second laws of thermodynamics?

E2: Energy does not disappear; rather, energy is transformed. According to the law of conservation of energy, matter neither disappears nor is created in nature. All kinds of energies can be transformed into each other. Here food is the energy source. Decomposers break down this food to be reused. Actually, during this energy transformation takes place, some amount of energy changes the form. Eighty per cent of the energy can be transformed during these transformations. The remaining parts of the energy can be transformed into voice, motion, and so on. When a car moves on the road, this is called kinetic energy. If the wheels of the car rub on the road, some amount of this energy is lost as heat. That is, the total energy cannot be transformed into motion. Some amount of energy is lost as heat. Similarly, photosynthesis also obeys this law [second law of thermodynamics], too. [interview]

I: Why would an increase in the atmospheric concentration of carbon dioxide not necessarily result in a corresponding increase in photosynthesis?

E2: Hmmm...During the day time, plants take in carbon dioxide; they take in water through their roots under the sunlight. They produce oxygen by synthesis. In this environment, the amount of oxygen is high, then. At night, as there is no sunlight, plants with green leaves start to use oxygen. If the plants with green leaves decrease in the environment, the amount of oxygen will also decrease, too. In this case, producers depend on consumers, and consumers depend on producers. It [producer] needs carbon dioxide to do photosynthesis; who will give off [carbon dioxide]? Will animals give off [carbon dioxide]? [interview]

Expert 2 implied only the green plants are producers, and they produce glucose. He knew the plants' food. He perceived photosynthesis as a linear process in which green plants take in carbon dioxide and water give off oxygen and produce glucose. He did not mention the seriousness of the complicated chemical process of photosynthesis in the organelle chloroplast. Moreover, he did not make any connection between photosynthesis with material cycles and energy flow in ecosystems during interviews. Related to the first and second laws of thermodynamics, he seemed to provide a scientifically correct explanation of both the first law and second laws of thermodynamics. In fact, he explained the energy transformation in photosynthesis, and some amount is lost as heat. Yet, he did not mention the amount of energy loss and the rate of energy efficiency when energy flows in ecosystems. He seemed to have difficulties with the limiting factors of photosynthesis.

Although he did not provide detailed information about energy and photosynthesis, Expert 2 was likely to have knowledge regarding energy flow in the ecosystem. He seemed to have a comprehension of the flow of energy that producers produced energy transferred to the consumers. However, he did not explain sun energy is converted to chemical bond energy stored within glucose as ATP, which is an important process for the energy flow in ecosystems. He was further asked questions about the food chain to deepen his knowledge of energy, presented in the next section.

4.4.2.2.1 Expert 2's Subject Matter Knowledge on Food Chain

I: What is the food chain?

E2: Well, inside an ecosystem, there are several organisms sharing the same area. These organisms feed on each other. Among these organisms, there are herbivores, carnivores, and decomposers. For example, inside an ecosystem, if the number of mouse increase, the organism feeding on the mouse will increase, too. [interview]

He explained the food chain as the sequence of the food transfer among organisms living in the same area. He also identified the trophic levels in food chains like herbivores, carnivores and decomposers even the missing other trophic levels such as the producers and omnivores. To deepen his understanding, he was asked to draw a food chain. Figure 4.16 presents Expert 2's food chain drawing.

I: Can you draw a food chain?

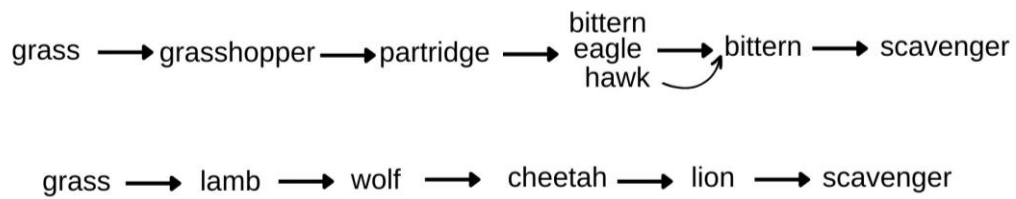


Figure 4.16 Expert 2 Food Chain Drawing (see Appendix E for original drawing)

E2: Now, when constructing a food chain, first of all, there must be producers in the first level. This means plants with green leaves. Those with herbaceous stems are here [in the trophic level of producers] in the food chain, [plants] with woody stems [in the same level] as well. Woody stems are trees, by the way. The fruitless ones [plants] are a separate group. There are those [organisms] who feed on plants and are in the position of primary consumers. By the way, plants with green leaves have to do photosynthesis. They [plants] make their own food. Those who make this [food] use some of it [food] in growth and development; they [plants] store some of it [food] as some stored in their [plants'] roots, stems, and leaves. Herbivores find the stem, root, and leaf [of the plants], and as a result, they eat wherever food is stored [in the plants]. What is more, who eats the grass? Let the grasshopper eat it [grass]. Then, who eats the grasshopper? Partridge eats...who eats the partridge, then? Fox eats besides hawk and eagle eat [partridge]. There are the ones who eat the eagle, too. Hmmm, who eats the eagle? The ones stronger than the eagle... These could be sparrow hawks, eagles, and hawks. [Interview]

Expert 2 drew two food chains indicating organisms' feeding relations in each. He also explained the food chains in line with the trophic levels and drew arrows consistent with to scientifically correct way. Expert 2 initiated his food chains with

producers stating that producers produce their own food and consume from herbivores. In fact, Expert 2 continued his food chains after producers, with the first consumers as herbivores like grasshoppers and lamb. However, he did not draw any decomposers in his food chains.

But Expert 2 explained decomposers operated after tertiary consumers that were identified as scavengers in interviews.

I: Is the length of a food chain limited?

E2: Of course, there is a restriction in the length [of the food chain]; there will be decomposers after those organisms [organisms in his food chain drawings]. The place of the decomposers is after the scavengers. When the scavengers die, the decomposers will operate to decompose their dead body into the soil. [interview]

I: As you mentioned about decomposers, can you explain the importance of decomposers in the ecosystem?

E2: When a human dies, its [human being's] death starts to decay. The body produces its own decomposers, and the body starts to be decomposed in this way. On the roots of the plants, there are bacteria fixing nitrogen. In this way, nitrogen in the air is transferred into the soil. The soil becomes amplified with nitrogen. Nitrogen in the soil means fertilizer. Plants are anchored to the soil by their roots. In this way, plants take in water and also dissolve nitrogen from the soil. These plants are consumed by primary consumers, which are herbivores. These organism's wastes, urine, and death are transformed into soil. This time, there are decomposers in the soil function. These decomposers are produced by organisms. Bacteria

are the decomposers produced by the body of the organism, for instance.

There is a huge importance of decomposers in the nitrogen cycle, indeed. They provide a decomposition of green plants' death as well. If the soil is not rich in terms of nitrogen, fruitful plants cannot grow there too. If there are not fruitful and various plants, there cannot be various kinds of animals. In the end, if there are no decomposers, life cannot continue. [interview]

I: How do you explain the relationship between producers, consumers, and decomposers, if any?

E2: Producers produce oxygen; consumers produce carbon dioxide. If the organisms that take in oxygen and give off carbon dioxide decrease in number, they cannot give off carbon dioxide anymore. For this reason, producers depend on consumers; consumers also depend on producers. In order to photosynthesize, producers need carbon dioxide. Producers take in carbon dioxide with the help of consumers. [interview]

Expert 2 was found to have misconceptions regarding decomposers. He stated that the body of organisms produces decomposers and operates after tertiary consumers. He explained the importance of decomposers in relation to the nitrogen cycle. Producers, consumers, and decomposers relation was explained regarding the material transfer rather than energy. Although he thought that food chain length was limited, he did not imply energy as the factor. Overall findings revealed that he needed to explain producers, consumers, and decomposers' relations in ecosystems in food chains. He asked more about the food chain.

I: What do the arrows in the food chain represent? Please explain.

E2: The arrows point toward the forward direction. In the food chain, grass is a general term, and lamb is a general term. [The arrows explain that] lamb eats grass [The arrows also explain that] and the wolf eats the lamb. [interview]

I: Why did you draw 5- 5-level and 6-level food chains then? Could they be 7-8-9-10 too?

E2: Of course, you can increase the chain more. The limit for all of them [food chains] is their [organisms'] death. [interview]

Expert 2 was likely to need help understanding the length of the food chains and limiting factors. Although he drew five and six levels in his food chains, he thought the food chain levels could increase more. Moreover, he did not associate the limitation of food chains with the 2nd law of thermodynamics. He also explained arrows with organisms' eating relations. He neither mentioned the role of arrows in the food chain in the direction of energy flow nor separated the organisms' roles as producers, first consumers, second consumers, top consumers, etc., and conveyed populations' feeding type as producers, herbivores, omnivores, carnivores.

To gain further insight, Expert 2 was provided some food chain examples from the literature and asked several related questions.

I: Are the -nectar, a butterfly, a bird, and decomposers- constituents of a food chain? (Reiner & Eilam, 2001)

E2: What is nectar? [interview]

I: It is the part of the plant.

E2: Okay, then...Where does the butterfly live? Their habitats are farms. A butterfly feeds on plants with herbaceous stems. The butterfly initially benefitted from the plants. It collects the nectar from plants. Where are the decomposers? They are inside the soil. They decompose the organism's wastes, urine, and death. If a bird dies, decomposers decompose its [birds'] death; if the bird's wastes drop onto the soil, decomposers decompose its [birds'] wastes, too. [interview]

I: What about a bacterium inside the human body? Could it be a part of a food chain? (Reiner & Eilam, 2001)

E2: Of course, they are part of a food chain, too...Human beings certainly eat something; they eat either vegetables or animals. When this nourishment continues, physical or chemical digestion occurs. The intestine is the place where bacteria live and water is absorbed. The first starting point of digestion is the mouth and the teeth, where physical and chemical digestion starts. The urine and excrement are the end products of digestion, which are thrown away in the soil for decomposition. [interview]

Expert 2 appeared to perceive nectar as a part of the food chain when he was provided information about its being part of the plant. However, he had difficulties in deciding the first trophic level of the food chain in which bacterium inside the human body is a part. He explained with irrelevant explanations related to human digestion. Therefore, he did not mention the producers and the other organisms in this food chain. Even he did not mention the bacterium inside the human body could have a role as the decomposer.

The 8th-grade ecology unit in 2009 associated the material cycles and food chains with the related objective [the related objective in the curriculum: 1.19. Explains the material cycles in parallel with the energy flow in the food chain.]. In line with this objective, Expert 2 asked a question to gain an understanding of the relationship between food chains and material cycles.

*I: Is there any relationship between material cycles and food chains?
Please explain.*

E2: There is a huge importance of decomposers in the nitrogen cycle, for instance. They provide an increase of nitrogen in the soil. Decomposers are also at each level of food chains. They decompose the deaths of the organisms; their excretes and urines... [interview]

Expert 2's responses about the relation between material cycles and food chains revealed that he underestimated most of the material cycles apart from nitrogen cycles and had difficulties in associating material cycles with food chains. For instance, he did not talk about water, carbon, nitrogen, and phosphorous cycles in relation to food chains. He also did not explain the details of the factors that contributed to the relation of material cycles with food chains. Although Expert 2 stated the biological fixation of nitrogen by a series of micro-organisms in the soil in another interview question previously, he did not provide an explanation for the aquatic fixation of nitrogen in aquatic environments that the organisms of these environments are also part of food chains of these environments. He also neither expressed nitrification, which is one of the processes accomplished through the relation of bacteria with plants, nor denitrification. Although he did not clearly explain ammonification related to the nitrogen cycle, he could explain the breaking down of organic materials in dead organisms and the wastes of the organisms by decomposers.

The next part documented Expert 2's SMK on the food web.

4.4.2.2.2 Expert 2's Subject Matter Knowledge on Food Web

Expert 2's concept map did not consist of the concept of food web (Figure 4.15). First, Expert 2 asked to define the food web.

E2: The food chain, as I defined previously, is the linear series of species' eating relations. The food web can be defined as the combination of these chains. The food web is the place where all different kinds of food exist. There are kinds of species sheltering, and reproducing inside the forest, for instance. These organisms should find food for themselves there [forest]. So, the food web is the diversity of food in an area. [interview]

I: So, what is the difference between a food chain and a food web?

E2: The food chain is the linear series of chains formed by species. But the food web is the combination of these chains, as I said previously. [interview]

Expert 2 defined the food web as the sequence of organisms having feeding relations. In fact, the food web was explained in line with the diversity of the food in an area. Expert 2 also stated the difference between the food chain and the food web as the food chain is the linear sequence of organisms, and the food web is the totality of food chains. Although his explanation was the implication of complex relations of organisms in the food web, he asked several questions according to the food web diagram (Webb & Bolt, 1990) to reveal his knowledge regarding the food web. The letters in the sample food web represent a population in the food web. The following questions are targeted to uncover teachers' knowledge of complex relations of the

populations in the food web. The questions probed the understanding at different levels of complexity and disclosed the possible misconceptions teachers have. The findings of the sample food web questions presented in relation to common related misconceptions in the groups of “A change in one population will only affect another population if the two populations are related as predator & prey.”; “A population located higher on a food chain within a food web is a predator of the next adjacent populations located below.”; “A change in the size of a prey population has no effect on its predator population”; “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” (Griffiths & Grant, 1985).

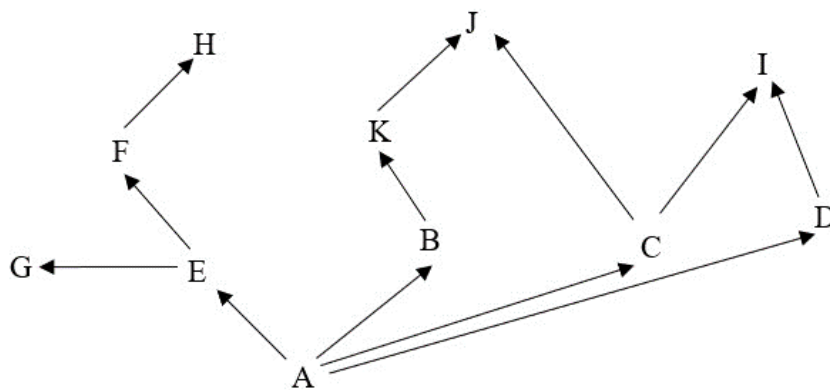


Figure 4.17 A sample of food web (Webb & Bolt, 1990, p.188)

Group1. A change in one population will only affect another population if the two-populations are related as predator & prey (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population H have on population E? Explain your answer.

E2: Population H is eagle; if population H decreases, population F increases. Population F is partridge. If the partridge population (F)

increases, the grasshopper population (E) decreases. Then, the grass population (A) increases. [interview]

I: What effect will a sudden decrease in population E have on the size of population H? Explain your answer.

E2: Population E is the grasshopper. If the grasshopper population (E) decreases, the partridge population (F) will start to decrease. This situation is related to food. Then, population H decreases because of the relation. [interview]

The above questions were to understand whether Expert 2's misconception in one population will only affect another population if the two populations are related as predator & prey. The first question was targeted “to determine the effect of a sudden size change in one population on a second non-adjacent population located lower on the same food chain” (Webb & Bolt, 1990). The second question was targeted to elicit “the effect of a sudden size change in one population on a second non-adjacent population located higher on the same food chain when the effect is transmitted only in one route” (Webb & Bolt, 1990). Expert 2 seemed to be aware that one population will affect another population, not only if they are interrelated as predator and prey populations. If the populations are more distantly connected in the food web, Expert 2 appeared to identify interactions of populations correctly.

Group2. A population located higher on a food chain within a food web is a predator of the next adjacent populations located below (Griffiths & Grant, 1985).

I: What effect will a sudden increase in population H have on the size of population F? Explain your answer.

E2: As population H increases, population F increases. Because if population H decreases, population F disappears. If population H

increases, population F increases. That is, E is lamb population; lamb is eaten by wolf population (F). Who eats wolf (F)? Vulture (H) eats wolf. If vulture population (H) increases, population F decreases. Population E increases. Let's call population B as grasshopper. Who eats grasshopper population? Partridge population (K) eats grasshopper. Partridge (K) can be eaten by eagle (J). If eagle population (J) increase, partridge population (K) decrease. If partridge population (K) decreases, grasshopper population (B) increases. If grasshopper population (B) increases, grass population (A) decreases. [interview]

I: What effect will a sudden decrease in population J have on B? Explain your answer.

E2: The sudden decrease in J means fox consume population K. The rabbit population (B) will start to decrease. This cause grass population (A) increase. [interview]

Above are the food web questions targeted to whether Expert 2 could identify “the effect of a sudden size change in a predator population on its prey population” (Webb & Bolt, 1990). Although he confused the effect of a sudden size change in a population on a second adjacent population located higher on the same food chain in his explanations, he could provide correct answers indicating his knowledge of to identify the effect of a sudden size change in a predator population on its prey population. In fact, he did not seem to have a common misconception that populations depicted high on the food chain of the food web will not always be predators of populations lower in the food chain.

Group3. A change in size of a prey population has no effect on its predator population (Griffiths & Grant, 1985).

I: What effect will a sudden decrease in population F have on the size of population H? Explain your answer.

E2: Well, what is population A? As it is at the bottom of the food web, it is producers. If population A decrease, population E decreases, too. If population F decreases, population H decreases. Food is the main reason, I have to point out. [interview]

I: Write down the letter indicating populations through which the effect of an increase in population A is passed on to population J. Explain your answer.

E2: First of all, population A is the producer. If we call population B a rabbit and population C a mouse, who eats a mouse? Fox population (K) eats mice. Who eats rabbits? Eagle eats the rabbit. If the number of rabbits is high, the number of eagles increases. Eagle eats the mouse and the fox population (K) number increase. [interview]

I: What effect will a sudden increase in population B have on population J? Explain your answer.

E2: What is population B? Population B is the rabbit population. There occurs a decrease in the mouse population (C). If the mouse population (C) decreases, the eagle population (J) cannot find Food. If rabbit population (B) is high in number, eagle population (K) increases in number. As rabbit population (B) increases, this causes fox population (J) to decrease. [interview]

The questions were targeted to elicit Expert 2's knowledge to determine "the effect of a sudden size change in a prey population on its predator population" (Webb &

Bolt, 1990). Expert 2 seemed to have knowledge on the relationships of populations identified as prey and predator. He identified “all possible pathways through which the effect of a change in one population is transmitted to a second” and “to determine the effect of a sudden size change in one population on a second non-adjacent population located higher on the same food chain where the effect is transmitted along one than one route” (Webb & Bolt, 1990). The responses of Expert 2 revealed that he had the conception of a change in size of a prey population affect its predator population. He provided scientifically correct response that indicate his knowledge on the relation between organisms who are prey population and the other predator population. He explained the relation of populations according to feeding relations. He could identify the roles of trophic levels in food web like population A is the producer.

Group4. 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(Griffiths & Grant, 1985).

I: What effect will a sudden increase in population G have on population F? Explain your answer.

*E2: A is the producer. The grasshopper population (E) is eaten by the partridge population (F), and the grasshopper population (E) is also eaten by the pheasant population (G). As the pheasant population (G) increases, this causes the grasshopper population (E) to decrease. As the pheasant population (G) is high in number and the partridge population (F) is low in number, this affects the eagle population (H).
[interview]*

I: What effect will a sudden increase in population I have on the size of population K? Explain your answer.

E2: If population I increase, let's call I population a lion. Then, population D decreased. Let's call population D as buffalo. If buffalo decrease, the grass population that is A population will increase. The grass population is consumed by the rabbit population (B). The rabbit population is consumed by eagles. Therefore, the eagle population is influenced by this increase positively. If population I decrease, then buffalo population (D) will increase; rabbit population (B) will decrease; eagle population (K) will decrease; and fox population (I) will decrease. [interview]

The above food web questions targeted to understand Expert 2's knowledge "to determine the effect of a sudden size change in one population on a second population not located on the same food chain, when the effect may be transmitted along one than one route" (Webb & Bolt, 1990). In that respect, Expert 2 seemed to identify the "effect of a sudden size change in one population on a second population which is not on the same food chain, when the effect may be transmitted along more than one route." (Webb & Bolt, 1990). He interpreted correctly that the size change of one population in the food web does not correspond to the change in the other populations of the food web in the same way.

Briefly, Expert 2 explained food web questions referring to the organisms' feeding relations. That is, he did not mention the energy transfer between organisms in the food web. Although he confused the interactions of populations while determining the size change when the other populations altered, he could identify both the prey and predator populations in the food web and the proper size change effects on populations in general. Hence, he seemed to have an understanding of the complex relations of populations in the food web. In fact, he could explain the effects of multiple pathways transmitted in different routes. It was seen in his responses in explaining the questions regarding the sample food web (Webb & Bolt, 1990) that

he could state the roles of trophic levels in which he provided population examples to each of the letters representing a population.

4.4.2.2.3 Expert 2's Subject Matter Knowledge on Energy Pyramid

In Figure 4.15, Expert 2's concept map was found to be inadequate for depicting the energy pyramid. As a result, interviews, examples, drawings, and their interpretations were used to capture Expert 2's understanding of the subject matter. To begin with, he sought clarification on the definition of the energy pyramid.

I: What is the energy pyramid?

E2: It was a figure illustrated that the level of energy decreases to the upper levels. [interview]

I: Can you draw an energy pyramid?

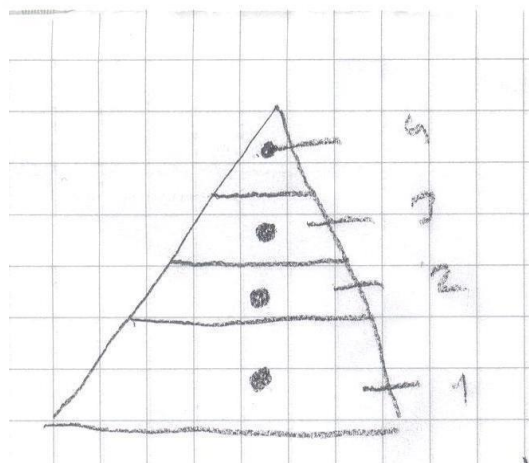


Figure 4.18 Expert 2's Energy Pyramid Drawing (see Appendix E for original drawing)

E2: To the upper levels of the energy pyramid, the level of energy decreases. The bottom of the energy pyramid is large. There are producers at this level [bottom]. Then, herbivores that feed on producers are the second level of the energy pyramid. The omnivores are the third level [of the pyramid], and at the top of the energy pyramid, the carnivores are placed.

Decomposers are at each level of the energy pyramid. It is not true to say that decomposers are in a separate place. Every organism dies at a certain time. At this time, decomposers decompose their deaths. [interview]

I: Why is the pyramid of energy pyramid in shape?

E2: The reason is that the number of organisms decreases to the upper levels. Carnivores are rarely seen in ecosystems. Therefore, their [carnivores'] numbers are low. [interview]

I: Does the energy pyramid represent something?

E2: It [energy pyramid] represents the volume. That is, it [energy pyramid] shows that the volume of populations is narrowed to the upper levels. The figure of the energy pyramid represents the number of organisms. [interview]

Expert 2 defined the energy pyramid in relation to energy flow between organisms. Although he mentioned energy decreases from producers to consumers at each level, he did not specify the amount of energy transferred to the upper levels. He seemed to provide a scientifically correct explanation of the energy pyramid with trophic levels as producers, consumers, and decomposers. However, he wrote neither the trophic levels nor the decomposers in his concept map drawing (Figure 4.15).

Although he did not place decomposers in his energy pyramid drawing, he stated that decomposers operated at each trophic level of the energy pyramid with the explanation that every organism dies and decomposers have the role of decomposing their deaths. He identified the feeding types of consumers as herbivores, omnivores, and carnivores, stating their trophic levels in the energy pyramid. In another response, Expert 2 explained the shape of the energy pyramid with the number of organisms at each trophic level. In fact, he did not associate the energy pyramid with the 2nd law of thermodynamics.

Overall findings of Expert 2 regarding SMK on ecology revealed that he has limited knowledge of basic ecological concepts and principles such as ecosystem, species, extinction-prone species, habitat, population, community, producers, consumers, decomposers, biological diversity, food chain, food web, energy pyramid, energy flow in ecosystems and photosynthesis. He was likely not to have knowledge of ecological niches, so he did not provide any definition. Although he drew his food chain with the concepts of biology and ecosystem examples, he explained the relations of the ecosystem with species, population, living and non-living things, producers, consumers, and biological diversity in interviews. Moreover, he found to have misconceptions regarding decomposers.

This section documented Expert 2's SMK on ecology. In the next section, PCK of Expert 2 with the components presented.

4.4.3 Expert 2's Pedagogical Content Knowledge on Ecology

Expert 2's pedagogical content knowledge (PCK) was documented in the light of Magnusson et al. (1999) model of PCK in terms of four components. These components are knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies and knowledge of assessment. Expert

2's PCK was revealed through pre-interviews, post-interviews, and classroom observations. In the present study, the findings related to knowledge of curriculum were collected in 2010.

4.4.3.1 Expert 2's Knowledge of Curriculum

Knowledge of curriculum is one of the components of PCK, referring to teachers' knowledge of the goals and objectives of the subject and specific curricular programs and materials (Grossman, 1990; Magnusson, 1999). Goals and objectives include the knowledge of teachers regarding vertical and horizontal curricula outlined within the national documents. Teachers' knowledge of curriculum programs and materials, on the other hand, consists of knowledge of programs, activities, and materials offered for a specific topic. To get the advantage of the spiral nature of the science curriculum and to gain a deep understanding of science teachers' PCK on ecology, science teachers were analyzed while teaching the 8th-grade ecology unit in the study. In the present study, the findings related to knowledge of curriculum were collected in 2010. Therefore, Expert 2's knowledge of curriculum findings was analyzed in line with the prescribed ecology curriculum in 2009 by the Türkiye Ministry of National Education (MoNE).

Two constituted components of knowledge of curriculum, which are knowledge of goals and objectives and knowledge of materials, were presented in this section under two separate sections. In the first section, Expert 2's knowledge of the goals and objectives of ecology was presented.

4.4.3.1.1 Expert 2's Knowledge of Goals and Objectives

According to the Türkiye national science curriculum (2009), ecology units first appeared in 4th grade as the 2nd unit under the heading of "world of life." The

specified objectives in the 4th-grade level were “as a result of the observations; students provide daily life examples to living and non-living things”, “living and non-living things decided through questioning”, “discovering that there are different types of habitats around”, “predicting the living things that can be found in a living space.”, and “observing and recording living things in a living space around.” Moreover, in the 5th grade, ecology was included in the 6th unit named “Identifying the world of life and natural life in our country and in the world”. The objectives of the 5th-grade ecology unit were “As a result of the observations; students give examples of various living things living in their surroundings.”, “providing examples of living and non-living things unique to their country”, “comparing the similarities and differences in the nutrition of living things in a habitat students observe.”, “constructing a sample food chain illustrating feeding relations of the organism”, “discussing the consequences that may arise with the disappearance of a link in the food chain.” And “searching for endangered species and creating projects to protect these species”. In the 6th grade level, there was not included a unit related to ecology. In the 7th grade level, in the 6th

unit of “organisms and life” consists of ecology objectives which “explains the concepts of species, habitat, population and ecosystem and the relations of these concepts.”, “explains the relations of living organisms with each other and non-living factors in an ecosystem, defines food chain and food web, and gives examples.”, “make predictions about living things that can be found in different ecosystems (lake, sea, forest, etc.),” “recognize and emphasize the importance of biodiversity in the ecosystem.”, “give examples of extinction-prone species in the country and in the world.” And “Offer suggestions to protect extinction-prone species.”

In the current study, Expert 2 was interviewed, asked to create a lesson plan and observed later while teaching ecology to 8th graders. The curricular objectives prescribed by MoNE and related findings of Expert 2 were presented in Table 4.29.

Table 4.29 Expert 2's Knowledge of Goals and Objectives regarding G-8 ecology objectives in the Science and Technology Curriculum (MoNE, 2009)

Unit	Interviews	Classroom observations
6: Living things and energy relations		
Content: Food chains		
1. Related to organisms in the food chains, students are able to;	Not mentioned	Not mentioned
1.1. Infer those producers are at the beginning of food chains.		
1.2. List what is required for photosynthesis.	Not mentioned	T: If we examine the general equation of photosynthesis, the carbon dioxide taken from the air and the water in the leaves are taken, and the carbon atoms in the carbon dioxide are transferred into the glucose, that is, the food.
1.3. Observe the necessity of light in photosynthesis by experimenting.	Not mentioned	T: Yes, now let's get to know the materials that go into and out of photosynthesis... Yes, we start with the light factor...
1.4. State that producers produce simple sugars and oxygen by photosynthesis.	Not mentioned	T: The plant produces glucose as a result of photosynthesis and stores this glucose in the form of starch in the leaf. T: yes, now we will see proof of oxygen output in photosynthesis... In this case, we have proven the oxygen output in photosynthesis, as a result, the plant produces oxygen as a result of photosynthesis.
1.5. Express photosynthesis with an equation.	Not mentioned	T: yes, when we look at the general equation of photosynthesis, it starts with the synthesis of carbon dioxide plus water in chlorophyll and produce glucose and oxygen.
1.6. Discuss the importance of photosynthesis for living things.	Not mentioned	Not mentioned
1.7. State that producers convert solar energy into usable energy by photosynthesis.	Not mentioned	Not mentioned

Table 4.29 Cont'd

Unit	Interviews	Classroom observations
1.8. Explain that living things need energy to survive.	Not mentioned	T: ...Well, as a result of this respiration, we give carbon dioxide, we give water vapor and we get energy, where do we use the energy we get, we use it in movement.
1.9. Explains that consumers in the food chain meet their energy needs from producers.	Not mentioned	Not mentioned
1.10. Discuss the importance of respiration for living things.	Not mentioned	T: Respiration is a common feature of living things, listen please, living things cannot stay without breathing.
1.11. Define respiration.	Not mentioned	Aerobic respiration is the breakdown of nutrients in an aerobic environment.
1.12. Lists what is required for respiration	Not mentioned	T: Food plus oxygen turns into carbon dioxide plus water plus heat and the place where this event takes place is microscopic...
1.13. Indicate the products formed as a result of respiration with oxygen by experimenting.	Not mentioned	Not mentioned
1.14. Estimate the equation of aerobic respiration as a result of his/her observations.	Not mentioned	Not mentioned
1.15. Explain that some living things provide the necessary energy to survive without using oxygen.	Not mentioned	Not mentioned
1.16. Gives examples of anaerobic respiration from daily life.	Not mentioned	T: Let's remember anaerobic respiration, where products such as glucose, ethyl alcohol and lactic acid were added.
1.17. Establish a relationship by comparing the aerobic respiration equation with the photosynthesis equation.	Not mentioned	T: ...both events have a common aspect in aerobic respiration. In both cases, enzymes are used.

Table 4.29 Cont'd

Unit	Interviews	Classroom observations
1.18. Explain the relationship between producers and consumers in terms of nutrition and energy flow.	In general, the objectives are related with introducing students the different ecosystems, organisms living in these ecosystems, relationships of organisms and the organisms' feeding relations.	Not mentioned
1.19. Explains the material cycles in parallel with the energy flow in the food chain.		Not mentioned

Overall findings revealed Expert 2's knowledge of the goals and objectives of the ecology curriculum, except for food chain and material cycles. For example, the interviews and classroom observations documented that he could identify the objectives regarding photosynthesis and respiration (Table 4.29). Expert 2 was found to be well-informed about the curricular objectives and purposes of photosynthesis and respiration. However, he did not mention the curricular goals and objectives related to the food chain and material cycles. He seemed to have difficulties in the place of ecology in the 8th-grade curriculum. In the interviews, he could not state the ecology-related topic. According to MoNE (2009), ecology units were included in the 4th, 5th, 7th, and 8th grade levels. He was likely to have awareness where the ecology taught in previous grades, indicating his knowledge in vertical relationships. Expert 2 asked about the place of ecology in the elementary school curriculum program during interviews.

I: Do you know the place of ecology in science curricular programs?

E2: Well, ecology is taught in 6th, 7th, and 8th grades. Biological concepts are taught very briefly in 6th grade, so all introductory topics are in 7th grade. In fact, in 7th grade, there are few ecological concepts in the curriculum. There is only one unit related to ecology. In my opinion, science should be taught separately from physics, chemistry, and biology. In this way, allocating four hours for each of the subject areas will be more efficient. Now, twenty-two hours are allocated to the ecology unit in the curriculum. Why this is the case? I do not know. Maybe, biological concepts are perceived easier, or they are not given more importance compared to other subjects. The ecological concepts are also the last units of the curriculum. As students enter the SBS [High School Entrance Exam in Türkiye] at the end of the second semester, students do not come to school anymore. Therefore, I do not believe that biological concepts are taught effectively in schools. If biological units were allocated three or four hours a week, they would be taught in detail and efficiently. [pre-interview]

I: In 8th grade, in which unit is ecology taught?

E2: In 8th grade, ecological concepts are taught at the end of the semester. There is one more unit after the ecology unit related to space. [pre-interview]

Expert 2 stated that ecology is taught in 6th, 7th, and 8th grades and that he ignored the grades in 4th and 5th. He also did not express the place of ecology at the 8th-grade level. Although Expert 2's responses related to the grade levels ecology taught remained uncertain, he knew the place of ecology in previous grades, indicating his knowledge of vertical relations of ecology. He stated the following contents

indicating his knowledge of horizontal relationships. Expert 2 also asked about the purpose of ecology in the curricular program and the appropriateness of the curricular program in terms of skills and class levels.

I: What is the specified purpose of the ecology in the program?

E2: It is important to define ecology first. That is, we called ecology as being aware of living and non-living things in science lessons. If the balance is damaged, this relationship will also be damaged, too. As I said before, if human beings do not interfere with nature, the natural balance will continue and sustain. In this way, living and non-living things will also sustain their relationship. I have witnessed the situation that no one of the species wants another species to disappear. All these purposes are included in the curriculum. However, the curriculum developers deciding on these purposes must be the individuals who experience ecological issues within the ecosystems; they should be the ones who are aware of the environment. In this way, educational purposes can be more efficient and possible to achieve in classrooms. The ecology unit in 8th grade is the last unit of the curriculum. As the SBS [High School Entrance Exam in Türkiye] exam got closer, students started to not come to school during this time. Therefore, we cannot teach this unit each year effectively. For this reason, I cannot remember the objectives of the ecology unit exactly. In general, the objectives are related to introducing students to the kinds of ecosystems, organisms living in these ecosystems, relationships of organisms, and the organisms' feeding relations. [pre-interview]

Consistent with the interview responses, Expert 2 observed in the lesson that he made his students watch an informative video about the 8th-grade ecology objectives related to photosynthesis and respiration (Table 4.29). Although he observed that he strictly followed the prescribed curriculum, he seemed to ignore the curricular objectives regarding food chain and matter cycles in classroom observations. In fact, the specified purpose of ecology in the 8th-grade curriculum was “In this unit, students are aimed to understand photosynthesis, respiration, energy transformations, to explain the food chain and the elements that make up this chain, to discover the relationship between the elements, to realize the material cycles in life-related to environmental science, to know environmental problems and to offer solutions to environmental problems, to gain interest and skills in these.” (MoNE, 2009). Expert 2 neither stated the purpose of the ecology unit consistent with the prescribed curricular program nor observed to teach students the food chain and material cycles specified in the curricular purpose prescribed by MoNE (2009). Expert 2 stated that ecology objectives were suitable for the class levels and the skills that were aimed to be achieved; however, he believed that the learning environment school’s laboratory did not have the necessary facilities and materials.

The next part documented Expert 2’s knowledge of materials which is another sub-component of knowledge of the curriculum of PCK.

4.4.3.1.2 Expert 2’s Knowledge of Materials

Expert 2 either used or mentioned tutorials, documentaries and experimental materials for ecology teaching. In fact, he observed in his ecology lesson to use tutorials. The Table 4.30 presented the Expert 2’s knowledge of materials mentioned in pre-interviews and observed in his ecology lessons.

Table 4.30 Expert 2's Knowledge of Materials

Materials used	Interview questions	Classroom observations
Textbook, workbook and cram book	<i>textbook, workbook... although it is not allowed, the cram books...[pre-interview]</i>	Not mentioned
Instructional videos	<i>I have used instructional videos and documentaries. I have made experiments. Therefore, I used the materials of these experiments. [pre-interview]</i>	Expert 2 observed to use instructional videos in his lessons.
Experiment materials	<i>I have used instructional videos and documentaries. I have made experiments. Therefore, I used the materials of these experiments. [pre-interview]</i>	Not mentioned

Expert 2 asked a sequence of questions to gain insight into his knowledge of materials before classroom observations. The related pre-interview excerpts are provided below.

I: What kinds of materials do you use for ecology teaching?

E2: I have used instructional videos and documentaries. I have done experiments. Therefore, I used the materials for these experiments. [pre-interview]

I: What else do you use in your ecology lessons?

E2: Well, textbook, workbook... although it is not allowed to use [in public schools in Türkiye], the cram books... [pre-interview]

I: So, what was your aim to use these materials?

E2: Hmmm... Students need to learn biological issues by doing themselves. Therefore, I teach in the science laboratory, I do experiments, in general, to make the concepts more concrete. In addition, I use tutorials and documentaries for the same reasons.
[pre-interview]

Expert 2 stated that he used instructional videos, documentaries and experimental materials. He believed that students learn ecology when they actively engage with the learning materials. Therefore, he preferred experimental and visual materials to enable students.

Consistent with the pre-interviews, he observed that he conducted his lessons in the science laboratory. For the ecology lesson in 8th grade, he used instructional videos related to photosynthesis and respiration.

To understand her views and purposes to use the materials in his lessons, he was asked further questions after classroom observations.

I: Well, you taught in the form of watching tutorials I observed in which you asked questions on some points. Do you usually teach your lessons in this way?

E2: Now, if the lesson is related to mathematics, for example, this is not the case. So it is not appropriate to use videos and experiments. Mathematical subjects are explained, and their problems are needed to be solved. For example, there is a velocity content [in science], you can do their experiments, and you solve the related problems because you practice the same problem, thereby experimenting. Nevertheless, if it necessitates visuals, like biology, for example, if there is no need

for pen and paper, you prefer the visual materials or you just only explain the content. In one of my lessons, one day, the weather rained, and the students were shouting like crazy; they ran out, they went out to the school garden, and they saw the rainbow; I said, let's count the colours inside the rainbow. Therefore, these are important things to make students experience. [post-interview]

To conclude, Expert 2 was likely to have knowledge of vertical and horizontal relations; however had difficulties in the place of ecology curriculum and objectives. Regarding knowledge of materials, he preferred to use textbooks, workbooks and cram books and also instructional videos and experimental materials. Although he was not observed to conduct an experiment by using experimental materials, he was observed to use tutorials to teach photosynthesis and respiration. In this section Expert 2's knowledge of curriculum with the sub-sections presented, the next section documented Expert 2's knowledge of students' understanding of science.

4.4.3.2 Expert 2's Knowledge of Students' Understanding of Science

Expert 2's knowledge of science learners is documented in two sub-components which were knowledge of requirements for learning and knowledge of students' difficulty regarding ecology. Expert 2's knowledge on considering students' developmental levels, learning styles and abilities and Expert 2's beliefs about students' prior knowledge are presented in the sub-section of Expert 2's knowledge of requirements for learning regarding ecology. Expert 2's knowledge of students' difficulty ecology sub-section was about knowledge of students' difficulties regarding ecology including students' difficulties, errors and misconceptions.

4.4.3.2.1 Expert 2's knowledge of requirements for learning regarding ecology

Expert 2 stated that students required to relate the subject matter to their daily life, need to be interested in the subject and have prior knowledge to learn ecology. The students' interest in the subject matter was pointed out by Expert 2. Therefore, he stated that he provided students with daily life examples to draw their attention to enhance their learning in ecology. Table 4.31 presented Expert 2's knowledge of requirements for learning regarding ecology.

Table 4.31 Expert 2's Knowledge of Requirements for Learning Ecology

Requirements for learning ecology	Interviews	Classroom Observation
Relating with daily life	In order to know how bread produced, students should first recognize how the flour is produced..., students should know how seeds are germinated.. After germination, plant will start to photosynthesize. [pre-interview]	T(teacher): carbon in carbon dioxide... for example, sugar, honey... Look, all sweet has carbon.
Prior knowledge	Not mentioned	T: you learned about photosynthesis; it takes place in the chloroplast organelle.
Student's interest	I provided plenty of examples to students to take their attention to increase their interest. [pre-interview]	T: I will give a simple example right away: if your father, brother, uncle, or someone from your family has a hobby such as fishing, ask them that

I: What are your goals and purposes in teaching ecology?

E2: First of all, students should be aware of the sources of energy. The source of energy is the sun which fuses hydrogen into helium. According to the law of conservation of energy, all kinds of energy are transformed. Sun's energy is first taken by producers. Then, herbivores that feed on green plants take this energy. In the next level [in the energy pyramid], there are carnivores. The energy lessens to the upper levels level [in the energy pyramid] as energy is transformed. Some of the organisms eat vegetables only; some of them eat meat; some eat both vegetables and meat. Students should learn all these.

In order to know how bread is produced, first, students should recognize how the flour is produced; to recognize the production of flour, students should know how wheat is cultivated. In order to learn all of these processes, students should know how seeds are germinated. To germinate a seed, students should be aware of how to supply plants with the necessary heat, moisture, and whatsoever. After germination, the plant will start to photosynthesize. Then, at this point, students should be aware of the importance of sunlight, and water. [pre-interview]

I: In ecology teaching, what do you think about students' requirements?

E2: Every student has an interest in some of the concepts in science. When their interesting concepts are taught, they attend lessons willingly. Therefore, I believe that students should improve themselves in the area that they [students] have more interest in. I

provided plenty of examples to students to take their attention to increase their interest. [pre-interview]

Expert 2 pointed out the students' interest as the requirement to learn ecology in pre-interviews. In order to enhance students' interest, he mentioned serving several daily life examples. Moreover, Expert 2 mentioned students need to learn ecology to understand the importance of energy, and the events that occur in the ecosystem, like photosynthesis, cultivation of wheat, and germination of seeds. That is, Expert 2 seemed to explain students' requirements to learn ecology to be aware of their environment. In other words, he implied the importance of relating ecology to their daily life. In fact, in the classroom observations consistent with the pre-interview responses of Expert 2, he provided several daily life examples to students to foster their understanding. The following classroom observation excerpts revealed the related daily life examples Expert 2 provided.

T: Carbon in carbon dioxide... for example, sugar, honey, look, all sweet has carbon.

T: As we said in photosynthesis, we just said that living things make food and store it, and we said that it [food] is used in its [living things'] development in some parts; think of a sacrificial animal. When you buy it, you feed it because it [sacrificial animal] is weak. Is it true? What the animal is doing: it [animal] is constantly getting bigger and bigger: increase in volume and weight. How will it [sacrificial animal] increase in weight? Because it [sacrificial animal] will eat the food, it [sacrificial animal] has increased its weight in a period of time.

T: I will give a simple example right away: if your father, brother, uncle, or someone from your family has a hobby such as fishing, ask them that: there is plenty of algae in the ponds, especially in dams. These algae

have no roots attached to the soil. They [algae] are in motion in the water... the fish here, of course, do not stay out of the water, that is, they are 20 cm or 30 cm below the water surface, and the fish stand on these algae, that is, they [fishes] are not standing on the algae when they [fishes] are tired, but the reason why the algae choose to live among them [around the algae] is oxygen. In other words, it is the reason for getting the oxygen dissolved in water. That is, green plants do photosynthesis. While doing photosynthesis, thanks to those fishes, they provide the carbon dioxide inside the water, and the algae use the sunlight; they [algae] give off oxygen, and the fish benefit from this event; I have given you the example here in this way.

[classroom observation]

Apart from students' interest, although he did not mention the prior knowledge of students during pre-interviews, he recalled students' prior knowledge in his ecology lessons. As he used tutorials, at some points when students watched the instructional video he gave related explanations to the students. He reminded students of past learnings during these points. The related explanations of Expert 2 from classroom observation are provided below.

T: Again, you learned about photosynthesis; it takes place in the chloroplast organelle.

T: Mitochondria are one of the living organelles found in the cytoplasm. It has a double-layered membrane and is filled with a special liquid, and is an energy furnace. That is where the energy is produced, and this is very important I need to point out.

T: Well, [in aerobic respiration] our nutrient is broken down into carbon dioxide and water. That is, it [glucose] breaks down from inorganic substances. But let's remember anaerobic respiration, where products such as glucose turn out into ethyl alcohol and lactic acid...

[classroom observation]

To summarize, Expert 2 explained students' requirements to be interested in ecology and their prior knowledge to learn ecology. Regarding students' prior knowledge, Expert 2 was found to express photosynthesis and anaerobic respiration. He ignored the other ecological concepts like species, population, habitat, and biological diversity. Moreover, photosynthesis was the objective students expected to learn at the 8th-grade level. He seemed to exceed the curricular objectives in which he appeared to teach photosynthesis to the students in the previous year when they were at the 7th-grade level. He mentioned the importance of facilitating the learning environment to students according to their learning style, like watching documentaries, field trips, and observations.

Expert 2's knowledge of students' difficulties regarding ecology is presented in the next section.

4.4.3.2.2 Expert 2's Knowledge of Students' Difficulties Regarding Ecology

This section elicited Expert 2's knowledge of students' difficulties regarding ecology. Pre- and post-interviews and classroom observations were the data sources to unveil Expert 2's knowledge of students' difficulties regarding ecology.

Related to Expert 2's knowledge of students' misconceptions and learning difficulties, the findings showed that he perceived students to have few learning

difficulties and misconceptions in ecology. He simply mentioned students have learning difficulties in exemplifying organisms like certain animals and the concept of habitat. He stated that students learn the food chain and food web easily. He did not provide much about both some of the methods to detect misconceptions and the methods to remedy students' misconceptions. Table 4.32 presented Expert 2's knowledge of students' difficulties regarding ecology.

Table 4.32 Expert 2's Knowledge of Students' Difficulties Regarding Ecology

Interviews		Classroom Observation	
Learning Difficulties	Elimination Methods	Learning Difficulties	Elimination Methods
Exemplifying organisms	Laboratory	Not mentioned	Not mentioned
	activities and	Not mentioned	Not mentioned
	experiments	Not mentioned	Not mentioned
	Watching documentaries	Not mentioned	Not mentioned
Misconceptions	Elimination Methods	Misconceptions	Elimination Methods
Habitat	Questioning	Not mentioned	Not mentioned
	Lecturing videos		
	Documentaries		

I: Do your students have difficulty understanding ecological concepts?

E2: There were seven questions in SBS [High School Entrance Exam in Türkiye] related to ecological concepts last year. My students answered all of these questions correctly. I think they do not have difficulty understanding ecological concepts. However, if we do not

have the necessary materials in the laboratory, and if I cannot bring them [necessary materials] to the lessons, we [teachers] can perform forty per cent of the activities and experiments present in the science curriculum. I wish to increase this percentage to seventy per cent. However, the equipment and facilities of our school are limited, unfortunately... [pre-interview]

I: I see your students are well in ecology, although you have limited equipment and facilities in your school. What are the ecological concepts that students experience more difficulty with, then?

E2: Sometimes, students have difficulty with some ecological concepts, especially girls. I think this results from our culture. Girls do not have self-confidence. For instance, I asked students to give examples of birds. They [students] could not give. On the other hand, students experiencing village life answer these kinds of questions with enthusiasm. Today, most of the students are not aware of the animals. They [students] do not know whether hedgehogs reproduce by laying eggs or giving birth. Even some science teachers do not know these issues, too. [pre-interview]

I: What are the concepts that students learn easily?

E2: Students watching documentaries participate in the lessons regarding ecology enthusiastically. Students can learn better by observing, doing, and experiencing. Therefore, learning changes from student to student. However, in general, they easily learn the concepts of the food chain and the food web. They cannot observe the animals living in Africa if they have not visited the zoo. Therefore,

documentaries are important sources for ecology teaching. [pre-interview]

Although Expert 2 did not provide specific examples of students' difficulties in ecology, he provided specific concepts students learn easily, which were the food chain and the food web. He might underestimate students' difficulties in ecology. As the findings were gathered through interviews and classroom observation and he led to the whole lessons, the findings regarding students' difficulties were restricted to what Expert 2 provided. He also asked about the misconception.

I: What is a misconception?

E2: In my opinion, it has inaccurate information. As there is noise pollution, there is also information pollution. If the concepts are not used suitably, this causes concept confusion. For example, in our school, one of the teachers asked if there is a "direct [degree]." This is a misconception. There is nothing called a "derece [degree]." Teachers do not have any idea about Erlenmeyer flasks, beakers, and so on, for instance. If I do not have any idea about a concept, I admit students as I do not know this concept. Then, I search for the concept, and I share my findings with students. [pre-interview]

I: What are the main misconceptions students possess you detected in ecological concepts?

E2: Of course, there are misconceptions regarding ecology. In fact, students have ten per cent knowledge regarding ecology. The students who live in rural areas are lucky regarding ecological issues. They can experience things related to ecology. Students do not know how to use simple machines. This is a misconception. When I talk about

birds if I say chicken, goose, or turkey, they comprehend. On the other hand, if I talk about finches, they do not know. This is a misconception. Not having any idea about a concept is not a misconception, even though giving an irrelevant interpretation of a concept is a misconception.

They have misconceptions regarding ecology, especially about the concepts of habitat. For instance, I asked students why sheep and goats climb hills to find food. They answered that the grasses are more delicious in the hills. On the other hand, the reason is protection. This behaviour is related to their instinct. The hills are their habitat. Students have misconceptions related to this [habitat] concept. [pre-interview]

I: Okay, how do you understand that if your students have misconceptions?

E2: The student should be able to tell what s/he thinks. It is necessary to give importance to her/his thoughts and listen to her/him. You should listen, and you should not criticize while listening as s/he is either right or wrong... you will listen, the truth emerges in these conversations, the student will notice the missing point with a smile... s/he even comes and tells me during the break. In such a case, the child should be guided to the related reading books, watching documentaries, and so on. [pre-interview]

I: Okay, then, do students' misconceptions influence your teaching?

E2: Of course, students' misconceptions influence my teaching. There are instructional videos I use to remedy students' misconceptions. [pre-interview]

I: Well, what else do you use to remedy students' misconceptions in ecology?

E2: Questioning and making students give interpretations about the concepts can be helpful in overcoming students' misconceptions. Related to ecology, instructional videos and documentaries are effective in remedying misconceptions. [pre-interview]

I: What are the sources of misconceptions, then?

E2: The misconceptions result from not being able to define the concepts properly, not being able to observe the issues, and not being able to comprehend them. Using local words may also cause misconceptions. Also, teachers may cause misconceptions. For example, there are teachers dividing organisms into three groups which are animals, plants, and human beings. These kinds of teachers may be the source of misconceptions. [pre-interview]

Expert 2 defined misconception as mostly inaccurate information. He emphasized irrelevant interpretations of a concept about the misconceptions. Apart from defining what the misconception is, he detected students' misconceptions about ecology. For example, he stated that students have misconceptions about habitat. The sources of the misconceptions were the local language of people and teachers. However, he mentioned neither questioning nor concept maps, quizzes, discussions, or short tests to detect students' misconceptions. In pre-interviews, he mentioned preferring questioning, lecturing videos, and documentaries to remedy students'

misconceptions. However, the conceptual change approach, analogy, and conceptual change texts were not mentioned as the methods for misconceptions to eliminate.

As he was observed in the classroom observations, he seemed to use lecturing, questioning, and tutorial videos for his ecology lessons. In addition, Expert 2 asked a few questions to the students related to ecological content. He directed some of the questions which were in the tutorial. Students gave short and right answers to these questions Expert 2 underlined the right answers after their responses. Therefore, in the lesson, there were not observed no misconceptions regarding ecology.

In the next section, Expert 2's knowledge of instructional strategies presented.

4.4.3.3 Expert 2's Knowledge of Instructional Strategies

Expert 1's knowledge of instructional strategies was documented in two parts. In the first part, Expert 2's subject-specific strategies; in the second part Expert 2's topic-specific strategies were presented. Expert 2's knowledge of instructional strategies was gathered through pre- and post-interviews and classroom observations.

4.4.3.3.1 Expert 2' Knowledge of Subject Specific Strategies

The findings regarding Expert 2's subject-specific strategies revealed that Expert 2 was likely to use direct teaching and questioning in general. He stated that he did experiments as a demonstration in his science lessons and field trips that were not observed. Table 4.33 presents Expert 2's knowledge of subject-specific strategies.

Table 4.33 Expert 2's Knowledge of Subject Specific Strategies

Subject specific strategies	Interviews	Classroom Observation
Direct teaching	Now, if the lesson is about mathematics, for example, it cannot be done with videos, there can be done experimentation, this subject is taught by lecturing. [post-interview]	He was observed to use direct teaching and questioning in the line with instructional video watched in TV.
Questioning	I generally use questioning in my lessons. [pre-interview]	
Demonstrations	We can make experiments as demonstration. [pre-interview]	Not mentioned
Field trips	One day, in the middle of the lesson, I said, let's get up, we're going to the zoo. [pre-interview]	Not mentioned

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

E2: Now look, the best method is this, in my opinion: first, the child will read this subject and come to the lesson. Then you will consider the child, you will act the child as a man, and you will talk to the child, so if you can make the child talk, too, then you can achieve success as a teacher. One day, in the middle of the lesson, I said, let's get up; we're going to the zoo. We went out; we walked to the zoo from here [school], then we arrived. We went in, here's what we told you [in the interviews] animals, plants, ecosystem and so on... I took him to visit Mustafa Kemal's house. At half past 3, the lesson was over, and we came back [to school]. Now the children said: 'My teacher, there is no such beauty. No one is like you... I asked the children, and they said that it was the first time in their lives, they had gone to the zoo. But there were also those who went with their mother and father

before. But there are those who come for the first time... aaa... there are also those who say: 'Teacher, is this a giraffe'... [pre-interview]

I: Apart from these instructional strategies, which types of instructional strategies do you think of using? What kinds of teaching strategies can be used for ecology?

E2: The best teaching method for ecology concepts is to teach these concepts within the environment. There is a television in our laboratory. So, we can watch documentaries, and instructional videos related to ecology. Apart from this, we can make experiments as demonstrations. I generally use questioning in my lessons. [pre-interview]

The interviews and classroom observation findings revealed that Expert 2 seemed to have knowledge of student-centred approaches like field trips, and demonstrations. However, he used teacher-centered methods in his lessons. He said to use questioning and observing in his lesson consistently. The related classroom observation notes are provided below.

T: Plants do not prevent a leaf from receiving sunlight from another leaf. If you look at the tree's leaves, no matter how many leaves are on the tree, they all turn towards the sun. This is a startling event and no leaf covers the other leaf. That's why your mothers, or those who have knowledge on this subject, know that... for example, if they are going to plant, they must plant it in an open field. So, if you plant cucumbers at the bottom of the trees in a wooded garden, what will the crop be like?

S(students)1: It [the crop] will not develop. [classroom observation]

The next subsection focused on Expert 2's topic-specific strategies in two subcomponents: knowledge of representations and knowledge of activities.

4.4.3.3.2 Expert 2's Knowledge of Topic Specific Strategies

This section documents knowledge of topic-specific strategies including representations and activities.

4.4.3.3.2.1 Expert 2's Knowledge of Representations

The pre-interviews and classroom observations were the sources to reveal Expert 2's knowledge of representations. Expert 2 was likely to use daily life examples and comparisons, analogies in his ecology lessons to enhance students' understanding. Table 4.34 presents Expert 2's knowledge of representations.

Table 4.34 Expert 2's Knowledge of Representations

Knowledge of Representations	Interviews	Classroom Observation
Daily life examples	I definitely use these examples in my lesson. [pre-interview]	T: Plants do not prevent a leaf from receiving sunlight from another leaf. If you look at the tree leaves, no matter how many leaves are on the tree, they all turn towards the sun. This is a startle event and no leaf covers the other leaf. that's why your mothers, or those who have knowledge on this subject, know that... So if you plant cucumbers at the bottom of the trees in a wooded garden, what will the crop be like? S(students)1: It [the crop] will not develop. T: Now, the euglena is at the forefront of single-celled organisms that can show both plant and animal characteristics. It is likened to an animal cell due to the appearance of its camper and eye spot, and to a plant cell because it contains chloroplasts. Similarly, there are the ladies who are knitting something, what was her name.... similar expression is used. Apart from blue green algae, bacteria can also photosynthesize.
Comparisons, analogies	Not mentioned	

I: What are the representations you provide in your ecology lessons?

E2: I used examples... Of course, the student will find the truth herself, if you tell something about yourself from daily life, the child will raise her hand and share. [pre-interview]

I: How do these examples influence your lessons?

E2: They [examples] definitely affect this lesson positively. I definitely use these examples in my lesson. [pre-interview]

Related to the representations, Expert 2 used daily life examples that he believed these examples affected his lessons positively. Consistent with his pre-interview responses, Expert 2 used several daily life examples in his lessons that are presented below.

T: Plants do not prevent a leaf from receiving sunlight from another leaf. If you look at the tree leaves, no matter how many leaves are on the tree, they all turn towards the sun. This is a startling event. And no leaf covers the other leaf. That's why your mothers, or those who have knowledge on this subject, know that... for example, if they are going to plant a vegetable, they must plant it in an open field. So, if you plant cucumbers at the bottom of the trees in a wooded garden, what will the crop be like?

S(students)1: It [the crop] will not develop.

[classroom observation]

T: As we said in photosynthesis, we just said that living things make food and store it, and we said that it [food] is used in its [living things'] development in some parts; think of a sacrificial animal. When you buy it, you feed it because it [sacrificial animal] is weak. Is it true? What the animal is doing: It [animal] is constantly increasing in weight. How will it [sacrificial animal] increase in weight? Because it [sacrificial animal] will eat the food, it [sacrificial animal]

within a certain period of time, its weight will be more. [classroom observation]

T: Carbon in carbon dioxide... for example, sugar, honey, look, all sweet has carbon.

[classroom observation]

T: It can be a large fruit tree that can live for many years, no matter what tree it is; if you look at the bottom of the trees, that is, around that trunk of the trees, you will see that there is no greenery. As has been said before, one of the factors affecting photosynthesis is sunlight. So, since the leaves of these trees will also block the sunlight, what can it do there? Then, photosynthesis will not occur quickly.

[classroom observation]

T: As a result of respiration, we give off carbon dioxide. We give water vapour as well. We got energy [with the process of respiration]. Where do we use the energy we get? We use it in motion. It [motion] is a common feature, that is, the common feature of living things. Since I mentioned a common feature, a question immediately came: Teacher, how do trees move? Kids, I said to you before, please do not confuse movement with displacement; what is displacement? The difference between the initial position and the final position of a mover. When you look at trees today, the fact that their leaves constantly turn towards the sun. It is a movement, a startle. A lunar core with names like Günebakan [sunflower], and Gündoğdu [sunflower], be careful. The sun has risen in the east; where will it set?

S2: West. [classroom observation]

Above were the daily life examples Expert 2 gave in his ecology lessons. Besides examples, he used some comparisons to increase students' understanding. Examples of Expert 2's comparisons and analogies regarding ecology are presented below.

T: Now, the euglena is at the forefront of single-celled organisms that can show both plant and animal characteristics. It is likened to an animal cell due to the appearance of its camper and eye spot, and to a plant cell because it contains chloroplasts. Again, these are the ladies who are knitting something, what was her name.... similar expression is used. Apart from blue-green algae, bacteria can also photosynthesize.

[classroom observation]

T: I will give a simple example right away: if your father, brother, uncle, or someone from your family has a hobby such as fishing, ask them that: there is plenty of algae in these ponds, especially in dams. These algae have no roots attached to the soil. They [algae] are in motion in the water... the fish here of course do not stay out of the water, that is, they are 20 cm or 30 cm below the water surface, and the fish stand on these algae, that is, they are not standing on the algae when they are tired, but the reason why the algae choose live among them [around the algae] is oxygen. In other words, it is the reason for taking oxygen dissolved in water. That is, that green plant has to do photosynthesis. While doing photosynthesis, thanks to those fishes, they provided the carbon dioxide inside the water and the algae took the sunlight, they [algae] have to give oxygen and because

the fish have to benefit from this situation, we have given the example here in this way.

[classroom observation]

T: You must have seen the high voltage lines that go from the mountains to the fields with the iron poles that carry 30,40,60 thousand volts, that is, the electric wires, that is, the high voltage lines, which send them from the place where they are produced to the places where they are consumed. Kids, although the conditions are the same all over the field where these poles are planted, it is observed that the vegetation at the bottom of the pole is much more developed than in other regions. Well, we have come to the end of April that will start of May, birds will have a desire to mate and they are in the act of mate selection. They will choose their spouses, everyone will determine a region as their living space, and others will leave this place. Well, some of these birds nest in the branches of trees. Some of them make it on the grassy stems of green grass, and some on the balcony, now the main thing here is that the vegetation at the bottom of that high tension in the same living area has grown more and more developed, so the bird builds its nest here, lays eggs, broods, and offspring out, and the offspring die. The cause is investigated. One reason is that the grass grows and develops more strongly there because they [plants under high voltage] do more photosynthesis, they [plants under high voltage] develop more because they [plants under high voltage] produce more food, but the same carbon dioxide causes the chick to die. In other words, the stronger the increase in the amount of carbon dioxide, the stronger the photosynthesis.

[classroom observation]

T: The better you take care of living things, the more ensure the variety, the more weight they will gain. or if we look at it in terms of energy, well-nourished athletes...they [camps of athletes] take place only in areas where the amount of oxygen is abundant, they [athletes] carry the camps there [where the amount of oxygen is abundant]. I think these are related to green areas there.

[classroom observation]

T: As the sun sets in the evening, the head of the sunflower seed is in the west in the direction of the sunset... pitch a tent there, lie down in the morning, get up, go, look... the head of the sunflower seed is in the east this time. Some things need to be perceived here, that is, they [people] think about the rotation of the world around itself, if they [people] do not have full knowledge of the subject, they think that I am stationary, the mountains on the other side are spinning.

[classroom observation]

Overall findings from interviews and classroom observations regarding Expert 2's knowledge of representations revealed that he used daily life examples and comparisons, analogies to improve students' understanding. This section documented Expert 2's knowledge of representations. The next section revealed Expert 2's knowledge of activities.

4.4.3.3.2.2 Expert 2's Knowledge of Activities

The other dimension of knowledge of topic strategies was knowledge of activities presented with the gathered findings from the pre-and post-interviews and classroom observations.

Expert 2 preferred to use direct instruction, questioning and instructional videos in his ecology lesson. In fact, his beliefs about ecology teaching were different from his enacted teaching. He argued the reason was because of the limited equipment in the science laboratory and SBS [High School Entrance Exam in Türkiye]. Expert 2 used instructional videos on TV about photosynthesis and respiration. He stopped the video at some points to make an explanation and exemplification with his words. During these breaks, he asked questions to the students. After covering the content, in the video, there are content-related multiple-choice questions he solved with students. Apart from these, he mentioned the effectiveness of field trips, experiments and the activities students conduct themselves like projects in the interviews. Table 4.35 summarises Expert 2's knowledge of activities.

Table 4.35 Expert 2's Knowledge of Activities

Activities	Interviews	Classroom Observation
Problem solving	Not mentioned	V(video): Yes, now let's move on to another question, in an experiment conducted in a lighted environment, the top of the lit candle is covered with a glass bell as shown in the figure. After a while, it is observed that the candle goes out. Which of the following creatures should be placed in order for the candle to burn longer in the bell jar? T: what do you think? S1: C [multiple choice item included 'bean plant'] T: Let me hear your voice. S2: C [multiple choice item included 'bean plant'] T: Tell me why? is it just beans or can't anyone else be here? S3: Starch
Experiments	Experiments should be made, but how, the units related to plants should be placed in time of spring... it is important to be able to show the root, the stem, the leaves and the flowers. Now the period of growing chickpeas and beans on the plate is over. The child must learn the things happened in the nature. [pre-interview]	Not mentioned
Projects	There are things that the child wants to do individually, I did a project homework here. I asked students to do whatever they want as project...[pre-interview]	Not mentioned

I: What kinds of activities are within the curriculum related to ecology?

E2: There are things that the child wants to do individually, I did a project homework here. I asked students to do whatever they wanted as a project. They [students] said: 'Teacher, I will make yoghurt'. Okay, the child made it himself. [the other students said:] 'Teacher, I'm going to pickle', it's ok. Here comes the other one, 'Teacher, I will do the physical or chemical changes of the egg' I said come on! you can do it. 'Teacher, I will make menemen [tradition food in Türkiye maid with tomato, onion and egg]', I asked him/her [student] 'Why are you going to make it?' S/He said, "You'll see, the things will undergo a chemical change." These are short examples. Now when kids do these [the projects students did], they [students] become extremely motivated here, also about biology issues... kids confuse movement with displacement. I said that acceleration is the beginning of the movement. Here, while the plants receive the sun's rays, the green leaves are in a position to turn towards the sun. One day, we need to sit under a tree and tell the children about it. Why does the pear fall to the ground? It is necessary to talk about gravity. It should be explained that the pear also pulls the ground towards itself... [pre-interview]

I: If you have enough time, are there any activities that you want to do?

E2: I wish I had time if I could take the children: maybe there is a child living in Ankara, those who have not seen the zoo.... he should visit the botanical park in Çankaya [district in Ankara], he should go

to a forest, Beynam. The child would learn what s/he sees and experiences more meaningfully without giving lectures with many repeats in the classrooms. Now, in our laboratories, you can experiment with a subject related to physics or chemistry, but in order to conduct an experiment related to biology, you need to have a separate laboratory. Instead of talking about these [biological] topics in class, you should take them [students] to the botanical park. If only I could say to the children there are trees, these are herbaceous trunks, these are woody trunks... If only s/he could see the rabbit roaming freely there... Experiments should be made, but how, the units related to plants should be placed in time of spring... it is necessary to be able to show the root, the stem, the leaves and the flowers. Now the period of growing chickpeas and beans on the plate is over. The child must learn the things that happen in nature. [pre-interview]

I: According to you, are these activities enough and suitable for elementary students?

E2: When I came to this school, there was no laboratory. But the program was prepared as if there were laboratories in the schools of the whole country. Educational programs are prepared as if all the tools were present [in schools]. If the laboratory is not perfect here, forty minutes of lesson time is not enough for a teacher trying to assemble that equipment, apart from lecturing. Everything must be in the laboratory. The child must do it himself. No one should teach in their own way. Programs should be determined accordingly. There are method differences, of course. However, the teacher should do it [difference in teaching method] with the students. Teachers do not

need to say to the students that: write what I say. Rather, the student should tell their beliefs and thoughts, the students should find the truth themselves. [pre-interview]

Expert 2 seemed to have knowledge of activities regarding ecology. Although he mentioned projects, experiments and field trips are effective activities to enable students to learn ecological concepts and issues effectively in pre-interviews, he observed to use of teacher-centered instruction. Accordingly, he conducted only problem-solving as an activity. In the instructional video Expert 2 used in his ecology lesson, there were experiments about photosynthesis. Therefore, students were able to see the experiments as demonstrations. The related classroom observation notes regarding problem problem-solving activity are presented below.

V(video): Yes, now let's move on to another question, in an experiment conducted in a lighted environment, the top of the lit candle is covered with a glass bell as shown in the figure. After a while, it is observed that the candle goes out. Which of the following creatures should be placed in order for the candle to burn longer in the bell jar?

T: what do you think?

S1: C [multiple choice item included 'bean plant']

T: Let me hear your voice.

S2: C [multiple choice item included 'bean plant']

T: Tell me why is it just beans or can't anyone else be here?

S3: Starch

T: Is it starch? Any plant will do [produce food]. So, you can say any or you add plants with a green leaf. What should the plant do?

S4: Photosynthesis

[classroom observation]

He was further asked about the activities he planned to conduct for the next year in post-interviews.

I: Is there anything you plan to do next year that you didn't do in class this year regarding ecology?

E2: Now look, believe me, it is useful to be in the ecosystem in terms of concepts. Now, from time to time, children ask questions. They [students] said, teacher, when I go to the village, or to my grandfather or my grandmother, they [students] said someone is going to get water from the fountain in winter, but the water was hot... so you can reverse it [situation]. We couldn't put our hands in the water in August. It is so cold... why is that? They [students] asked. Now there is either evasive answering to these questions or there is conscious answering... a biology laboratory must be big, should be comprehensive enough [with equipment]. Here, I am telling the children about the events that I have experienced personally. But I'm just like a kid right now. What am I saying? I wish you could take the kids outside to provide them opportunities to experience the concepts... and I claim... they [students] gain a great education. They [students] must learn inside the ecosystem... [post-interview]

To sum up, Expert 2 appeared to have conflicts between enacted and believed PCK in terms of knowledge of activities. In fact, during interviews, he pointed out the

effectiveness of activities that are parallel to student-centred instructional approaches like experiments, field trips, and projects. However, Expert 2 observed to use of direct instruction and questioning. He used daily life examples, comparisons and analogies as the representations of ecology.

The current section presented Expert 2's PCK component of knowledge of instructional strategies. The next section revealed Expert 2's knowledge of assessment.

4.4.3.4 Expert 2's Knowledge of Assessment

Expert 2's knowledge of assessment was examined in terms of knowledge of what to assess, types of assessment, knowledge of assessment methods and sources of assessment. Expert 2's knowledge of assessment regarding ecology is presented in the next section.

4.4.3.4.1 Expert 2's Knowledge of Dimensions of Science Learning to Assess

Expert 2's knowledge of dimensions of science learning to assess was investigated through pre-interviews and classroom observations. Table 4.36 summarizes Expert 2's knowledge of dimensions of science learning to assess.

Table 4.36 Expert 2's Knowledge of Dimensions of Science Learning to Assess

Dimensions of Science Learning to Assess	Pre-Interviews	Post-interviews	Classroom Observation
What to assess	Knowledge Attitude Skills	Not mentioned	Knowledge

I: What is your aim to assess in students?

*E2: Now, we may sometimes conduct an experiment with kids...or a demonstration experiment. If equipment is limited, a demonstration experiment is conducted under the supervision of the teacher. Or the kids will do it [experiment] themselves. Now we give grades to the classroom activity; we give a project, and now the children are doing their own projects here [in a laboratory]. They [students] said that the tongue and the nose serve the same purpose. They [students] brought it and showed it here. They [students] brought a lot of fruits. They [students] smelled the fruits, called their names, and then ate them. What I mean here is this: I watch while they do it. If you have tools and equipment, measurement and evaluation take place at the same time. I see that there is someone who takes notes, but some of them do not take notes; I took all these into account for evaluation...
[pre-interview]*

Expert 2 seemed to assess students' knowledge, attitudes and skills according to pre-interviews. However, in the lesson, Expert 2 used multiple-choice questions in the instructional video. He mentioned students are assessed in classroom activity in pre-interviews. Therefore, he seemed to assess students' skills that are necessary to conduct an experiment. He defined himself as an observer when students perform a classroom activity. Therefore, it was inferred from his response that he assessed students' attitudes towards the content of the activity. On the contrary, in the ecology lesson, Expert 2 might not be observed to assess students' attitudes rather he seemed to assess students' knowledge in terms of their responses to the multiple-choice questions.

In the next section, Expert 2's knowledge of methods of assessment presented.

4.4.3.4.2 Expert 2's Knowledge of Methods of Assessment

Expert 2's knowledge of methods of assessment presented in Table 4.37.

Table 4.37 Expert 2's Knowledge of Methods of Assessment

Methods of Assessment	Pre-Interviews	Post-interviews	Classroom Observation
How to assess	Open-ended questions	formative	formative
	Fill in the blanks		summative
	Multiple-choice questions		
	During the lesson,	Not mentioned	During the lesson
When to assess	At the end of the lesson		
Knowledge domains influence assessment methods	Subject matter knowledge Knowledge of students	Subject matter knowledge Knowledge of students	Not mentioned

I: Which assessment methods and techniques do you use to assess students in ecology?

E2: We assess students with the exams. I ask each type of question in my exams. In fact, in ecology, I try to ask open-ended questions that students write their own thoughts. They [open-ended questions] are better...The [ecology] lessons are mostly based on interpretations. Learning is not based on memorization. That is, the learning is based on making students recognize the environment...Therefore, it is logical to expect students to answer the open-ended questions.

However, the fill-in-the-blank questions require memorization. It [fill in the blank questions] can cause confusion of concepts, too. [pre-interview]

I: Which one of the assessment methods that you use is more effective in terms of understanding whether students learn ecological concepts or not?

E2: The [assessment] methods can be diversified. However, according to the facilities that we can utilize, they are enough. In my opinion, the best way is to make students do something themselves, experience things, and interpret something. The reason for students not being able to make interpretations is that they [students] do not have a chance in lessons to observe things, not being able to do things. They [students] only imagine them [things related to subject matter]. If they could do these things, they would never forget them. [pre-interview]

I: Apart from these assessment methods, what kinds of assessment methods can be used for ecology?

E2: I teach lessons through dialogues with students. Sometimes, we do experiments. Sometimes, I explain to students. Whatever the method of instruction, I also make assessments. [pre-interview]

I: When do you assess students in ecology?

E2: At the end of each unit, I make an assessment. I prepare tests. I ask students to prepare ten questions related to the unit. I selected fifty questions for the students for the test. That is, students prepare

their questions by themselves. Moreover, during lessons, I listen to them in order to understand what they know. [pre-interview]

I: Which knowledge do you have effective in determining your assessment method?

E2: You have to have sound knowledge of various assessment methods and be aware of students' knowledge levels to assess their learning. [Pre-interview]

During pre-interviews, Expert 2 stated to use summative assessment methods in which he mentioned open-ended questions, fill in the blank, and tests; he most probably meant the tests with multiple choice questions. Apart from summative assessment, he seemed to use formative assessment. He assessed students when they interpreted the learning material and conducted an instructional activity. However, he mentioned their restricted facilities to conduct activities that prevent him from making formative assessments. In general, Expert 2 seemed not to know alternative assessment methods in ecology.

In classroom observation, he used an instructional video; there were multiple-choice questions in the video for assessment. The instructional video included the multiple-choice questions and their answer with explanations as well. Expert 2 either directed these questions to the students or made the video explain the questions. In fact, he used short answer questions in his lesson. The related classroom observation notes are provided below.

T: Plants do not prevent a leaf from receiving sunlight from another leaf. If you look at the leaves of the trees... no matter how many leaves are on the tree, they all turn towards the sun. This is a startling event. No leaf covers the other leaf. So, your mothers, or those who have

knowledge on this subject, know that if they are going to plant a vegetable, for example, they must plant it in an open field. So, if you plant cucumbers at the bottom of the trees in a wooded garden, what will the crop be like?

S1: It will not develop.

[classroom observation]

V(video): Yes, now let's move on to another question, in an experiment conducted in a lighted environment, the top of the lit candle is covered with a glass bell as shown in the figure. After a while, it is observed that the candle goes out. Which of the following creatures should be placed in order for the candle to burn longer in the bell jar?

T: what do you think?

S1: C [multiple choice item included 'bean plant']

T: Let me hear your voice.

S2: C [multiple choice item included 'bean plant']

T: Tell me why. is it just beans or can't anyone else be here?

S3: Starch

T: Is it starch? Any plant will do [produce food]. So, you can say any or you add plants with a green leaf. What should the plant do?

S4: Photosynthesis

[classroom observation]

Different from pre-interview responses that he expressed formative assessment techniques; Expert 2 seemed to use traditional assessment methods in his ecology lessons. Consistent with the classroom observation, he explained to use of traditional assessment techniques in his ecology lessons apart from alternative assessment.

I: How did you assess students in ecology?

E2: This unit did not contain mathematical equations. We made classical exams in which many short-answered questions. I asked around fifty questions with short answers in the exam. [Post-interviews]

I: Did you think that these assessment methods are sufficient in order to determine whether students understand ecological concepts or not?

E2: There is no such thing as understanding or not. I taught this lesson by speaking. You don't always lecture. Now there are some subjects to be experimented with. There are some topics that the teacher explains. There are some subjects that are handled by the teacher-student talking. In these [ecology] lessons, you have to make everyone talk. [Post-interviews]

I: Which knowledge did you have effective in determining your assessment method?

E2: The questions require interpretation and do not have only one correct answer. Students do not have to answer these questions as they want. You have to decide whether their answers are correct. Therefore, you have to have sound knowledge of the concept you ask. You have to prepare the answer key for the exam. In order to prepare this key efficiently, you have to have knowledge regarding concepts.

The answers to the questions about physics, mathematics, and chemistry are certain; however, in biology, the answers to the questions are various. [Post-interview]

To sum up, Expert 2 mentioned mostly traditional assessment methods like tests with multiple choice, short answer and fill-in-the-blanks rather than alternative assessment techniques like observations, performances, rubrics, and portfolios three types of assessments which were formative and summative assessment in the findings of interviews and classroom observations. He neither explained nor used formative assessment methods in ecology. He seemed to focus on the conceptual understanding of students in ecology apart from interdisciplinary themes, the nature of science, and science process skills.

The following section presents the summary of Expert 2's PCK.

4.4.3.5 Expert 2's PCK Summary

Expert 2's pedagogical content knowledge with its aspects in teaching ecology presented in this section in Table 4.38.

Table 4.38 Expert 2's Pedagogical Content Knowledge in Teaching Ecology

KoC		KoL		KoIS		KoA
Goals and objectives	Materials	Requirements	Learning difficulties	Subject specific	Topic specific	What to assess
See Table 4.30	Textbook, workbook Cram book Instructional videos Board Experiment materials	Relating with daily life Prior knowledge Student's interest	Exemplifying organisms	Direct teaching Questioning Demonstration Field trips	<i>Representations:</i> Daily-life examples Comparison/analogy	<i>Activities:</i> Problem solving Experiments Projects <i>Knowledge</i> Skill Attitude <i>Methods of assessment:</i> <i>Formative assessment:</i> classroom observation, questioning <i>Summative assessment:</i> open-ended questions, multiple choice questions, fill in the blanks
<i>Vertical and horizontal relations:</i> <i>G-8</i> Ecosystems Organisms' relations Photosynthesis Respiration			<i>Misconceptions:</i> Habitat			

KoC: Knowledge of Curriculum
 KoL: Knowledge of Students' Understanding of Science
 KoIS: Knowledge of Instructional Strategies
 KoA: Knowledge of Assessment

In this section, science teachers' subject matter knowledge and pedagogical knowledge was revealed. In the next section, novice and expert science teachers' SMK comparison and PCK comparison tables were presented.

4.5 Expert and Novice Science Teachers' SMK Comparison

This section presents Table 4.39, aiming to provide a concise comparison of SMK findings between expert and novice science teachers. This comparison highlights the overall SMK findings of the teachers, which were elaborately presented in the preceding sections of Chapter 4.

Table 4.39 Expert and Novice Science Teachers' SMK Comparison

SMK/Teachers	Novice 1	Novice 2	Expert 1	Expert 2
Ecosystem	It is a place where organisms exist together both biotic and abiotic components. It is an environment including the animals living on the mountains, inside the forests and lowlands, water resources etc...	This [concept] is the content of 7 th grade [HERE, she informed that she had not taught 7 th grade curriculum before... it is the area living and non-living organisms live... Species produce fertile offspring	Living things in nature... in a certain area or the environment in which living and non-living things can exist. briefly, we can define it [ecosystem] as an environment.	It is the area that can be large or small in which living and non-living things exist together. All of these things [living and non-living things] interact with each other.
Species	They are genetically similar organisms which can reproduce new organisms which are similar to each other.		The group of organisms possessing similar characteristics and arise from same ancestors	Fox is a species, for instance. If the foxes come together, they form population.
Population	A population is group of organisms include same kind of species only; that should not include any other kind of species, as I suppose.	Population is a group of organisms that belongs to same species, living in a certain area.	The group of organisms of same species living in a certain area	It [population] is a life form in which group of organisms live together
Community	Is it the environment where more than one species lives together? I think it is something like that.	what can be the difference between community and habitat? I do not know.	It is not included in the curriculum. Therefore, I could not provide the definition.	Birds and crocodiles need to live as a community. In fact, organisms need to be live within community to survive.
Habitat	There is an appropriate environment for each living thing to live, adapt and meet their needs. So, we can call that environment as their habitat. In short, habitat is a place where an organism can meet all of its needs, shelter, feed and reproduce.	It [habitat] is the living and non-living things within the city of Ankara. It [habitat] can be certain communities living in the city of Ankara.	It [habitat] is the place where an organism lives in. it [habitat] is the place where it [organism] can be most probably found.	Habitat is a certain area that species can survive. For instance, goat can find food from steepness of the mountains because of protection from other organisms
Producer	Producers are plants, plants with green leaves	Producers are plants with green leaf ...that is, [the things] producing their own food.	They [producers] are green plants.	Plants are producers that photosynthesize. By this way, they produce their own food...

Table 4.39 Cont'd

SMK/Teachers	Novice 1	Novice 2	Expert 1	Expert 2
Consumer	Do consumers have a specific task? I mean, I can't explain it [your question] like that, but yes, every living thing has a specific task. Consumers do not exist in the ecosystem just to consume, perhaps they [consumers] contribute, in some way, to the survival of other living things in the ecosystem.	Like producers, consumers are also essential. They [consumers] provide carbon dioxide necessary for plants... In the end, if there are not consumers, there will not be producers.	Consumers feed on producers. That is, they are at the second level of food chain and second part of energy pyramid. We can say consumers are heterotroph organism. We can separate them as omnivores and carnivores.	Consumers produce carbon dioxide for producers to photosynthesize. They [consumers] take in oxygen and given off carbon dioxide...
Decomposer	Decomposers are the organisms which convert the wastes to the form that can be usable. They have roles in matter cycles... Their food resources are also the wastes.	Decomposers are even biotic components of ecosystems. They [decomposers] are tiny organisms within the soil facilitating breaking down of death organisms into inorganic or organic matters.	Decomposer is a kind of organism convert waste products into useful form. It is a kind of organism that can facilitate plants and animal to be more efficient. Bacteria, we can say bacteria.	Bacteria are the decomposers produced by the body of the organism, for instance. There is huge importance of decomposers in the nitrogen cycle. They provide decomposition of green plants' death.
Biological Diversity	A group of various organisms...they are genetically different, also different with respect to reproduction, feeding [habit] and the environment that they live.	Crossing over takes place during meiosis, and at the end different organisms are produced. We can call this as biological diversity.	The diversity of animals and plants in an area is called biological diversity...	Biological diversity is the diversity of species. If the plants living inside a pool are various, the species being able to live inside of this pool also vary.
Ecological Niche	no understanding	no understanding	no understanding	no understanding

Table 4.39 Cont'd

SMK/Teachers	Novice 1	Novice 2	Expert 1	Expert 2
Food Chain	<i>It's like a flow they [living things] create, that is, the energy will flow from one to the other, but this is not a linear messy thing...</i>	<i>Food chain can be explained like that organisms feed on each other in the same area. That is, one [organism] eats another [organism] and keeping this [feeding] relation as a chain. In the same area, it [food web] is organisms feeding on each other and in an eating relation, being just like a web.</i>	<i>Food chain is the eating relation of organisms living together; we can describe food chain like that.</i>	<i>Inside an ecosystem, there are organisms sharing same area. These organisms are feed on each other. Among these organisms, there are herbivores, carnivores and decomposers.</i>
Food Web	<i>It is a rather complex web network such as a spider web. Because in nature, as far as I know, no living thing feeds on a one kind of organism.</i>	<i>In the same area, it [food web] is organisms feeding on each other and in an eating relation, being just like a web.</i>	<i>Food web is formed by food chains which are formed by organisms in the same environment.</i>	<i>Food chain as I defined previously is the linear serious of species in an eating relation. Food web is the totality of these chains.</i>
Energy Pyramid	<i>Energy pyramid is a pyramid that illustrates the flow of energy... We can say that energy flows from producers to the consumers. Of course, energy will not be destroyed; however, the usable part of it is reduced.</i>	<i>Energy pyramid indicates an organism's transferring its energy to the other organisms.</i>	<i>Organisms feed on each other in nature. This kind of feeding relation is called the energy pyramid. That is, moving from the bottom level to the upper level, it is called the energy pyramid.</i>	<i>To the upper levels of energy pyramid, the level of energy decrease. The bottom of the energy pyramid is large. There are producers at this level. Then, herbivores which are feed on producers are the second level of energy pyramid. The omnivores are the third level and at the top of the energy pyramid, the carnivores are placed. Decomposers are each level of the energy pyramid.</i>

4.6 Expert and Novice Science Teachers' PCK Comparison

This section presents Table 4.40, aiming to provide a concise comparison of PCK findings between expert and novice science teachers. This comparison highlights the overall PCK findings of the teachers, which were elaborately presented in the preceding sections of Chapter 4.



Table 4.40 Expert and Novice Science Teachers' PCK Comparison

PCK /Teachers	Novice 1	Novice 2	Expert 1	Expert 2
	For curricular objectives, see Table 4.1 I think that ecology was taught in 7th and 8th grade, but not in 6th grade. It may also be introduced in elementary school, either in 4th or 5th grade, or possibly in both. However, However, I am still determining this.	For curricular objectives, see Table 4.11 In 6th grade, ecology is taught through various units... I think a unit in the 7th grade curriculum is related to ecology. In my two years of teaching experience, I haven't had the opportunity to teach 7th grade yet. As far as I know, ecology is only briefly covered at a 7th-grade level. It appears to be more thoroughly taught in the 6th unit during 8th grade.	For curricular objectives, see Table 4.20 Ecology concepts are typically introduced in 4th and 5th grade, with more in-depth instruction provided in 6th, 7th, and 8th grade. To teach about the benefits and harms of living species, it's important to learn about the food web and food chain, as well as the cycles of matter. Grouping organisms and describing their interactions can also aid in this understanding. Briefly, this knowledge can help us understand the benefits and harms to these species.	For curricular objectives, see Table 4.30 Ecology is taught in 6th, 7th, and 8th grades to introduce students to different ecosystems, the organisms that live within them, the relationships between them, and their feeding habits.
KoGO				
KoC	Teachers' guidebook Students' workbook, notebook Board Experiment materials Computer	Teachers' guidebook Students' workbook, notebook Board Exercise book Videos Photographs Posters, 3D models	Teachers' guidebook Students' textbook Board Projection Materials for role playing Materials for experiments periodicals, journals, computer	Textbook, workbook, cram book Instructional videos Experiment materials

Notes: KoC: Knowledge of Curriculum; KoGO: Knowledge of Goals and Objectives; KoM: Knowledge of Materials; KoR: Knowledge of Requirements; KoLD: Knowledge of Learning Difficulties; KoSS: Knowledge of Subject Specific Strategies

Table 4.40 Cont'd

PCK /Teachers	Novice 1	Novice 2	Expert 1	Expert 2
KoL	Last year, you learnt food chain and food web...	Let's remember the key concepts: What was the producers?	We need to teach the food chain, the food web [to children] in order to show them the different animal or living species they encounter in their daily life... Now, there is a flow in the food chain from basic to more complex... They will be aware of divergence among organisms.	Students should be aware of the sources of energy... Producers first take Sun's energy. Then, herbivores that are fed on green plants take this energy. In the next level [the energy pyramid], there are carnivores. The energy lessens to the upper levels level [the energy pyramid] as energy is transformed.
	Did you remember producers, consumers and decomposers you learnt last year?	What does consumer mean? What does decomposer mean?	Learning about population and habitat can be challenging for students. For example, some students may mistakenly believe that lions live in Turkey based on seeing them in zoos. Additionally, they may not be aware of different types of fish or have misconceptions about certain species, such as not knowing that carp are found in freshwater.	When I mention chicken, goose, or turkey, people understand that I am talking about birds. However, if I bring up finches, they may not know what I am referring to. It is important to note that not being familiar with a concept is not the same as having a misconception. A misconception would be providing an incorrect interpretation of something.
KoLD	When discussing an ecosystem, some students mistakenly believe it consists solely of living organisms like plants. Additionally, they may believe that plants respire during the day and photosynthesize at night.	We often use "habitat" and "community" in everyday conversations. However, some students still need help understanding these concepts, despite learning them through memorization.		
	Sometimes, the directions of the arrows in a food chain were reversed in students' drawings. In fact, the arrows indicate the flow of energy and show who eats whom.			

Notes: KoL: Knowledge of Students' Understanding of Science; KoGO: Knowledge of Goals and Objectives; KoM: Knowledge of Materials; KoR: Knowledge of Requirements; KoLD: Knowledge of Learning Difficulties; KoSS: Knowledge of Subject Specific Strategies

Table 4.40 Cont'd

PCK / Teachers	Novice 1	Novice 2	Expert 1	Expert 2
KoSSS	When it comes to teaching, my preferred method is lecturing. I like to use either a question-and-answer approach or demonstrations to engage my students.	If the lessons are taught only through lecturing, students may need help understanding. There can be used several methods. However, I do not know...	I make my students prepare posters related to content. I ask my students to watch documentaries and make them share examples...	If the lesson is about mathematics, for example, it cannot be done with television, there is no experiment, this subject is explained... I generally use questioning in my lessons... We can do experiments as a demonstration.
		I have conducted experiments as a demonstration.	Visual sources and experiments provide permanent learning.	
KoIS	Drawing figures Daily life examples Comparisons, analogies	Drawing figures Daily life examples Comparisons Models/posters Videos/ documentaries	Drawing figures Daily life examples Comparisons Visuals (presentations, posters) Role playing Experiments Knowledge Attitude Skills	Problem solving Experiments
KoA	What to assess	Knowledge Attitude	Knowledge Attitude Skills	Knowledge
	Methods of assessment	formative summative (Multiple choice questions open-ended questions)	formative summative (Multiple choice, matching, filling in the blanks, short answers...)	formative summative (open-ended questions fill in the blanks multiple-choice questions)

Notes: KoIS: Knowledge of Instructional Strategies; KoA: Knowledge of Assessment; KoGO: Knowledge of Goals and Objectives; KoM: Knowledge of Materials; KoR: Knowledge of Requirements; KoLD: Knowledge of Learning Difficulties; KoSS: Knowledge of Subject Specific Strategies

CHAPTER 5

DISCUSSIONS AND IMPLICATIONS

The scope of the study was to examine and compare the two novice and expert science teachers' SMK and PCK regarding ecology in the light of Magnusson et al. (1999) PCK model. This chapter focused on the discussions of the current study's findings regarding the expert and novice science teachers' SMK and PCK were discussed with reference to the related literature.

5.1 Discussions

The aim of the study was to analyze and compare the subject matter knowledge (SMK) and pedagogical content knowledge (PCK) of novice and expert science teachers in the area of ecology, using Magnusson et al.'s (1999) PCK model as a framework. This chapter presents a detailed discussion of the findings of the study, with a focus on comparing the SMK and PCK of novice and expert science teachers. The discussions were supported by relevant literature on the topic.

5.1.1 Novice and Expert Science Teachers' Subject Matter Knowledge in Ecology

Novice and expert science teachers' SMK in ecology was elicited through interviews, drawings, exemplifications, and interpretations. The overall findings of the teachers were compared and discussed in terms of novice and expert science teachers' SMK in basic ecological concepts and flow of energy.

The ecology concepts were highly interrelated to environmental and biological sciences such as sustainability, evolution, genetics, global warming, and climate change that were vital to increase environmental literacy and awareness of individuals (Özkan, 2001; Soylu, 2006; Tıraş, 2019; Sağbilge, 2022).

Consequently, science teachers need to have a strong conceptual understanding of concepts found in ecology to teach students meaningfully. In fact, science teachers need to possess a comprehensive knowledge of ecological concepts, as their limited or naive grasp of these concepts has the potential to impact their teaching practices. In order to elicit participating teachers SMK in basic ecological concepts, novices, and expert teachers were asked a series of questions about the ecosystem, species, population, habitat, community, producer, consumer, decomposer, food chain, food web, and energy pyramid.

The results of the interviews and concept maps suggested that all science teachers' knowledge levels need to be developed. Specifically in the concepts of basic ecological concepts such as ecosystem, community, producer, consumer, decomposer, biological diversity, extinction-prone species, ecological niche, food chain, and food web.

For instance, they thought the ecosystem consisted of biotic and abiotic factors. In their concept maps, except Expert 2, they identified the ecosystem as the central concept, which branched into living and non-living things without giving any emphasis on the interactions among the biotic and abiotic components. Their responses to other questions, however, implied that they knew more about ecosystems, habitats, species, and populations. When novice and expert science teachers' overall findings were compared, novice science teachers found a relatively high level of awareness about the interactions between biotic and abiotic components of the ecosystem and more concepts associated with the ecosystem in their concept

maps. Participants seemed to fail in the complex nature of the ecosystem and associations among the components and processes occurring in the ecosystem in constructing concept maps. For example, they either associated a few concepts with each other or used a few concepts with limited linking words or fewer numbers of crosslinks. Their concept maps included either few or no associations of the concepts of energy, food web, food chain, and energy pyramid. One reason for teachers' constructing simple concept maps could be attributed to their limited SMK in basic ecological concepts.

Their responses to other questions, however, implied that they knew more about the concepts associated with ecosystems. In fact, in the study, expert science teachers have more than 25 years of teaching and many years have passed since their undergraduate education, and they neither mentioned that they enrolled an in-service training on concept mapping nor they learned how to construct a concept map previously. However, novice science teachers' concept map included many associations among ecosystem, producer, consumer, and decomposer. They also explained those concepts in interviews.

previously conducted studies. Supported the present findings by revealing that having poor knowledge in a specific content area corresponds with less meaningful relationships between concepts (Novak & Govin, 1984; Zak & Munson, 2008). In Zak & Munson's research (2008) a substantial number of pre-service elementary teachers faced challenges when connecting the ecological concepts in meaningful ways. More specifically, Zak and Munson (2008) used concept mapping techniques to elicit preservice teachers' understanding of basic ecological concepts. They found that preservice teachers' limited SMK resulted in few associations between ecological concepts and preservice teachers identified the ecosystem as the top central concept in their hierarchical concept maps. The findings of Zak and Munson

(2008) were highly similar to the findings regarding the concept maps of novice science teachers in the current study.

Zak and Munson (2008) also reported that preservice teachers associated common species and populations with the ecosystem in their concept maps which was also a consistent finding with Novice 2's and Expert 1's concept maps. Novice 1 and Expert 2 did not integrate species, populations and habitats in their concept maps. Although one of the experts, Expert 2 was found to have knowledge of the ecosystem in which he stated the biotic and abiotic components and interactions in interviews, Expert 2 did not associate the ecosystem with biotic and abiotic components in his concept map, even his concept map revealed a simple, not targeting ecosystem concepts, indicating his difficulty in concept map construction.

The finding of the current study was also consistent with the studies conducted with preservice science teachers. For example, in Martín-Gómez et al.'s study (2020), preservice science teachers' knowledge of the ecosystem was investigated through poster drawing. They found, similar to the teachers in the current study that preservice science teachers indicated knowledge deficiencies in the ecosystem, especially in excluding interactions of biotic and abiotic components in their initial ecosystem poster drawings.

What is more, there were some basic ecological concepts teachers, either novice or expert, found to have difficulties. One of these concepts was community. Although Expert 1 did not provide a definition for the community because the concept is not included in the science curriculum (MoNE, 2004), Novice 1 defined community with hesitation, stating that community was something formed by species, although she was unsure because she believed species formed population.

In addition, believing that community was not present in the science curriculum, Novice 2 confused community with the habitat by asking herself the difference

between community and habitat and did not explain them. Another concept was ecological niche. Expert 1 said that she could not define ecological niche and community because these concepts were not included in the science curriculum. All novice and expert science teachers could not define ecological niche; surprisingly, Expert 2 said that he never heard of this concept before. In fact, novice science teachers stated that they did not remember what the ecological niche is. Accordingly, findings also implied that participants' ecology subject matter knowledge was limited to the curriculum, called curriculum-led teacher by Şen et al. (2018). The study by Tıraş (2019) in the context ecosystem is consistent with the current study in many ways. First, her findings revealed that experienced science teachers were not able to define community and ecological niche, saying that both concepts are not included in the 7th-grade science curriculum prescribed by MoNE (2018). Second, one of the experienced science teachers confused the community with the population as well. Third, two experienced science teachers were found to have difficulties in the flow of energy and misconceptions in some basic ecological concepts such as decomposers, food chain, and arrows in the food web; teachers provided the energy pyramid drawing and explanations with scientifically accepted definitions. Tıraş (2019) explained these findings through teachers' limited comprehension of ecological concepts.

Students often encounter challenges in grasping the fundamental biological concepts related to the interconnectedness of relationships and the flow of energy within ecosystems. These concepts are essential for the survival of all living organisms and for maintaining the intricate balance of life on our planet. Proficiency in deciphering food chains and food webs is pivotal for effectively communicating and comprehending the intricate relationships among organisms within the field of biology. The present studies' findings revealed that regarding energy and energy flow in the ecosystem, novice and expert science teachers were found to have insufficient knowledge. For instance, they defined energy related to chemical or

physical perspective apart from ecological one, except Expert 2. Expert 2 defined energy in terms of an ecological perspective stating that all kinds of energy sourced by the sun are transferred to producers. In fact, all science teachers, either experts or novices, knew the energy source for the organisms was the sun, and the flow of energy in ecosystems started with sunlight in photosynthesis. However, teachers neither explained the sequence of chemical reactions in photosynthesis nor stated the energy efficiency in photosynthesis-related to the first and second laws of thermodynamics.

There was an exception in the latter that Novice 2 explained the energy efficiency by referring to the first and second laws of thermodynamics. Teachers stated the reactants and end products of photosynthesis without referring to chemical reactions in the process, implying their grasp of photosynthesis as a simple, linear chemical reaction. Similarly, Beals et al. (2012) study with elementary and middle school teachers revealed that teachers had difficulties in energy flow in ecosystems, especially in energy sources of the ecosystems, photosynthesis and respiration, decomposers, and differentiating primary and secondary consumers. Beals, Krall, and Wymer (2012) claimed that teachers had difficulties in the identification of the roles of the trophic levels. Beals et al. (2012) stated in-service elementary and middle school teachers' difficulties in the energy source for a forest ecosystem, the role of decomposers as nutrient recyclers rather than energy recyclers, and the distinction between primary and secondary consumers specifically. Teachers were found to perceive energy flow in the ecosystem as unidirectional and identify soil as the energy source and they were found to have difficulties in understanding the decomposers' roles in the ecosystem. Beals et al. (2012) suggested professional development programs for inservice and preservice teachers to enhance their understanding of energy flow in ecosystems and to overcome their non-scientific conceptions of ecological concepts. Parallel to the findings of Beals et al. (2012), science teachers in the current study were found to have deficiencies in energy flow

through an ecosystem. In addition, teachers did not associate the energy flow and material cycles as the previous research denoted (Beals et al., 2012; Wernecke et al., 2018). Wernecke et al. (2018) claim that the energy concept is a critical and challenging concept to understand the ecological processes, they revealed students' difficulties in understanding the energy flow in the ecosystem and the relation between energy flow and material cycles as teachers in Beals et. al. (2012) study. Wernecke et al. (2018) suggested teachers need to be knowledgeable to cope with students' learning difficulties and misconceptions regarding energy and provide appropriate instructions for students. In line with these findings,

in the current study, science teachers' simple explanations regarding energy flow supported the need for professional development programs for teachers to enhance their SMK regarding energy and energy flow in ecosystems.

Teachers either novices or experts in the present study were not aware of the holistic nature of material cycles and perceived the materials' process as linear. Related to the food chain, food web, and energy pyramid, they were found to not be able to draw a correct food chain. For example, Novice 1 and Expert 2 did not identify decomposers in their food chain drawing. Although Novice 2 integrated decomposers in her food chain, she did not place the arrows correctly. Expert 1 drew a cyclic food chain exceptionally different from others' food chains, decomposers identified with their examples such as bacteria and fungi. Furthermore, none of the teachers explained their food chain and food web with energy transfer between organisms. Consistently, all teachers in the study assumed the food chain length was limitless. All teachers did not convey the arrows' role in the separation of the trophic levels in the food chain. On the other hand, they explained the roles of trophic levels in different questions related to either the food web or the energy pyramid. The teachers also found differences in their perception of their understanding of the relationship between the food chain and material cycles. They commonly explained

the relation superficially and underestimated the roles of producers, consumers, and decomposers in this relationship.

Related to the food web, apart from Novice 1, teachers interpreted the questions with organisms' eating relations.

Novice 2 and Expert 2 were found to have difficulties in interpreting the effect of one population's size change on the second population if the effect was transmitted along more than one route. Regarding energy pyramids, both novices and experts of this study, despite an unexpected finding because of their limited understanding of energy flow in ecosystems, were found to have knowledge of energy pyramids' shape, energy rate of trophic levels, and roles of each trophic level.

The studies also pointed out that teachers are one of the main sources for students' misconceptions (e.g. Demirdöğen et al., 2016; Thomson & Logue, 2006; Sadler & Sonnert, 2016) and share common misconceptions with students. For example, science teachers in this study possessed misconceptions similar to that of students such as decomposers, food chain, and food web (Adeniyi, 1985; Çetin et al., 2015; Griffiths & Grant, 1985; Hogan, 2000; Leach, Driver, Scott & Wood-Robinson, 1995; 1996;

Munson, 1994; Özkan, 2001; Özkan et al., 2004; Preston, 2018; Soylu, 2006). There also were studies that pointed out the need to make students conceptually differentiate decomposers and scavengers (Yeo et al., 2022) like that of Expert 2 in the current study. In addition, Expert 1's concept map was a cyclic concept map that supported her perception of energy's cycling in an ecosystem like students perceived in Soylu's (2006) study. In fact, Expert 1's cyclic food chain revealed her misconception in energy flow that was a compatible finding to the previous researches that they indicated energy in ecosystem was perceived as either cycled by decomposers or reused and recycled (Adeniyi, 1985; Barman & Mayer, 1994;

Burger, 2001; Beals et al., 2012; Çetin et al., 2015; Griffiths & Grant, 1985; Hogan, 2000; Lancor, 2012; Eilam, 2002; Preston, 2018; Reiner & Eilam, 2001; Traş, 2019; Wernecke et al., 2018; Yorek et al., 2010). Reiner and Eilam (2001) found that students perceived the food chain as unlimited because of its cyclic nature. For example, one of the students in their study said "I don't think there is a first or a last element because it's a cycle, and in a cycle, you can't have a beginning and an end".

Studies claimed that difficulties in the flow of energy in the food chain and in the role of energy corresponded to the difficulties of students in understanding the length of the food chain (Eilam, 2002). In relation to this, Novice 2 explained her difficulty in the energy concept because of its abstract nature, consistent with what the previous study found in students' comprehension regarding energy in the ecosystem (Eilam, 2002). Supporting the energy comprehension of novice teachers and Expert 1, Lancor (2012) mentioned the "rote response" of physicists, whose common definition was "energy is the ability to do work".

It could be also inferred from teachers' energy definitions in the current study that their energy conceptions were limited to different contexts. Parallel to an earlier study by Lancor (2012) in which the researcher investigated students' energy understanding in different domains like ecosystems, chemical reactions, mechanical systems and circuits. It was found that students' energy comprehension was highly related to the context.

The other surprising finding was Novice 2 perceived carbon dioxide as poison which was found a common misconception among students by Keleş and Kefeli (2010).

Keleş and Kefeli (2010) studied with 6th and 7th-grade students and found that students had misconceptions regarding photosynthesis and respiration. In fact, the studies found students' difficulties in comprehension of photosynthesis and respiration (Köse, 2008; Özay & Öztaş; Yenilmez & Tekkaya, 2006) and teachers'

as well (Çakıroğlu & Boone, 2002; Parker et al., 2012). Contrary to the previous studies that found the soil perceived as the energy source for plants and misconceptions and naïve understanding of the energy pyramid (Adeniyi, 1985; Beals et al., 2012; Krall et al., 2009; Özay & Öztaş, 2003; Özkan, 2001; Soylu, 2006; Wernecke et al., 2018), expert and novice teachers knew the energy source of plants and energy pyramid in the current study.

The discussions around the participant expert and novice science teachers' SMK regarding ecology demonstrated that teachers, either expert or novice in the current study, need to develop their SMK in ecological concepts and processes in many aspects. In fact, teachers were found to need help with the ecological concept and principles consistent with the related science literacy regarding teachers, pre-service teachers and even students. Therefore, it could be inferred from the current study's findings that science teachers need to develop an advanced repertoire of SMK in ecology.

5.1.2 Novice and Expert Science Teachers' Pedagogical Knowledge regarding Teaching Ecology

In this section, novice and expert science teachers' PCK regarding teaching ecology was compared with respect to knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment.

In the study, science teachers' knowledge of the curriculum in ecology was elicited with the data collected from interviews, classroom observations, and lesson plans. Generally, the gathered findings revealed that expert science teachers tended to have more knowledge of curriculum, instructional strategies, and assessment compared to novice science teachers.

One possible reason for these differences was attributed to the expert science teachers' teaching experiences. Participating expert science teachers were more familiar with the ecology topics from their past experiences since they have been teaching the concepts of ecology for years in each grade level, from 6 to 8 (Hanuscin et al., 2010; Kınık, 2022; Lankford, 2010; Melo et al., 2020; Mihlandız & Timur, 2011; Şen, 2014; Tıraş, 2019). They were additionally more acquainted with students' needs to learn ecology and their learning difficulties. Although expert teachers mentioned students learning difficulties in ecology, they were better capable of adopting instructional strategies to foster students' understanding and to provide feedback about their learning process. Another reason might be the teachers' high sense of confidence (Appleton, 2006). Studies reported that PCK components accumulated in time with teaching practice in experienced teachers (Hanussin, Araujo, Cisterna, Lipsitz & Garderen, 2020; Jang, 2011; Jang et al., 2013; Kind, 2009; Lee et al., 2007; Mulholland & Wallace, 2005). These studies showed that expert teachers implemented gradual, step-by-step approaches to lead students to reach the expected outcomes they wanted to learn (Kind, 2009). In fact, researchers commonly agree that teachers accumulated PCK through experience teaching specific content (Lee et al., 2007). Indeed, Jang et al. (2013) found that experienced instructors preferred to use life examples and experiments rather than novice instructors who stated to use explanations and quizzes in physics. Hanussin et al. (2020) claimed that when experienced elementary teachers were reassigned to a different grade level, although they experienced difficulties in CK, PCK and knowledge of learners, they revealed different capabilities to teach new and unfamiliar topics. That is, they showed a higher PCK than novices. The experienced teachers claimed to offer a higher level of readiness in terms of PCK in different aspects, such as instructional methods with the help of their prior teaching experience.

Another possible reason might be their knowledge of curriculum, knowledge of students' understanding of science, and knowledge of instructional strategies components were found to be related to teachers' teaching experiences in ecology. In line with those ideas, it is inferred that although expert science teachers did not have strong SMK in ecological concepts, their long-term experience in teaching might enable them to cope with their knowledge deficiencies. In the following parts, novice and expert science teachers' PCK are discussed with respect to each component separately.

5.1.2.1 Novice and Expert Science Teachers' Knowledge of Curriculum regarding Teaching Ecology

In the study, science teachers' knowledge of the curriculum in ecology was elicited with the data collected from interviews, classroom observations, and lesson plans. Regarding teachers' knowledge of goals and objectives, the gathered findings revealed although Expert 2 underestimated the objectives related to food chains and material cycles in his ecology lessons, expert science teachers tended to have more knowledge in the place of ecology in the curriculum, curricular goals and objectives of ecology, vertical and horizontal relations compared to novice science teachers.

Expert 2's ignorance could be attributed to frequent changes in the science curriculum at the time of the study. At the time of the study, the science curriculum was revised frequently because of the adoption of the new approach. In fact, the science curriculum established in 2000 in line with the constructivist approach, and after this program, starting from the academic year 2005-2006, the name of the 'Science Course' has been changed to the 'Science and Technology Course', and the content of the program has been organized based on the 'spiral approach' different from the previous program. In fact, from the establishment of the Republic of Turkey in 1924 to 2005, a total of 11 various versions of the science curriculum were created

and proposed (Aydemir, 2014). Indeed, Çalık and Ayas (2008), it was noted that Turkish educators were unable to fully implement the previous curriculum before transitioning to the subsequent new curriculum. In fact, expert teachers might be more resistant to changes in curriculum. They tend to follow the curriculum they are accustomed to and might have more difficulties adopting (Aydemir, 2014).

Even, Expert 2 did not prepare a lesson plan for his lesson; rather, he preferred to follow the teacher's guide, which included all of the science topic's goals, objectives, limitations, students' possible misconceptions, and directions for teaching. Novice science teachers, however, covered few curricular objectives of ecology compared to experts.

Among the novice teachers, Novice 1 was more consistent in terms of their combined findings in the objectives. In fact, Novice 2 showed her inconsistency between enacted PCK and believed PCK in terms of knowledge of curricular objectives because she observed to teach more objectives in her ecology lesson than in her lesson plan objectives like expert teachers. One reason for the inconsistency might be Novice 2's limited knowledge of ecology concepts and issues. In fact, studies claimed that teachers need to have good SMK to plan and enact PCK for effective teaching experiences (Childs & McNicholl, 2007; GessNewsome & Lederman, 1995; Kind, 2009; Sanders et al., 1993).

Moreover, both novice and expert science teachers in this study were found to follow the prescribed curriculum by MoNE (2004) strictly, and they did not prefer to teach any ecology concept outside of the curricular program, contrary to the previous studies (Aydemir, 2014; Graf et al., 2011; Kınık, 2022; Lankford, 2010; Şen, 2014; Sağbilge, 2022; Tekkaya & Kılıç, 2012; Tıraş, 2019). However, studies suggested that teachers should be competent in modifying prescribed curriculum in a way to compensate for the student's learning needs (Şen, 2014).

Deficiencies in novice and expert science teachers' SMK identified among all participants might result in not being able to go beyond the specified ecology curriculum. Both novices' and experts' preferences might be feeling confident about teaching ecology and compensate for their limited SMK through strictly the following curriculum, as Hashweh (1987) stated. In fact, Hashweh (1987) stated that when teachers feel inadequate in content knowledge, they tend to use books as a guide to organize the lesson. The other possible reason for not exceeding the curriculum and strictly following the program could be time-saving by teaching in the frame of the prescribed curriculum. The high school entrance exams (SBS) were applied at the end of the year when students in the 8th-grade level in Türkiye. Therefore, teachers tended to guide students in this exam, forced teachers to teach curriculum according to what MoNE prescribed because of the questions regarding curricular objectives (Kınık, 2022; Sağbilge; 2022; Şen, 2014; Tıraş, 2019). Therefore, the context of the novice and expert science teachers was found to have an influence on teachers' decisions regarding curricular objectives. In the study of Bianchini (2012), the beginning science teachers were highly pointed out to be influenced by teaching contexts such as instructional resources in schools.

One possible reason for the difference between novice and expert science teachers' difference in knowledge of the curriculum in general, the curricular objectives, and the place of ecology, in particular, stemmed from the teachers' teaching experiences. As expert science teachers were more familiar with the ecology topics in each grade level from their past experiences, they were potentially aware of the curricular objectives and the place of the topic.

Previous research on inservice science teachers also found expert science teachers to be knowledgeable about curricular objectives and the place of the related science topic (Hanuscin et al., 2010; Lankford, 2010; Melo et al., 2020; Mıhlандız & Timur, 2011; Şen, 2014; Tıraş, 2019). Indeed, with the help of substantive teaching

experience, teachers were found to cultivate 'curricular saliency' that refers to teachers' expertise in determining when to teach a particular topic and how to establish associations between other concepts and topics (Aydın et al., 2014; Geddis et al., 2013).

Additionally, expert science teachers mentioned additional objectives in their lesson plans and during the lessons. For example, Expert 1 mentioned the objectives of the food chain and photosynthesis in her lesson plan; she covered the objectives of aerobic and anaerobic respiration in the lesson. Additionally, she mentioned the food chain and the relation of material cycles with energy flow in food chains in the interviews. Moreover, their instructions exhibited a smoother flow of teaching curricular objectives in coherence compared to novice teachers. Expert teachers' curricular knowledge and competency in transferring their curricular knowledge into practice enabled them to confidently teach ecology (Hanuscin et al., 2011; Sağbilge, 2022; Şen, 2014; Şen et al., 2018). Hanuscin et al. (2011) studied with teachers in a professional development workshop about NOS. They found that teachers became more capable of integrating NOS into their curriculum and improving their knowledge of the curriculum via practice. In the study of Sağbilge (2019), experienced science teachers investigated in the context of seasons, weather, and climate revealed their adequate knowledge of the curriculum interpreted their being familiar with the concepts in the curriculum for many years. Compatible with the current study, Şen et al. (2018) provided evidence in their study for expert teachers' knowledge of curriculum by providing their knowledge of vertical and horizontal relations in cell division and plenty of instructional materials. On the contrary, Şen (2014), in his study with three inservice science teachers, stated three reasons for exceeding the curriculum. One of which was teachers' limited knowledge of cell division, the second one was their personal high interest in the topic, and teachers' beliefs and pedagogical concerns were the third reason, such as for taking students' attention and interest; teachers tended to give daily life examples from outside of the

curriculum. In a follow-up study, Şen et al. (2018) stated that content-expert teachers extended the curriculum objectives in a way to exceed with more complicated concepts that confirmed the findings of the previous study rather than presented contradiction with the current study. Although expert science teachers in this study were labelled as "expert science teachers" according to their experience in science teaching, they were found to have mostly limited knowledge of ecological concepts and issues like novice science teachers. That is, expert science teachers in this study might not be labelled as "content-expert" as in the study conducted by Şen et al. (2018). According to their limited SMK and possessing some misconceptions in ecological concepts, expert science teachers with the novices acted as "curriculum-led" teachers, defined in Şen et al. (2018) study as teachers following the prescribed curriculum firmly.

There were considerable studies with preservice science teachers reported similar findings (Aydın et al., 2015; Graf et al., 2011; Tekkaya & Kılıç, 2012). For instance, in their study with preservice science teachers, Aydın et al. (2015) examined teachers' knowledge of the curriculum in an intervention process that concluded with teachers' enhancement in their knowledge of the curriculum overtime during the process and increased interaction of their knowledge of curriculum with other components of PCK such as their orientation and knowledge of instructional strategies. Graf et al. (2011) studied two Turkish and two German preservice science teachers and found that both Turkish and German preservice science teachers did not have adequate curricular knowledge regarding evolution. Correspondingly, Tekkaya and Kılıç (2012) put forward the difficulties of preservice science teachers in curricular knowledge in evolution and their reasons for frequent changes in the science curriculum in Türkiye.

The instructional context was also found to have an effect on teachers' knowledge of materials. Novice science teachers mentioned experimental materials, computers,

visuals like posters, and 3D materials to provide students effective learning environment in ecology. However, they found inconsistency in their knowledge of materials in which they used different materials in their teaching from their beliefs. They used textbooks, teachers' guidebooks, and boards in their lessons in common. The reason why novice teachers used teacher-centred instructional materials could be explained by their past learning experiences from elementary education to higher education regarding teaching (Aydemir, 2014; Tobin et al., 1994). However, expert science teachers found consistency in their knowledge of materials that they used in teaching ecology and their believed ones for effective teaching in ecology.

Contrary to novices, Expert 1 and Expert 2 used computer-based presentations, role-playing activity materials and posters, and instructional videos, respectively. Studies argued that teachers should adopt curriculum materials regarding students' learning advantages in a particular content area (Bayar & Davis, 2012; DeJong & Van Driel, 2004; Lee & Luft, 2008; Şen, 2014). Consistent with this study's findings, Lee and Luft (2008) examined experienced chemistry teachers' PCK in which they investigated these experienced teachers' repertoires of knowledge of materials in teaching science. Moreover, in their study, knowledge of resources in teaching science was a separate component, and they reached the finding that teachers' knowledge of materials influenced their curricular organization and instructional practices needed to be explored as a separate component of PCK. Therefore, teachers need to have plenty of knowledge of curricular materials and be competent in adjusting these materials.

5.1.2.2 Novice and Expert Science Teachers' Knowledge of Students' Understanding of Science

Students' understanding of science was highly associated and influential component of PCK with the other components and teaching a particular science topic (Carlson

& Daehler, 2019; Cochran et al., 1993; Gess-Newsome, 2015; Magnusson et al., 1999; Shulman, 1987; Veal & MaKinster, 1999). In fact, the studies claimed that the better teachers are aware of the student's requirements and difficulties, the better they provide students with effective learning opportunities (Aydın, 2012; Aydın et al., 2014). Therefore, it is important to compare in terms of whether novice or expert science teachers were better aware of their students' requirements, difficulties, and misconceptions and how they differ from or are similar in providing appropriate learning opportunities in ecology teaching.

Related to the knowledge of requirements for learning ecology, the study's findings briefly indicated that both novice and expert science teachers were knowledgeable about students' prior knowledge and learning difficulties, yet they needed to gain the necessary knowledge of students' misconceptions. The studies generally associated teachers' difficulties in understanding students' learning difficulties with their low SMK. A prior study by Şen et al. (2018) suggested that teachers' subject matter knowledge had a positive impact on teachers' knowledge of students' pre-requisite knowledge and learning difficulties. Other research conducted on different science topics; photosynthesis and plant growth (Käpylä et al., 2009) in seasons, weather, and climate (Sağbilge, 2022); ecosystem (Tıraş; 2019); in electrochemical cells and nuclear reaction (Aydın et al., 2014); in graphs of motion (Mazibe et al., 2018) also confirmed those findings. For example, Sağbilge (2022) found that experienced science teachers in her study had difficulties detecting students' learning difficulties and misconceptions on the topic of seasons, weather, and climate, although they had more than ten years of teaching experience. Käpylä et al.'s (2009) overall results revealed a positive impact of CK on teachers' knowledge of students' understanding, with the findings of increased CK corresponding to increased awareness of students' conceptual difficulties. Consistently, Aydın et al. (2014) claimed that the reason for teachers' high awareness of students' misconceptions, pre-requisite knowledge, and learning difficulties was related to teachers' high SMK in a particular topic.

In some studies, on the other hand, experienced science teachers were found to have a sound understanding of students' pre-requisite knowledge in the context of genetics (Aydemir, 2014); seasons, weather, and climate topic (Sağbilge, 2022); human body systems (Kınık, 2022); ecosystem (Tıraş, 2019), and in cell division (Şen, 2014). In the study conducted by Şen et al. (2018) stated that content experts and curriculum-led teachers had a more extended understanding of students' pre-requisite knowledge than content-novice teachers, especially content experts were reported to be highly capable of detecting students' misconceptions (Aydın, 2012; 1999; Aydın et al., 2014; Canbazoglu, 2008; Canbazoglu et al., 2010; Käpylä et al., 2009; Magnusson et al., Park, & Oliver, 2008a; Rollnick, 2016; Şen et al., 2018).

The other aspect was knowledge of students' difficulties regarding ecology. Regarding students' learning difficulties and misconceptions, it was found that expert science teachers believed that students learned ecology concepts easily and did not possess many learning difficulties and misconceptions, which was a consistent finding with the previous studies as well (Kim & Fortner, 2006; Tekkaya et al., 2001). Although teachers found ecology concepts easy for students to learn, as in this study's findings, Kim and Fortner (2006) stated that teachers' preferred and actual teaching practices in ecology differed because of barriers resulting from time, curriculum, and subject matter knowledge of the teachers. Consistently, teachers in the sample of Tekkaya et al. (2001) perceived ecological concepts as easy for students to comprehend and to transfer to their daily lives.

In the current study, both novice and expert teachers expressed misconceptions about ecological concepts similar to those of students reported in the related literature (Beals et al., 2012; Krall et al., 2009; Summers et al., 2000). However, compared to experts, novice science teachers were found to list more ecology concepts regarding students' difficulties and misconceptions. This meant that novice science teachers had more knowledge about students' misconceptions regarding ecology, which was

a highly contrasting finding with the studies that argued the positive impact of teachers' experience on their knowledge of students' understanding of science (Bravo & Cofré, 2016; Pitjeng-Mosabala & Rollnick, 2018). In their study, Bravo and Cofré (2016) and Pitjeng-Mosabala and Rollnick (2018) found science teachers improved their knowledge of students' misconceptions and learning difficulties in particular science topics when they practice teaching a particular science topic.

However, none of the teachers in the study identified the methods of recovering students' misconceptions in ecology through a conceptual change approach by using concept maps, analogies, and conceptual change texts. Indeed, expert teachers in this study graduated about 30 years before, and they might take teaching methods courses with different teaching approaches, most probably apart from the constructivist approach. Yılmaz, Türkmen, Pedersen, and Huyuguzel-Cavas (2007) stated that the teacher education programs in science restructured according to constructivist theory, multiple intelligence theory, and students-centered approaches beginning in the 2000s. Therefore, although the experts in this study knew what the misconception is, they might have difficulties in grasping students' misconceptions and how to eliminate their misconceptions to change their conceptual understanding in a meaningful way with appropriate elimination methods. Even though expert teachers declared more student-centred approaches for remediating students' learning difficulties and misconceptions than novice science teachers they revealed their awareness to capture students learning difficulties in their ecology lessons, and also they provided immediate feedback.

In fact, similar to the findings of the current study, Halim and Meerah (2002) found pre-service physics teachers had inadequate knowledge of students' misconceptions. The researchers reported that even though teachers detected students' misconceptions, they did not deal with them and underestimated them; they just provided concepts and explanations that were very similar findings of this study

reported both for novice and expert science teachers about knowledge of students' learning difficulties.

Both novice and expert science teachers' difficulties in detecting students' learning difficulties and misconceptions could be explained by their own limited SMK and their misconceptions of ecological concepts and issues. Teachers' misconceptions of ecological concepts might cause them to ignore students' misconceptions. Even novice and expert science teachers were found to have similar conceptions that students found to hold in scientific literacy regarding ecology (Beals et al., 2012; Halim & Meerah, 2002; Kind, 2009; Krall et al., 2009; Özkan, 2001; Özkan et al., 2004; Soylu, 2006; Tıraş, 2019; Wernecke et al., 2018) (see also Section 5.1.1).

5.1.2.3 Novice and Expert Science Teachers' Knowledge of Instructional Strategies

In this study, both expert and novice science teachers were found to use teacher-centred subject-specific strategies in general. However, exceptionally, Expert 1 used student-centred teaching methods for her ecology lessons like role-playing, and presentations. Indeed, role-playing was the teaching strategy used by teachers in different contexts (Clark, 2000; Şen, 2014; Tekkaya & Kılıç, 2012). For example, teachers found to use role-playing in evolution (Tekkaya & Kılıç, 2012); in cell division Şen (2014) and Clark (2000). Additionally, the positive influence on students' learning of role-playing strategy was also supported in the related science literacy (Bailey & Watson, 1998; Clark, 2000; Çokadar & Yılmaz, 2010).

On the contrary, Expert 2 was found to have inconsistency in his thoughts regarding teaching strategies for ecology and his practice. He used teacher-centred instructional strategies; however, he thought that student-centred teaching strategies like field trips and demonstrations were more effective for ecology learning.

Previous research approved that expert science teachers either having limited SMK or knowledge of instructional strategies, act like novice teachers, showing their difficulties in teaching specific science topics (Brickhouse & Bodner, 1992; Chapoo et al., 2014b; Rollnick et al., 2008; Sanders et al., 1993; Şen, 2014). Therefore, the limited content knowledge and knowledge of student-centred instructional strategies regarding ecology could be potential consequences for Expert 2's conflict.

Expert science teachers' preference in instructional strategies to teach science might result from the differences in their knowledge of students' learning difficulties in ecology. In fact, Expert 1 taught ecology lessons with students' presentations and role-playing activities in which she provided explanations and immediate feedback to the students' reflections. Conversely, Expert 2 used instructional videos that he also provided further exemplifications and asked students related questions. The studies mostly claimed that teachers' knowledge of students in teaching particular science topics highly related to their knowledge of instructional strategies (Brown et al., 2012; Carlsen, 1993; Cohen & Yarden, 2008; Gess Newsome, 1992; Hasweh, 1987; Käpylä et al., 2009; Sanders et al., 1993; Şen, 2023; Veal & Kubasko, 2003; Veal et al., 1998).

Novice science teachers are found to underestimate students' difficulties and misconceptions about ecology. Rather, they focused on the curricular objectives they covered. This restriction of novices, especially Novice 1, caused them to teach ecology lessons in a mass. In fact, Novice 1 strictly followed the textbook and the concepts in it, which prevented her from teaching the lesson in coherence and smooth flow between concepts, especially when students asked questions outside of the objectives or disturbed the sequence of the concepts in the book. However, she perceived project and problem-based instructional strategies to teach ecology were effective (Lewinsohn et al., 2014). Moreover, novice science teachers had difficulties wrapping up the students' answers and turning back to the concepts to be focused on.

With these confusions and chaos, they tended to miss students' learning difficulties and even their misconceptions, supporting the previous research findings arguing that experienced teachers were better at adopting their strategies for students' learning difficulties and misconceptions (Gomez & Zwiep, 2008; Halim & Meerah, 2002).

Research conducted regarding PCK revealed mostly that successful teaching is closely tied to teaching expertise (Hashweh, 2005). Even preservice science teachers improved their knowledge of instructional strategies when they were provided with sufficient teaching practice and reflection (Hashweh, 2005; Clermont et al., 1993; Çoruhlu & Çepni, 2010; Nilsson & Loughran, 2011; Park & Oliver, 2008; Pitjeng-Mosabala & Rollnick, 2018; Van Driel, Verloop & De Vos, 1998). Indeed, experienced science teachers exhibited greater confidence and competence in choosing suitable strategies and representations for a particular subject due to their extensive repertoire (Angell et al., 2005; Clermont et al., 1994; Kind, 2009).

Moreover, SMK of teachers was an important determinant for selecting teaching strategies in science (Aydın et al., 2010; Kaya, 2008; Käpylä et al., 2009; Kind, 2009a; Lederman et al., 1994; Lucero et al., 2017; Sağbilge, 2022; Şen, 2014; Traş, 2019; Şen et al., 2022; Tekkaya et al., 2011). Teachers limited SMK in ecology might result in the corresponding findings of using teacher-centred strategies, which were direct teaching and questioning in general. In fact, none of the experts and novices neither mentioned nor applied teaching strategies with the constructivist approach like inquiry, 5E, and conceptual change approaches, although these strategies are highly suggested for effective ecology learning (Eilam, 2012; Jordan et al., 2009). In fact, there were studies conducted with experienced teachers revealed teachers' insufficient knowledge of subject-specific instructional strategies (Aydemir, 2014; Brown et al., 2013; Faikhamta et al., 2009; Kınık, 2022; Şen, 2014; Sağbilge, 2022; Traş, 2019). In the context of teaching genetics, Aydemir (2014); cell division, Şen

(2014); human body system, Kınık (2022); climate change, global warming, and the greenhouse effect, Kınık (2022) and ecosystem, Traş (2019), in their researches, they commonly argued experienced science teachers' using traditional instructional strategies with their deficiency in knowledge of subject-specific strategies.

Teachers could cope with their SMK deficiency, i.e., Expert 1, through their experience in teaching and knowledge of instructional strategies. In fact, repeated practice and reflections provided teachers to gain confidence and enhancement in their teaching as approved by the related science literacy (Bravo & Cofré, 2016; Mazibe et al., 2018; Melo et al., 2020; Pitjeng-Mosabala & Rollnick, 2018; Supprakob et al., 2016; Van Driel et al., 1998). Park and Oliver (2008) studied two biology teachers in teaching evolution and concluded that teachers enhanced their teaching practice by engaging teachers with plenty of training opportunities in evolution. When they examine the novice science teachers' development of TSPCK in the context of the particulate nature of matter, Pitjeng-Mosabala and Rollnick (2018) put forward the positive impact of professional development intervention teachers enrolled verify their improvement in knowledge of subject-specific instructional strategies through substantive teaching practice. Faikhamta, K. Coll, and Roadrangka (2009) conducted a study with preservice chemistry teachers and claimed that teachers improved their knowledge of instructional strategies when they enrolled in PCK-based methods courses.

Apart from limited knowledge of subject-specific strategies, teachers tended to teach what they got accustomed to, learned in their school years and rejected to adopt new approaches to teaching (Aydemir, 2014; Tobin et al., 1994). The overloaded curriculum (Aydın, 2012; Barendsen & Henze, 2019; Samuelowicz & Bain, 1992), time constraints to cover curricular objectives for national examinations (Aydemir, 2014; Kınık, 2022; Şen, 2014; Sağbilge, 2022; Tıraş, 2019), the context of the learning environment (Aydın et al., 2010; Bianchini, 2012; Kınık, 2022; Sağbilge,

2022; Şen, 2019) and their knowledge of learners (Aydın, 2012 Park & Chen, 2012; Boesdorfer, 2015) might be the factors restrict both novice and expert science teachers in deciding teaching strategies in ecology.

Experienced science teachers were found to be more capable of adapting teaching strategies according to students learning difficulties and interests (Angell et al., 2005; Aydın et al., 2017; Clermont et al., 1993, 1994; Van Driel et al., 1998). Consistently, expert science teachers in this study provided immediate feedback to the students. When they captured students' learning difficulties and misconceptions, they supported students with correct explanations and examples. Expert science teachers mentioned they decided on the teaching methods according to the subject matter and adopted their strategies according to students' needs to make the content concrete and understandable (Hume & Berry, 2011). Although they did not use experiments in their lessons, expert science teachers stated the positive impact of experiments (Finn et al., 2002) and field trips (O'Neal & Skelton, 1994; Farmer et al., 2007) to support students' meaningful learning in ecology.

Apart from their inconsistency in the knowledge of subject-specific strategies, novice and expert science teachers' knowledge of topic-specific strategies was found adequate in terms of representations. In fact, they used several representations apart from activities. Indeed, novice science teachers' teaching practices in ecology are mostly based on representations such as drawing figures, daily life examples, comparisons, and analogies. The activities they mentioned were experiments for respiration and photosynthesis, simulations, and animations for material cycles in the interviews. However, they did not perform these activities in their lessons. Expert science teachers also mentioned experiments as the activities in ecology lessons; however, they did not observe to perform during their lessons. Although Novice 1 used analogies, these analogies were very simple and did not represent a good application of the analogy technique. In fact, analogies were used to foster students'

meaningful learning (Brown & Salter, 2010; Mastrilli, 1997; Şen, 2014). As Şen (2014) mentioned, Novice 1 did not apply analogies appropriately with identifying mapping, analog concept, target concept, and breaking points that might be the consequences of teachers' limited understanding of the technique coming from their school years.

Because of the limited knowledge of representations and activities, teachers denoted in science literacy experience trouble and avoid applying some of the representations and activities (Gencer & Akkuş, 2022; Lederman & Latz, 1993; Magnusson et al., 1999). Gencer and Akkuş (2022) reported the change in preservice chemistry teachers' preferences in activities from teacher-centred to student-centered with various different alternatives when teachers engaged in the chemistry methods course.

5.1.2.4 Novice and Expert Science Teachers' Knowledge of Assessment

Novice and expert science teachers focused on assessing students' conceptual understanding in common. They were found to use traditional assessment techniques like questioning for formative assessment and tests for summative assessment. Exceptionally, Expert 1 stated that she assessed students' performances in role-playing and presentation through observation. However, none of the participants mentioned rubrics and portfolios in reference to alternative assessment techniques.

Due to the science teachers' focus on curricular objectives in their ecology lessons, both novices' and experts' attention was predominantly directed toward assessing curricular objectives (Şen, 2014; Tekkaya & Kılıç, 2012; Tıraş, 2019). According to Park and Oliver (2008), teachers' assessment strategies were determined by the curricular objectives. Consistently, novice and expert science teachers in this study might limit their knowledge of assessment to curricular obligations. They

disregarded the assessment of the nature of science, science process skills, and science, technology, and society consistent with the findings of previous studies (Kınık, 2022; Sağbilge, 2022; Şen, 2014; Tıraş, 2019).

There were several studies propose influential aspects of teachers' decisions in assessment. For example, contextual factors (Bianchini, 2012; Şen, 2014; Uşak et al., 2011; Yarden & Cohen, 2009); science teachers' lack of knowledge about alternative assessment methods (Canbazoğlu, 2008; Canbazoğlu et al., 2010; Kaya, 2009; Park & Oliver, 2008; Sağbilge, 2022; Şen, 2014; Şen, & Öztekin, 2019; Üner, 2016); national high school entrance exams (Aydın, 2012; Cohen, & Yarden, 2009; Ekiz Kıran, 2016; Üner, 2016; Kınık, 2022; Tıraş, 2019; Sağbilge, 2022 Şen, 2014; Şen et al., 2018); teachers' orientation toward science (Aydın, 2012; Kınık, 2022; Şen, 2014; Tıraş, 2019), and knowledge of students (Henze et al., 2008; Kınık, 2022; Tıraş, 2019); objectives in the curriculum (Park & Oliver, 2008; Sağbilge, 2022).

When the above factors are taken into account, novice and expert science teachers in this study share similarities. All of the teachers mentioned the time constraints, limited materials and facilities in schools, national central examination for transition to secondary education in Türkiye (SBS), and the overloaded curricular objectives' restriction in deciding assessment methods. Indeed, teachers were expected to cover several topics in a year, restricting the time allocated to a specific topic. Therefore, in general, teachers tended to use traditional assessment techniques because of their convenience in many respects, and they were mostly familiar apart from alternative assessment techniques. Expert 1 said that she enrolled in inservice training regarding assessment techniques. However, similar to the other participants, she mentioned applying traditional techniques like tests with different kinds of questions such as multiple choice, open-ended matching, filling in the blanks, and short answers. These questions, especially multiple-choice questions, were asked to the students by the teachers to enable them to be ready for the SBS [National Central Examination for

Transition to Secondary Education in Türkiye] (Şen, 2014). In fact, in the SBS, students were expected to answer several multiple-choice questions prepared by MoNE in a restricted allowed time. In the same manner, as the questions in the SBS applied at the 8th grade in line with the curricular objectives, teachers tended to ask questions in line with the curricular objectives to make them familiar with the questions in SBS.

Novice 1 mentioned there could be different ways to assess students in ecology because of the nature of the topic, which requires the active participation of students to learn effectively. In fact, she taught that ecology included concepts that triggered students' skills and exemplified field trips and observations to support students' learning. Expert 1 and Expert 2 were also said to prefer to assess students in a way to enables them to observe and interpret ecological issues in experiments, field trips, demonstrations, and so on. On the contrary, Novice 2 mentioned she did not know any other assessment techniques apart from traditional exams in pre-interviews. However, in post-interviews, she stated that she assessed students' interest and participation through classroom observations, and she also mentioned she assessed students with their activities in the lesson, like posters. Therefore, it was likely that Novice 2 changed her mind in terms of her knowledge of assessment after teaching experience in ecology. Supporting the finding, Yılmaz-Yendi (2019) stated teachers' requirement for professional development training in how to apply alternative assessment techniques forces teachers to use traditional assessment methods. Akdeniz and Gürçay (2018) stated that preservice science teachers enhanced their knowledge of assessment in heat and temperature when they enrolled in intervention. Indeed, there were studies supported the concern about teachers' limited knowledge of alternative assessment techniques arise from their undergraduate education (Canbazoglu, 2008; Canbazoglu et al., 2010; Kaya, 2009; Park & Oliver, 2008; Sağbilge, 2022; Şen, 2014; Şen, & Öztekin, 2019; Üner, 2016).

Novice teachers and Expert 1 assessed students' prior knowledge at the beginning of the lessons by questioning. Classroom interactions were used for formative assessment from both novices and experts in their lessons. In line with the research regarding PCK (Aydın, 2012; Ekiz Kıran, 2016; Friedrichsen et al., 2009; Kınık, 2022; Sağbilge, 2022; Şen, 2014; Tıraş, 2019; Üner, 2016), teachers used formative and summative assessment to assess students in ecology. With an experienced biology teacher, Chapoo, Thathong, and Halim (2014a) found that she used formative assessment techniques like multiple-choice tests, concept mapping, classroom observation, peer evaluation, written journals, drawings of the students, and homework assignments. Contrary to this study, the experienced biology teacher in Chapoo et al.'s study was highly aware of students' learning difficulties, student-centered instructional methods like inquiry, experimentation, and active learning strategies to provide students effective learning environment. Therefore, teachers' knowledge of students' understanding, instructional methods, and knowledge of curriculum might have an influence on their preference for assessment techniques as well. In fact, Magnusson et al. (1999) included knowledge of assessment into their PCK model to point out that assessing students' learning outcomes resulting from the instructions of teachers stresses the interactions of other PCK components. There were studies stressed teachers' knowledge of students' understanding affected teachers' knowledge of assessment (Kınık, 2022; Park & Chen, 2012; Park & Oliver, 2008; Sağbilge, 2022; Tekkaya et al., 2011; Şen, 2014; Tıraş, 2019). One more contradiction with this study and supporting the argument of the previous study was in the study of Aydın et al. (2017). Aydın and her colleagues (2017) found experienced science teachers in their study used alternative assessment techniques in sustainable development. In fact, they stated experienced teachers were well knowledgeable in students' understanding of the content and used student-centred instructional methods as well.

However, some of the researchers claimed that teachers' knowledge of assessment was discrete and not in relation to the other PCK components (Barnett & Friedrichsen, 2015; Gess-Newsome & Latz, 1994; Gess-Newsome, 2015; Großschedl et al., 2015; Kaya, 2008; Şen, 2014) and there were studies argued that assessment was not topic specific (Gess-Newsome, 2015). This study's findings regarding expert and novice science teachers approved that novice and expert science teachers' knowledge of assessment was not in relation to their experience.

To conclude, in this section, novice and expert science teachers' SMK and the components of PCK (KoC, KoL, KoIS, KoA) were discussed to compare their knowledge components in ecology teaching in the light of related science literacy. In a broad sense, novice and expert science teachers had similar aspects in some of the knowledge bases to some extent and differed as well. Their limited SMK in ecology and their KoA were the components they found to have similarities; KoC, KoSU, and KoIS were the components novice and expert science teachers of this study found to have divergent characteristics, as mentioned in the previous sections. In the next section, implications and recommendations were presented.

5.2 Implications and Recommendations

The study's findings put forward several outstanding implications and recommendations for science teachers, curriculum developers, policymakers, and researchers about PCK and SMK in ecology. The findings of the study showed that novice and expert science teachers had insufficient knowledge of ecological issues. Additionally, novice and expert science teachers' PCK differ in some of the components in many respects.

Their limited SMK in ecology elucidated the novice and expert science teachers' need for inservice training on ecology to improve their SMK. In the current study, it

was revealed that novice and expert science teachers had either limited knowledge or misconceptions about some of the ecological concepts and issues. Earlier studies highlighted the teacher's role in transferring their SMK into the forms students could learn effectively (Carre, 1998; Shulman, 1986) and teachers were denoted as the main sources of students' learning difficulties and misconceptions in science literacy (Demirdöğen et al., 2016; Thomson & Logue, 2006; Sadler & Sonnert, 2016), novice and expert science teachers need to be supported with professional development training to enhance their SMK in specific science topics, ecology as well.

Ecology is an interdisciplinary topic (Özkan et al., 2004). The knowledge deficiencies in ecological concepts and issues might cause students to learn other science topics and issues incorrectly or deficient as well. Therefore, the professional development programs for inservice teachers should be developed by taking into account the main misconceptions detected in teachers and students in ecology and provide teachers with profound SMK in ecological concepts and issues to better capture students learning difficulties and misconceptions as well as to provide students effective learning opportunities with their integrated SMK. These professional development training also should integrate and put emphasis on the associated concepts in ecology. Moreover, the content of this training should contain the interaction of humans and the environment in order to increase teachers' awareness of interaction and teach their students accordingly. The findings of the current study about novice and expert science teachers' difficulties in ecological concepts and issues contributed important feedback to inservice training and curriculum developers to shed light on novice and expert science teachers' SMK difficulties to provide adequate and appropriate content and facilities in ecology teaching.

In this study, novice science teachers, who had just started their profession, had approximately one year of teaching experience, whereas experienced teachers had

around 30 years of experience in science education. Despite having a background in science education and recently completing their university training, novice teachers demonstrated limited knowledge in ecology concepts such as energy, energy flow in ecosystems, food chain, food web, ecological niche, and photosynthesis. On the other hand, experienced teachers received three years of education at education institutes, including training in ecology during their programs. After many years of their education, they emphasized that they continued to improve their professional competence through further training and voluntary participation in various activities. However, similar to novice teachers, some knowledge deficiencies and misconceptions in certain ecology topics were found among experienced teachers.

Moreover, this study aimed to compare novice and expert science teachers' PCK in teaching ecology. Therefore, the focus was on novice and expert science teachers' substantive knowledge rather than syntactic knowledge. It is recommended for future research to examine novice and expert science teachers' syntactic knowledge. Through this combination of research in science, teachers' syntactic and substantive knowledge enlightens their knowledge of SMK components regarding ecology in a holistic way.

Teaching experience in a specific content area does not promise highly structured, well-integrated PCK (Friedrichsen et al., 2009; Hanussin et al., 2020; Traş, 2019). In fact, in the current study, not only novice science teachers but also expert science teachers revealed difficulties in some of the PCK components. In this study, there were two expert science teachers found to have differences in their PCK components, although they had been teaching ecology for approximately the same many years. The emerged differences in PCK components could be explained by their context, background knowledge, and the interactions of PCK components. Even expert teachers in this study were found to behave like novice science teachers who shared similar deficiencies, such as methods for recovering students' misconceptions.

Teachers, either expert or novice, need to be informed about students' learning difficulties and misconceptions and need sufficient training on detecting and remedying these difficulties and misconceptions in particular science content. Conversely, novice science teachers were found to be better able to recommend curricular materials in ecology teaching. Therefore, it was implied in this study that teaching years do not assure the well-integrated PCK and good teaching practice in a particular science concept. Moreover, teachers should be facilitated with up-to-date teaching approaches, and alternative assessment techniques to better able to serve learning opportunities to their students in ecology.

Although expert science teachers were better able to compete with teaching ecology with the help of integrating some of the components of PCK, such as knowledge of curriculum, knowledge of students' understanding, and knowledge of instructional strategies, they were found to have limited knowledge in the knowledge of assessment. None of the teachers identified alternative assessment methods to trigger the application of constructivist approaches for active learning. In fact, novice science teachers focused highly on SMK when they experienced teaching and highly reflected on their PCK.

As studies claimed SMK as a prerequisite for good PCK (De Jong, 2000; Kind, 2009; Van Driel, De Jong & Verloop, 2002), novice and expert science teachers' PCK suggested being investigated in further research after the participation of inservice training on ecology aiming to support their SMK.

This study has some recommendations for further research. First, in this study, Magnusson et al. (1999) et al. PCK model was used to compare novice and expert science teachers' PCK. In the proposed model, there were five components, one of which was excluded in this study. Therefore, it is suggested that further studies to

compare novice and expert science teachers' orientations toward teaching ecology that was excluded from the scope of this study.

Second, the transformative PCK model of Magnusson et al. (1999) consented to PCK components integrated. Therefore, every five components in the model interacted. Although it was not the purpose of this study to examine the interactions of PCK components of teachers, their interactions were revealed implicitly. However, it is also recommended to examine novice and expert science teachers' PCK and students' achievement by using the Gess-Newsome (2015) PCK Consensus Model and the interactions of the teaching and learning process by using Carlson & Daehler's (2019) Refined Consensus Model of PCK.

Third, both two novice and two expert science teachers in the current study were teaching science in public schools. The private schools had more opportunities and better teaching facilities. Therefore, replicating the current study with teachers working in private schools contributed to understanding the context's influence on PCK. Moreover, expert and novice science teachers from different countries may show different PCK aspects. Therefore, further research contributes more to comparing the PCK of novice and expert science teachers in teaching ecology with participants from different cultures.

Fourth, in order to gain a deep understanding of the influence of science teachers' experience on their PCK, pre-service science teachers' PCK in teaching ecology is recommended to be compared in further research.

Last, the findings of this study were gathered in 2010. This circumstance may have led to different results for some components of novice and expert science teachers' PCK compared to today's conditions of novice and expert science teachers. Indeed, nowadays, teachers might be teaching ecology using smart boards, technological tools, and digital teaching materials. However, during the time of data collection, the

use of such technological and digital tools was not common and was severely rare in schools. As the data collection year was earlier, not only did instructional materials and strategies differ compared to current circumstances, but also the ecology curriculum was changed. Therefore, it is important to take into account the current study's comparison of novice and expert science teachers' PCK in teaching ecology presented in light of the ecology curriculum prescribed by MoNE (2009). Therefore, it is highly recommended that this study be replicated under current conditions to compare novice and expert science teachers PCK in teaching ecology.



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APPENDICES

A. Subject Matter Knowledge Instruments Regarding Ecology Used in The Study (In Turkish)

EK 1. İÇERİK GÖSTERİMİ MÜLAKAT SORULARI

Sayın öğretmenim,

Merhaba, ben Özge TAŞTAN. Orta Doğu Teknik Üniversitesi, Eğitim Fakültesi İlköğretim Fen Eğitimi Bölümü yüksek lisans öğrencisiyim. Ortaokul fen bilimleri öğretmenlerinin ekoloji 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 cevaplandırmayabilirsiniz. Görüşme esnasında toplanan veriler tamamen gizli tutulacak, kimlik bilgileriniz kesinlikle gizli kalacak, veriler ve kimlik bilgileri herhangi bir başka yerde kullanılmayacaktır. Görüşmeyi sesli kayıt cihazı ile 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.

BÖLÜM 1. KİŞİSEL BİLGİLER

1. Bugüne kadar almış olduğunuz eğitimden bahseder misiniz?

1. Hangi yüksek öğrenimden mezun oldunuz?
2. Master veya doktora dereceniz var mı? Varsa hangi konu üzerine?

3. Yüksek öğrenimde almış olduğunuz;
- i.Eğitim dersleri nelerdir?
 - ii.Fen eğitime yönelik almış olduğunuz dersler nelerdir?
 - iii.Biyoloji ve özellikle ekoloji ile ilgili aldığınız dersler nelerdir?
- d. Yüksek öğrenimden sonra;
- i.Eğitim,
 - ii.Fen eğitimi,
 - iii.Biyoloji ve özellikle ekoloji eğitimi aldınız mı? Aldıysanız ne tür bir eğitim aldınız? Hizmet içi eğitimler, kurslar, vb. Aldıysanız bu eğitimlerin içeriğinden bahseder misiniz?
2. Kaç yıldır öğretmenlik yapıyorsunuz?
- a. Kaç yıldır Fen ve Teknoloji öğretmenliği yapıyorsunuz?
 - b. Fen ve Teknoloji ve biyoloji eğitiminde öğretmenlik deneyimleriniz nasıl gerçekleşti?
 - c. Ne kadar süre ile bu öğretmenlikleri yaptınız?
 - d. Hangi sınıf seviyelerinde öğretmenlikler yaptınız?
 - e. Devlet okulu, özel okul, özel ders, dersane, vb.
- f. Dersaneler veya yayın evlerinin test kitapları için vb. amaçla biyoloji /ekoloji üzerine soru hazırlıyor musunuz?
3. Biyoloji /ekoloji konularında bilgi edindiğinizi düşündüğünüz bilgi kaynakları nelerdir?
- a. Eğitim, seminer, kurs vb.; herhangi bir kurumun vermiş olduğu eğitimi aldınız mı?
 - b. Hobi: özellikle biyoloji ve ekoloji üzerine
 - i. Kitap okuma,

- ii. Gazete veya dergi haberlerini takip etme,
 - iii. Televizyon haberlerini takip etme,
 - iv. İnternette araştırma yapma,
 - v. Belgesel izleme gibi hobileriniz var mı? Buralardan ne düzeyde bilgi elde ettiğinizi düşünüyorsunuz?
- c. Çalışma arkadaşlarınız veya başka insanlarla biyoloji/ ekoloji üzerine konuşmak veya konuşmaları dinlemekten hoşlanır mısınız?

BÖLÜM 2. YARI YAPILANDIRILMIŞ EKOLOJİ KONUSU ALAN BİLGİSİ SORULARI

1. Ekoloji kavramlarını kullanarak bir kavram haritası çizer misiniz?
2. Aşağıdaki kavramları nasıl tanımlarsınız?
 - a. Ekosistem:
 - b. Habitat:
 - c. Ekolojik niş:
 - d. Komünite:
 - e. Tür:
 - f. Popülasyon:
 - g. Biyolojik çeşitlilik:
 - h. Ayrıştırıcı:
 - i. Besin zinciri:
 - j. Besin ağı:
 - k. Enerji piramidi:

3. “Sınıfınıza kapalı ekosistemin nasıl oluşturulacağını öğretiyorsunuz ve öğrencilerinizden bu konuyla ilgili bir ev ödevi hazırlamalarını istiyorsunuz. Öğrencilerinizden Ceren ve Ali okuldan sonra ödevine başlamak için buluşurlar. Ali, Ceren’e yapacakları ödevleri için şöyle bir öneride bulunur, ‘üç tane cam kavanoz alalım. Bir tanesinin içerisine tüm cansız şeyleri; taş, toprak, su, hava gibi, koyalım ve üzerine bir ampul koyalım güneşi simgelemesi için. Diğer kavanoza sadece bitkileri ve üçüncüne de sadece hayvanları koyalım. Her şeyi ayrı tutmak en temiz olacaktır!’.

- Ali’nin ekosistem önerisini nasıl değerlendirirsiniz.
- Üç kavanozda zaman içerisinde neler olabileceğini tahmin ediniz. Tahminlerinizi açıklayınız.

4. Üreticilerin ekosistemdeki önemi nedir?
5. Tüketicilerin ekosistemdeki önemi nedir?
6. Ayrıştırıcıların ekosistemdeki önemi nedir?
7. Üreticiler, Tüketiciler ve Ayrıştırıcılar arasındaki ilişkiyi açıklayınız.
8. Nesli tükenme üzere olan türlerin karakteristik özellikleri nelerdir?
9. Enerji nedir?
10. Ekosistemlerdeki enerji akışını nasıl açıklarsınız?
11. Bitkinin besini nedir? Bitki besinini nasıl yapar? Açıklayınız.
12. Fotosentezin amacı nedir? Açıklayınız.
13. Fotosentezin mekanizmasını açıklar mısınız?
14. Sizce fotosentez, Termodinamiğin 1. ve 2. kanunlarına uyar mı? Nedenlerini açıklayınız.

15. Atmosferdeki karbondioksit konsantrasyonunun artması, fotosentez hızında da sürekli bir artışa neden olur mu? Cevabınızı açıklayınız.
16. Bir besin zinciri çizebilir misiniz?
17. Besin zincirinde ayrıştırıcılar nerede yer alır?
18. Besin zincirinin uzunluğu sınırlı mıdır? Diğer bir deyişle, bu uzunluğu belirleyen unsur var mıdır?
- Bir önceki soruda neden besin zincirinizi’lı (4’lü, 5’li...) çizdiniz? 7-8-9-10’lu da olabilir mi?
19. Besin zincirindeki oklar neyi ifade etmektedir? Açıklayınız.
20. “Nektar, bir kelebek, bir kuş, ayrıştırıcılar” verilen organizmalar, verilen sıraya göre, bir besin zinciri oluşturdukları düşünülebilir mi?
21. İnsan vücudu içerisindeki bakteriler bir besin zincirinin parçası mıdır?
- Eğer öyle ise bu besin zincirini oluşturan diğer canlılar neler olabilir?
22. Madde döngüleri ve besin zinciri arasında bir ilişki var mıdır? Açıklayınız.
23. Besin ağı ve besin zincirinin farkı nedir?
24. Enerji piramidi nedir?
- Bir enerji piramidi çizebilir misiniz?
 - Neden piramit şeklinde olduğunu açıklar mısınız?
 - Enerji piramidi bir şeyi simgeler mi?
 - Ayrıştırıcılar enerji piramidinde hangi basamakta yer alırlar? Açıklayınız.

- Enerji piramidinin tersine çevrilmesi mümkün müdür (sivri uç altta, geniş kısım üstte olacak şekilde)? Açıklayınız.

25. Hintlilerin ve Çinlilerin et yerine daha çok pirinç tüketmelerinin nedeni sizce ne olabilir?

- Diğer bir deyişle, Hintliler ve Çinliler neden Amerikalılar kadar et tüketmezler?

26. Aşağıda bir besin ağı örneği yer almaktadır. Bu besin ağındaki:

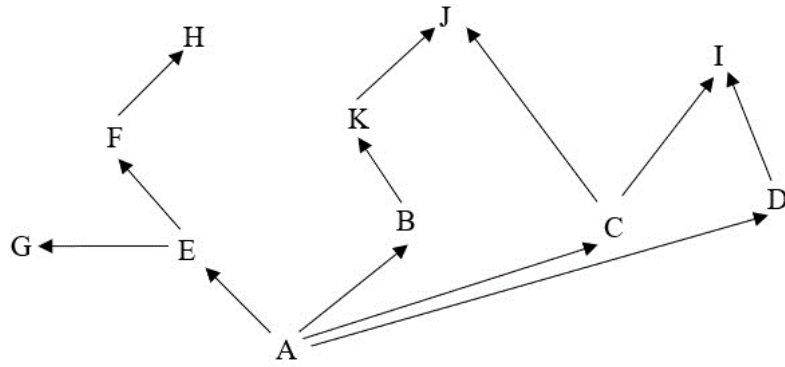
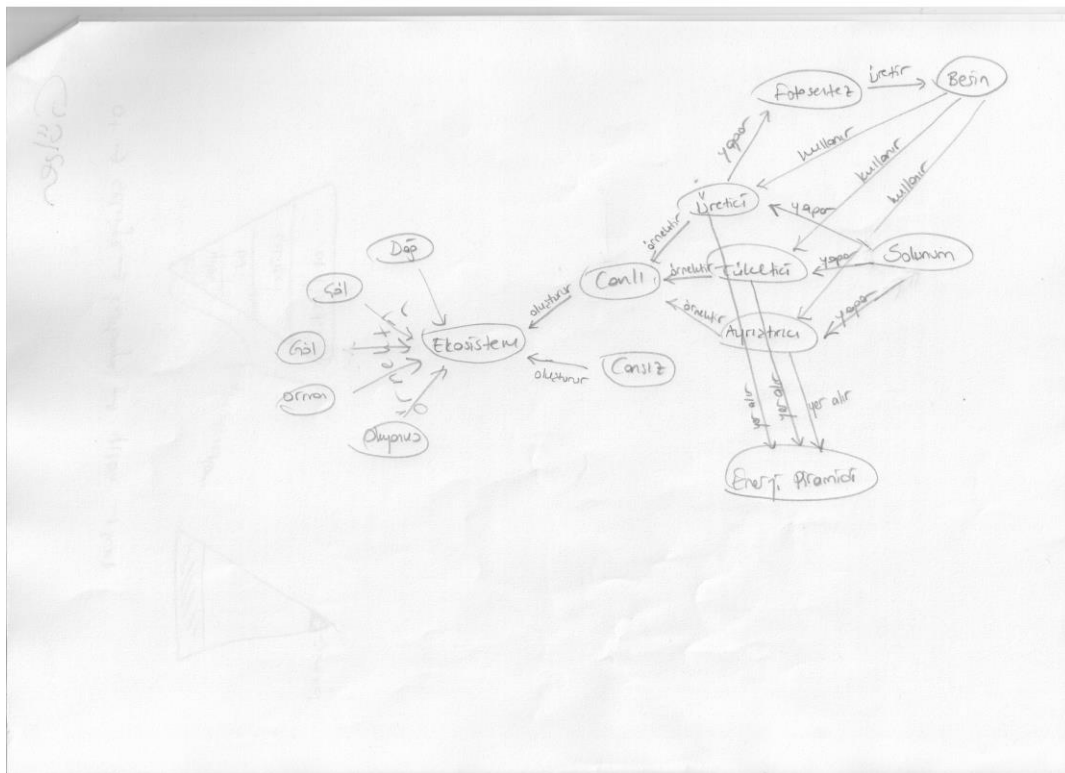


Figure 4. 3; 4.7; 4.11; 4.17 A sample of food web (Webb & Bolt, 1990)

1. F populasyonundaki ani azalma, H populasyonunu nasıl etkiler? Açıklayınız.
2. H populasyonundaki ani artış, F populasyonunu nasıl etkiler? Açıklayınız.
3. E populasyonundaki ani azalma, H populasyonunu nasıl etkiler? Açıklayınız.
4. G populasyonundaki ani artış, F populasyonunu nasıl etkiler? Açıklayınız.

- ### B. Original Drawings of Novice 1



556

ot → selinge → kurbaga → yılan → kuş

Figure 4.2 Novice 1 Food Chain Drawing

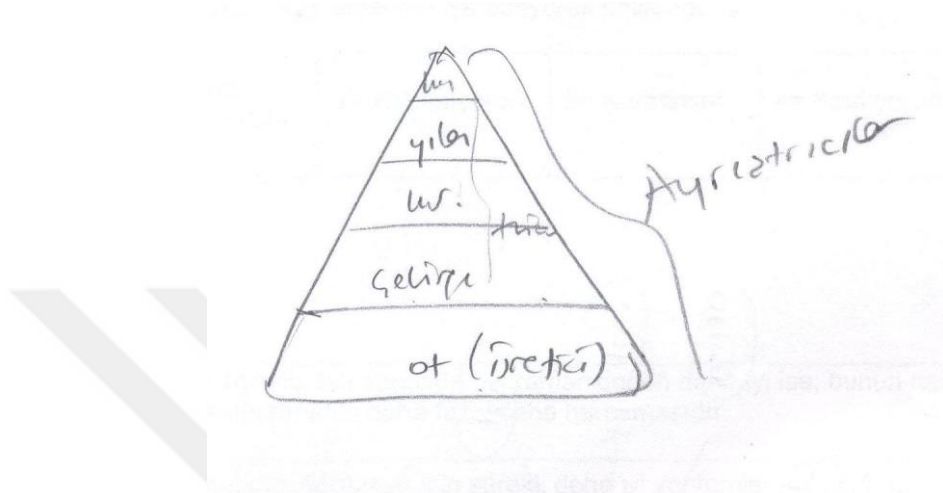


Figure 4.4 Novice 1 Energy Pyramid

C. Original Drawings of Novice 2

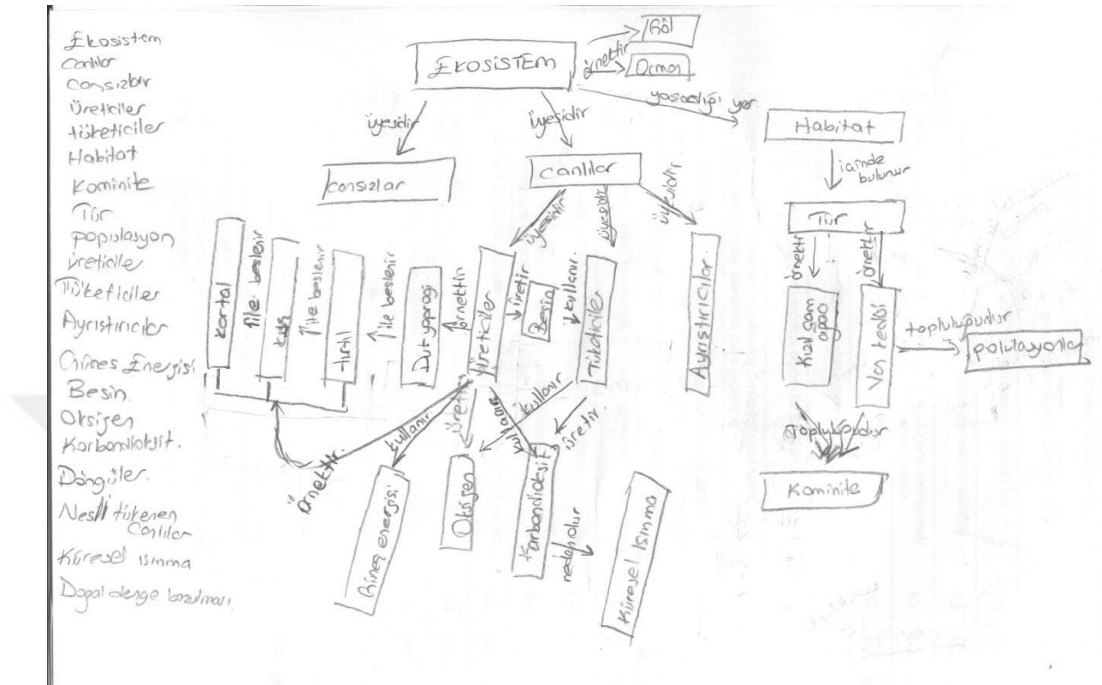


Figure 4.5 Novice 2 Concept Map

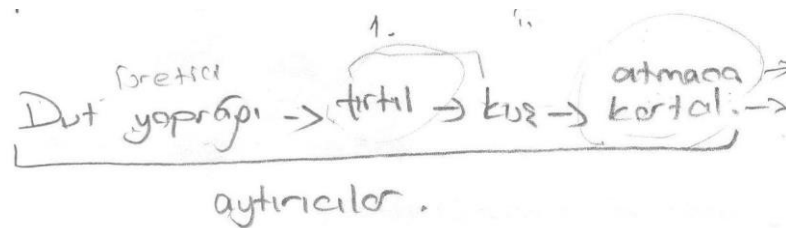


Figure 4.6 Novice 2 Food Chain Drawing

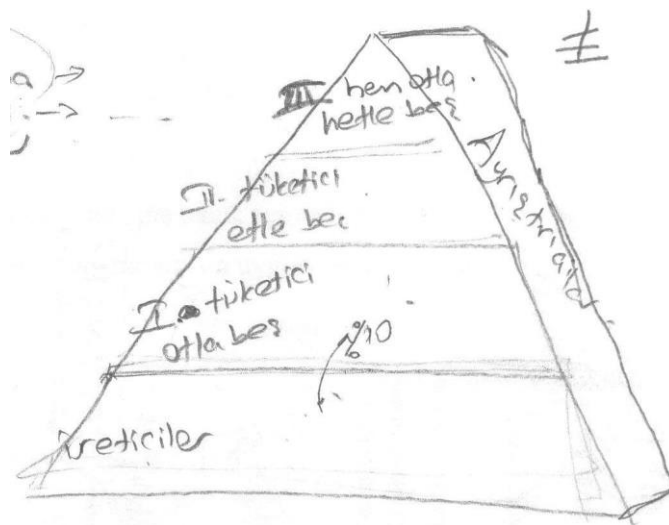


Figure 4.8 Novice 2 Energy Pyramid Drawing

D. Original Drawings of Expert 1

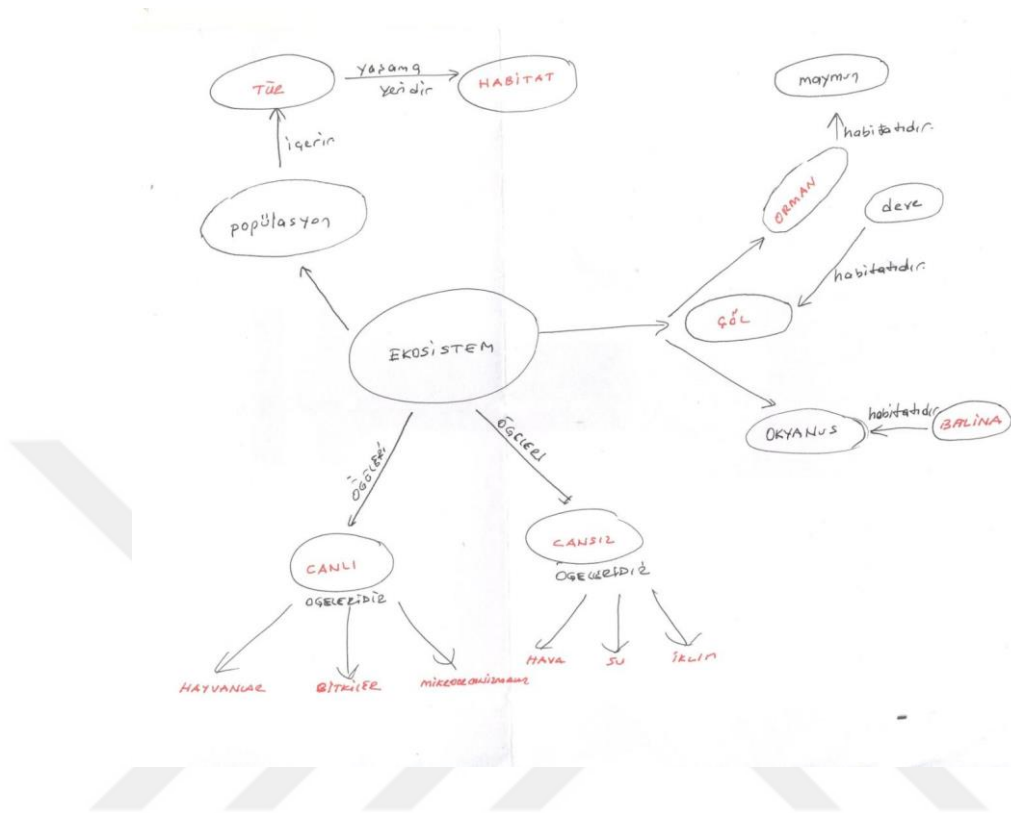


Figure 4.9 Expert 1' Concept Map

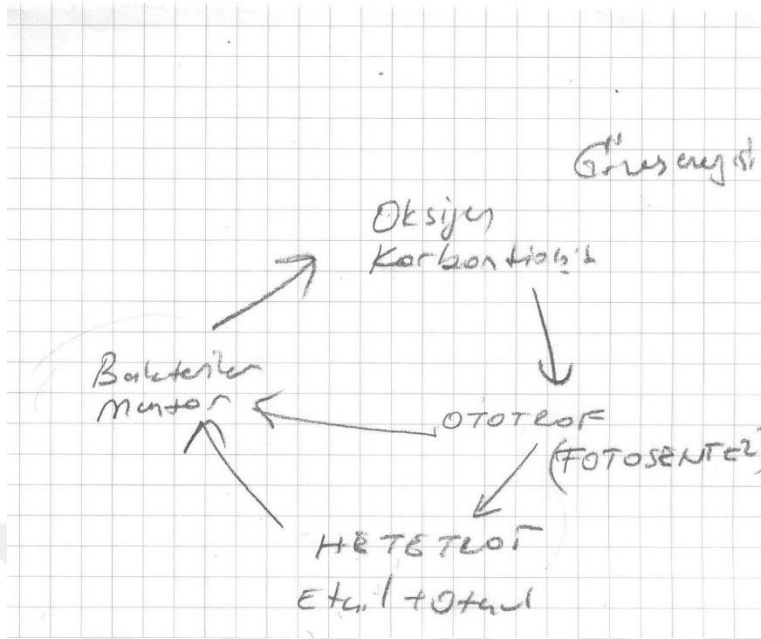


Figure 4.10 Expert 1 Food Chain Drawing

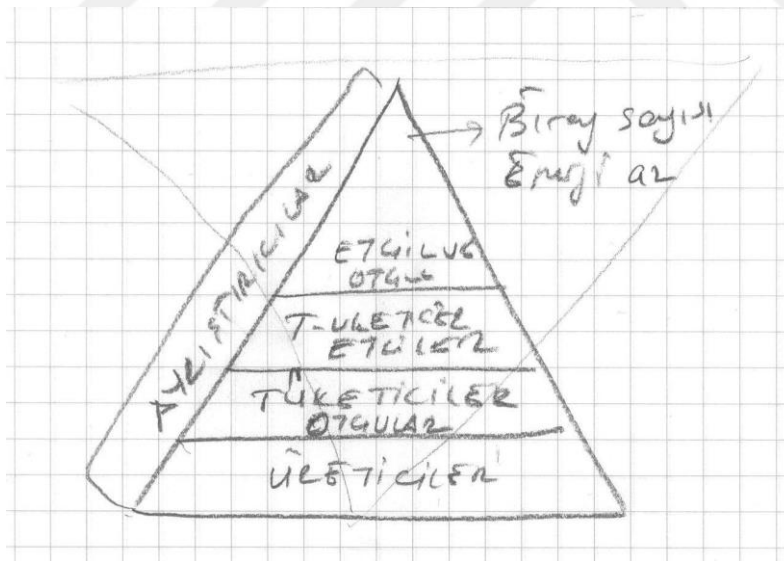


Figure 4.12 Expert 1 Energy Pyramid Drawing

E. Original Drawings of Expert 2

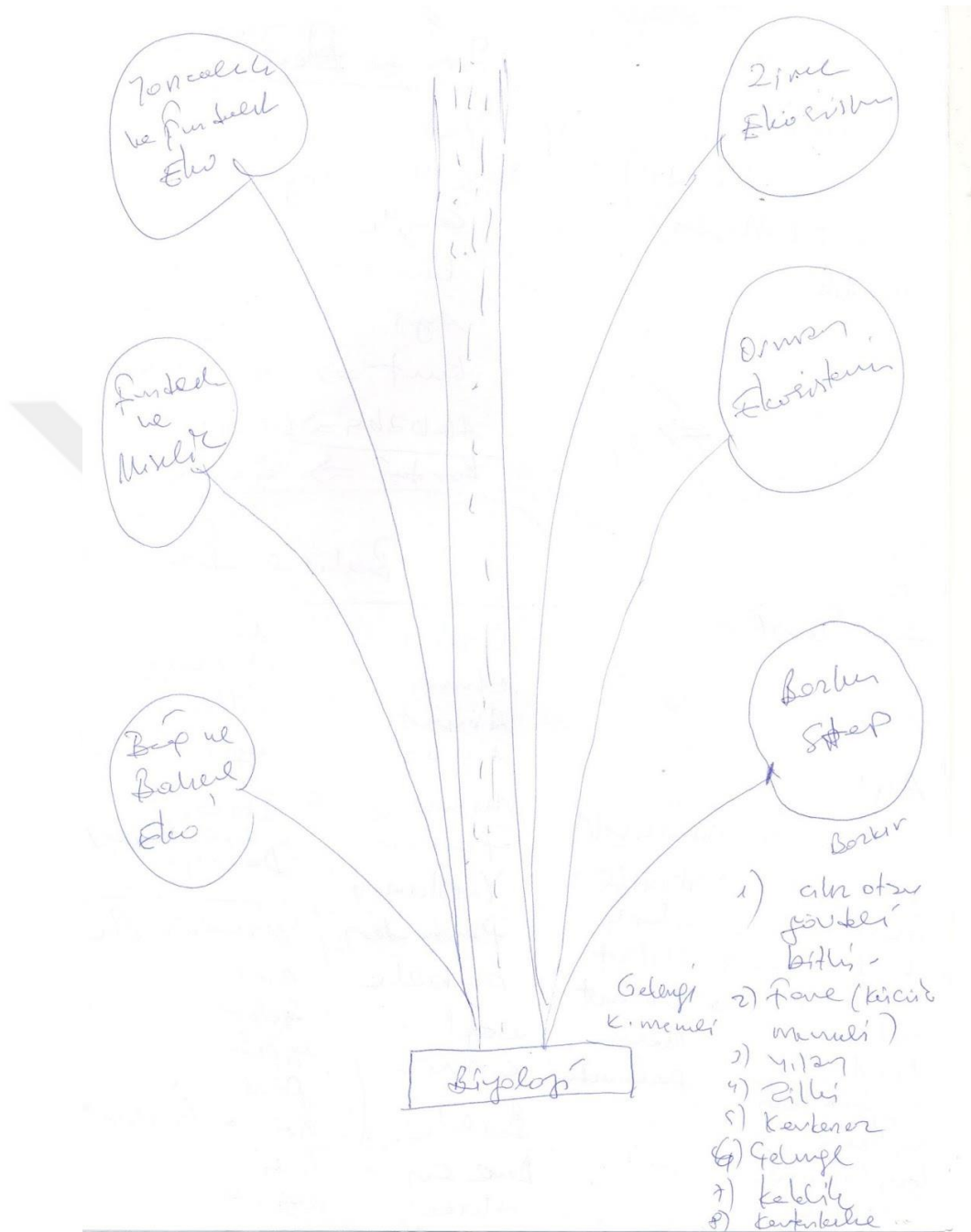


Figure 4.15 Expert 2' Concept Map

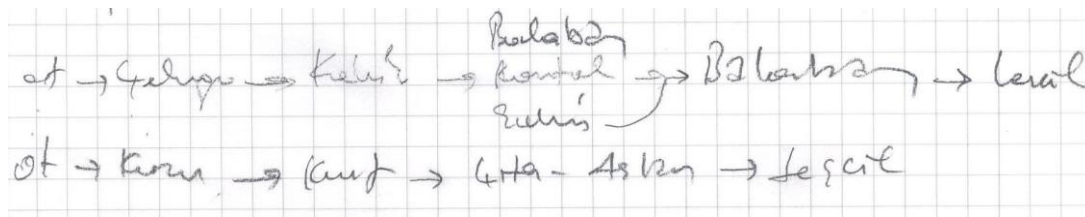


Figure 4.16 Expert 2 Food Chain Drawing

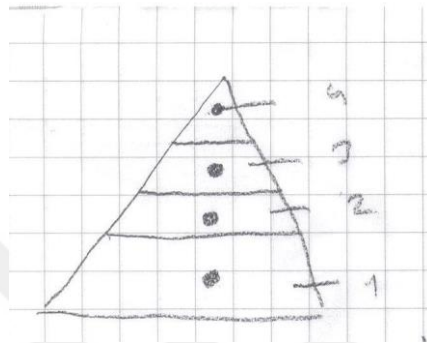


Figure 4.18 Expert 2's Energy Pyramid Drawing

F. PCK Instruments Used in The Study (In Turkish) - Yarı Yapılandırılmış Pedagojik Alan Bilgisi Ön Görüşme Soruları

BÖLÜM 1: MÜFREDAT BİLGİSİ

1. Ekoloji konularının ilköğretim müfredatındaki yerini biliyor musunuz?
 - Ekoloji ünitesi kaçınıcı sınıfta/sınıflarda yer almaktadır?
 - 8. sınıf düzeyinde kaçınıcı ünite de ekoloji konuları yer almaktadır?
 - Ekoloji ünitesine müfredatta 8. sınıf düzeyinde kaç haftalık süre ayrılmış? Sizce belirtilen süre yeterli midir?
 - Ekoloji ünitesinin müfredatta belirtilen amacı nedir? Sizce ne olmalıdır?
 - 8. sınıf ekoloji ünitesinin kazanımları nelerdir?
 - Sizce ekoloji konularının kazanımları belirlenen sınıf seviyelerine uygun mu?
 - Sizce müfredatta belirtilen kazanımlar, öğrencilere bu konuda kazandırılmak istenen beceriler açısından yeterli midir?
 - Kazanımları değiştirme şansınız olsaydı hangi kazanımları nasıl değiştirdiniz?
2. Ekoloji konuları için ne gibi etkinlikler müfredatta mevcut? Sizce bu etkinlikler yeterli ve ilköğretim öğrencilerine uygun mu?

BÖLÜM 2: ÖĞRENCİ BİLGİSİ

1. Öğrencilerinizin ekoloji konularını öğrenmeleri sizce önemli mi? Nedenlerini açıklayınız.
2. Ekoloji ünitesi ile ilgili öğretmek istediğiniz en önemli şeyler sizce nelerdir?
 - Neden bunların önemli olduğunu düşünüyorsunuz?

3. Dersinizde öğrettiğiniz _____ ekoloji kavramını öğretmenizdeki amaçlarınız veya hedefleriniz nelerdir? (ekosistem, besin zinciri, besin ağı, enerji)

- Öğrencilerinizin bu kavramı öğrenmesi niçin önemli?

4. Bu kavramın öğretilmesini etkileyen öğrencilerinize ait bilgileriniz nelerdir?

- Öğrencilerinizin ders için gerekli olan hazır bulunuşluluğu; bilgi, beceri/yetenek, öğrenme stilleri gibi bilgiler.
- Öğrenme güçlükleri; soyut olması, kavram yanlışları, daha önceki öğrenim ve yaşantısı ile bağlantısının az olması veya uzak olması, problem çözme ile ilgili yaşanan zorluklar gibi bilgiler.

5. Sizce öğrencilerin başarıları her konu alanında farklılık gösteriyor mu? Açıklayınız.

6. Ekoloji ünitesiyle ilgili öğrencileriniz sınıfa günlük hayata ilişkin örnekler getiriyorlar mı? Nedir bu örnekler?

7. Öğrencileriniz ekoloji konularını anlamada zorlanıyorlar mı?

- En zorlandıkları kavramlar nelerdir? Nedenleri nedir?
- Kolay anladıkları kavramlar nelerdir? Nedenleri nedir?

8. Ekolojide öğrettiğiniz en önemli şey nedir?

9. Ekoloji konusunda sizin bildiğiniz ancak öğrencilere öğretmediğiniz bilgiler var mı? Varsa bu bilgiler neler?

10. Kavram yanlışlığı nedir?

11. Öğrencilerde kavram yanlışlığının var olduğunun farkına nasıl varırsınız? Açıklayınız.

- Öğrenciler büyüyüp geliştikçe bu kavram yanlışlarında bir değişme meydana gelir mi? Açıklayınız.

12. Ekoloji ünitesinde yer alan kavramlara ilişkin öğrencilerde gözlemlediğiniz temel kavram yanlışları nelerdir?
13. Öğrencilerdeki ekoloji konularına ilişkin kavram yanlışlarının temel sebepleri/kaynaklar neler olabilir?
14. Bir öğrencinin ekoloji konularına ilişkin kavram yanlışına sahip olması bu konuya ilişkin gerçekleştirilen öğretim sürecini nasıl etkiler?
15. Öğrencilerin ekoloji konularına ilişkin sahip oldukları kavram yanlışlarını düzeltmelerine nasıl aracılık edersiniz, bu konuda onlara nasıl yardımcı olursunuz?
16. Öğrencilerin kavram yanlışlarını gidermek için hangi öğretim yöntem ve stratejileri kullanılabilir?

BÖLÜM 3: ÖĞRETİM STRATEJİLERİ BİLGİSİ

1. Ekoloji konusunu işleyeceğiniz ders için nasıl bir hazırlık yaparsınız?
 - Diğer konular için de hazırlık süreci benzer midir? Yoksa her konu için farklı mıdır?
 - Bu hazırlık için hangi kaynaklardan faydalanırsınız?
2. İlköğretim öğrencilerine ekoloji konularını öğretirken ne tür öğretim methodlarını ve yöntemlerini kullanmayı düşünüyorsunuz?
 - Sunum esnasında kullandığınız gösterimler, örnekler, modeller, analogiler, hatıralar vb. tercih sebepleriniz nelerdir?
 - Öğrencilerinizle yaptığınız veya öğrencilerinize yaptırdığınız aktiviteler; araştırma, problem çözme, deney, oyun, drama, bilgisayar simülasyonu tercih sebepleriniz nelerdir?
 - Öğrencilerinizin ekoloji konularını iyi anlamaları için neler yaparsınız?

- Ekoloji konularının öğretilmesi için en uygun ve etkili öğretim yöntemi veya methodu sizce nedir? Bu yönetim uygulanabilirliği nedir? Siz derslerinizde uyguluyor musunuz?
 - Ekoloji öğretimi sırasında ne tür materyallerden yararlanıyorsunuz? Ulaşamadığınız ancak öğretim sırasında kullanılması gerektiğini düşündüğünüz materyaller var mı? Varsa nelerdir?
3. Öğretim stratejinizi seçmenizi etkileyen öğrencilerinize ait bilgiler nelerdir?
- Öğrencilerinizin ders için gerekli olan hazır bulunuşluluğu; bilgi, beceri/yetenek, öğrenme stilleri gibi bilgiler.
 - Öğrenme güçlükleri; soyut olması, kavram yanılgıları, daha önceki öğrenim ve yaşantısı ile bağlantısının az olması veya uzak olması, problem çözme ile ilgili yaşanan zorluklar gibi bilgiler.
4. Bu öğretim stratejinizi seçmenizi etkilediğini düşündüğünüz diğer faktörler nelerdir?
- Kendinize ait faktörler nelerdir? (konu bilgisi, pedagojik yeterlilik vb.)
 - Diğer faktörler nelerdir? (Zaman, konu yoğunluğu veya miktarı, öğretme ortamı ve materyal, okulun ve öğrencinin sosyal durumu, okul yönetimi vb.)
 - Bu faktörler öğretiminizi nasıl etkilediğini düşünüyorsunuz?
 - Bu faktörlere göre öğretiminizi neleri değiştirdiniz ve neleri adapte ettiniz?

BÖLÜM 4: DEĞERLENDİRME STRATEJİLERİ BİLGİSİ

1. Öğrencilerinizin ekoloji konularını anlayıp anlamadıklarını nasıl ölçersiniz? Açıklayınız.
- Sizce bu yöntem yeterli mi?

- Ekoloji konularının ne kadarının öğrenciler tarafından anlaşıldığını ölçmek amacıyla kullanılabilecek en etkili ölçme tekniği nedir?
 - Ekoloji konularına ilişkin başka ne tür ölçme ve değerlendirme yaklaşımları kullanılabilir?
2. Öğrencileri ekoloji ünitesi ile ilgili olarak ne zaman değerlendirirsiniz?
- Önbilgilerini ölçer misiniz? Nasıl ölçersiniz? Ne zaman ölçersiniz?
3. Öğrencilerinizde neyi değerlendirmeyi amaçladınız?
- Bilgi, beceri, vb
4. Değerlendirme metodunuzu belirlemenizi etkileyen faktörler nelerdi?
- Pedagojik bilgi (değerlendirme yöntemleri bilgisi)
 - Konu bilgisi
 - Öğrenciye ait bilgi

G. Post-Interview PCK Questions of Novice 1

1. Ders planı hazırlamak nasıl bir deneyimdi? Sizce bir problem var mıydı?
Varsa nedir?
2. Bu ders için nasıl bir hazırlık yaptınız? Nelerden faydalandınız? Neler yaptınız? Ders hazırlığınızın niteliği kazanımlara ulaşmadaki başarıyı nasıl etkiler?
3. Ders planını hazırlarken ne tür şeyleri düşünerek tasarladınız?
 - Dikkatinizi hangi noktaya yoğunlaştırdınız?
 - Sizce planınızın en önemli kısmı nedir?
4. Ekoloji konularına ilişkin işlemiş olduğunuz dersi nasıl değerlendirirsiniz?
 - Yeterli ve eksik yönleri var mıydı dersinizin? Zorlandığımız şeyler var mıydı? Varsa nelerdir? Sizde nedenleri nedir?
 - Kullandığınız yöntem ve metotlar etkili oldu mu? Ne kullansaydınız daha etkili olurdu?
 - Dersinize ne tür etkinlikler uyguladınız? Başka ne tür etkinlikler yapılabilirdi?
 - Dersinizde ne tür görseller, şekiller, örnekler kullandınız?
 - Bir sonra ki sefer bunu böyle değil de şöyle yapmalıyım dediğiniz bir şey var mı? Varsa nedir?
 - Ekoloji konularını işlemede herhangi bir değişiklik yapmayı düşünüyor musunuz? Evetse, Hangi konuda, ne gibi?

- Kullandığınız materyaller etkili oldu mu? Ne kullansaydınız daha etkili olurdu?
- Öğrencilerin ekoloji kavramlarına ilişkin zorlukları var mıydı? Varsa nelerdi?
- Öğrencilerin kavram yanılgıları var mıydı? Varsa nelerdi? Kavram yanılgılarını gidermek için neler yaptınız? Ne tür yöntemler uyguladınız?
- Öğrencilerinizi ekoloji konusunda nasıl değerlendirdiniz?
- Tüm bu değerlendirme yöntemlerinin öğrencilerin ekolojik kavramları anlayıp anlamadığını belirlemek için yeterli olduğunu düşünüyor musunuz?
- Değerlendirme metodunuz belirlerken hangi bilgileriniz etkili oldu?

H. Post-Interview PCK Questions of Novice 2

1. Ders planı hazırlamak nasıl bir deneyimdi? Sizce bir problem var mıydı? Varsa nedir?
2. Bu ders için nasıl bir hazırlık yaptınız? Nelerden faydalandınız? Neler yaptınız? Ders hazırlığınızın niteliği kazanımlara ulaşmadaki başarıyı nasıl etkiler?
3. Ders planını hazırlarken ne tür şeyleri düşünerek tasarladınız?
 - Dikkatinizi hangi noktaya yoğunlaştırdınız?
 - Sizce planınızın en önemli kısmı nedir?
4. Ekoloji konularına ilişkin işlemiş olduğunuz dersi nasıl değerlendirirsiniz?
 - Yeterli ve eksik yönleri var mıydı dersinizin? Zorlandığınız şeyler var mıydı? Varsa nelerdir? Sizde nedenleri nedir?
 - Kullandığınız yöntem ve metotlar etkili oldu mu? Ne kullansaydınız daha etkili olurdu?
 - Dersinizde ne tür görseller, şekiller, örnekler kullandınız?
 - Bir sonra ki sefer bunu böyle değil de şöyle yapmalıyım dediğiniz bir şey var mı? Varsa nedir?
 - Ekoloji konularını işlemede herhangi bir değişiklik yapmayı düşünüyor musunuz? Evetse, Hangi konuda, ne gibi?
 - Dersinizde hangi materyalleri kullandınız?

- Kullandığınız materyaller etkili oldu mu? Ne kullansaydınız daha etkili olurdu?
- Öğrencilerin ekoloji kavramlarına ilişkin zorlukları var mıydı? Varsa nelerdi?
- Öğrencilerin kavram yanılgıları var mıydı? Varsa nelerdi? Kavram yanılgılarını gidermek için neler yaptınız? Ne tür yöntemler uyguladınız?
- Öğrencilerinizi ekoloji konusunda nasıl değerlendirdiniz?
- Tüm bu değerlendirme yöntemlerinin öğrencilerin ekolojik kavramları anlayıp anlamadığını belirlemek için yeterli olduğunu düşünüyor musunuz?
- Değerlendirme metodunuz belirlerken hangi bilgileriniz etkili oldu?

İ. Post-Interview PCK Questions of Expert 1

1. Ders planı hazırlamak nasıl bir deneyimdi? Sizce bir problem var mıydı?

Varsa nedir?

2. Bu ders için nasıl bir hazırlık yaptınız? Nelerden faydalandınız? Neler yaptınız? Ders hazırlığınızın niteliği kazanımlara ulaşmadaki başarıyı nasıl etkiler?

3. Ders planını hazırlarken ne tür şeyleri düşünerek tasarladınız?

- Dikkatinizi hangi noktaya yoğunlaştırdınız?
- Sizce planınızın en önemli kısmı nedir?

4. Ekoloji konularına ilişkin işlemiş olduğunuz dersi nasıl değerlendirirsiniz?

- Yeterli ve eksik yönleri var mıydı dersinizin? Zorlandığınız şeyler var mıydı? Varsa nelerdir? Sizde nedenleri nedir?
- Öğrencilerinizin ekoloji konularını daha iyi anlayabilmeleri için neler yaptınız?
- Sizce ekoloji konularını diğer fen konularını olduğu gibi etkili öğretebiliyor musunuz? (öğretmenliğinizin ilk yıllarıyla kıyaslarsanız daha mı etkili yoksa aynı mıdır?)
- Dersinizde hangi materyalleri kullandınız?
- Dersinizde kullandığınız materyalleri kullanma amacınız nedir?
- Kullandığınız materyaller etkili oldu mu? Ne kullansaydınız daha etkili olurdu?

- Kullandığınız yöntem ve metotlar etkili oldu mu? Ne kullansaydınız daha etkili olurdu?
- Dersinizde ne tür görseller, şekiller, örnekler kullandınız?
- Dersinizde ne tür etkinlikler gerçekleştirdiniz?
- Bir sonra ki sefer bunu böyle değil de şöyle yapmalıyım dediğiniz bir şey var mı? Varsa nedir?
- Ekoloji konularını işlemede herhangi bir değişiklik yapmayı düşünüyor musunuz? Evetse, Hangi konuda, ne gibi?
- Öğrencilerin ekoloji kavramlarına ilişkin zorlukları var mıydı? Varsa nelerdi?
- Öğrencilerin kavram yanlışları var mıydı? Varsa nelerdi? Kavram yanlışlarını gidermek için neler yaptınız? Ne tür yöntemler uyguladınız?
- Öğrencilerinizi ekoloji konusunda nasıl değerlendirdiniz?
- Tüm bu değerlendirme yöntemlerinin öğrencilerin ekolojik kavramları anlayıp anlamadığını belirlemek için yeterli olduğunu düşünüyor musunuz?
- Değerlendirme metodunuz belirlerken hangi bilgileriniz etkili oldu?

J. Post-Interview PCK Questions of Expert 2

1. Ders planı hazırlamak nasıl bir deneyimdi? Sizce bir problem var mıydı?
Varsa nedir?
2. Bu ders için nasıl bir hazırlık yaptınız? Nelerden faydalandınız? Neler yaptınız? Ders hazırlığınızın niteliği kazanımlara ulaşmadaki başarıyı nasıl etkiler?
3. Ders planını hazırlarken ne tür şeyleri düşünerek tasarladınız?
 - Dikkatinizi hangi noktaya yoğunlaştırdınız?
 - Sizce planınızın en önemli kısmı nedir?
4. Ekoloji konularına ilişkin işlemiş olduğunuz dersi nasıl değerlendirirsiniz?
 - Yeterli ve eksik yönleri var mıydı dersinizin? Zorlandığınız şeyler var mıydı? Varsa nelerdir? Sizde nedenleri nedir?
 - Diğer fen konularıyla kıyasladığınız da ekoloji üzerine işlemiş olduğunuz dersle ilgili neler söyleyebilirsiniz? (farkları, benzerlikleri sizin ve öğrenciler açısından)
 - Dersinizi her zaman videolar ve öğrencilere aralarda yönlendirdiğiniz sorularla mı işlersiniz?
 - Sizce ekoloji konularını diğer fen konularını olduğu gibi etkili öğretebiliyor musunuz? (öğretmenliğinizin ilk yıllarıyla kıyaslarsanız daha mı etkili yoksa aynı mıdır?)

- Bir sonra ki sefer bunu böyle değil de şöyle yapmalıyım dediğiniz bir şey var mı? Varsa nedir?
- Öğrencilerinizi ekoloji konusunda nasıl değerlendirdiniz?
- Tüm bu değerlendirme yöntemlerinin öğrencilerin ekolojik kavramları anlayıp anlamadığını belirlemek için yeterli olduğunu düşünüyor musunuz?
- Değerlendirme metodunuz belirlerken hangi bilgileriniz etkili oldu?



K. Lesson Plan of Novice 1 (Turkish Version)

DERS PLANI

BÖLÜM I

Dersin adı	Fen ve Teknoloji
Sınıf	8
Ünitenin Adı/No	Canlılar ve Enerji İlişkileri / 6
Konu	Besin Zincirinde Enerji Akışı
Süre	40+40=80'

BÖLÜM II

Öğrenci Kazanımları /Hedef ve Davranışlar	Besin zincirindeki canlılarla ilgili olarak öğrenciler; Besin zincirlerinin başlangıcında üreticilerin bulunduğu çıkarımını yapar. Üreticilerin fotosentez yaparak basit şeker ve oksijen ürettiğini belirtir. Fotosentez için nelerin gerekli olduğunu sıralar. Fotosentezi denklemlerle ifade eder. Fotosentezin canlılar için önemini tartışır. Üreticilerin fotosentez ile güneş enerjisini kullanılabildiğini enerjiye dönüştürdüğünü ifade eder.
Öğrencilerin Önbilgileri	Öğrenciler önceki sınıflarda “ekosistemler”, “besin zinciri”, “besin ağları” konuları ile ilgili temel kavramları, ayrıca ülkemiz ve dünyadaki çevre sorunlarını 7. sınıf “Canlılar

	ve Hayat” öğrenme alanı, “İnsan ve Çevre” ünitesinde öğrenmişlerdi.
Ünite Kavramları ve Sembolleri	Üretici, tüketici, ayrıştırıcı, fotosentez, klorofil, besin zinciri, besin ağı
Güvenlik Önlemleri (Varsa):	-
Öğretme-Öğrenme-Yöntem ve Teknikleri	Düz anlatım, Soru-cevap
Kullanılan Araç, Gereçler (Öğretmen, öğrenci)	Ders kitabı, Öğretmen kılavuz kitabı, Tahta, Tebeşir
Öğretme-Öğrenme Etkinlikleri	
Özet	
Giriş Dersin başında öğrencilere yeni bir üniteye giriş yapılacağı vurgulanacak ve ünitenin adı tahtaya yazılacaktır. Ünitedeki konu başlıkları okunarak öğrencilerin bu üniteye neler öğreneceklerine dikkat çekilecektir. Ardından ünitenin başındaki ünitenin geneli ile ilgili olan merak uyandırıcı sorular okunup, öğrencilerle kısa tartışmalar yapılacaktır. Bu aşamada burada yer alan soruların cevapları tam olarak verilmeyip öğrencilerin daha çok merak etmeleri sağlanacaktır. Oğrencilerin hazırbulunuşluk düzeyleri de bu soru-cevap süresince gözlenip, dersin gelişme bölümünde bu düzeye göre ilaveler veya kısaltmalar yapılacaktır. Gelişme Ünite ile ilgili genel bir bilgi verilip, öğrencilerin geçmiş bilgileri yoklandıktan sonra ünitenin ilk konusu olan “<i>Besin Zincirinde Enerji Akışı</i>” konusuna giriş yapılacaktır. Öğrencileri hedeften haberdar etmek için öncelikle ünitenin anahtar kavramları okutulacaktır. Ardından 7. sınıfta öğrendikleri “besin zinciri” kavramına	

geri dönölerek öđrencilerin tahtaya bir besin zinciri çizmeleri istenecektir. Çizilen bu besin zincirinde hata varsa bu hataların öncelikle öđrenciler tarafından tespit edilmesi sağlanacaktır. Ardından besin zincirinin her halkası tek tek incelenerek ilk halkanın önemi vurgulanacaktır.

Besin zincirinde yer alan canlıları “üretici” ve “tüketici” olarak gruplandırmaları istenecektir.

Üretici kavramı üzerinde durularak, üreticilerin önemini öđrencilerin bulmasını sağlayacak yönlendirici sorular öđrencilere yöneltilecektir. Ardından tüketici kavramı açıklanacaktır. Son olarak ise ayrıştırıcı kavramı üzerinde durulacaktır.

Bu üç kavram açıklandıktan sonra tahtadaki besin zincirine geri dönölerek bu zincirdeki okların neyi temsil ettiđi öđrencilere sorulacaktır. Tartışmanın ardından bu okların enerji aktarımını gösterdiđi açıklanacaktır.

Ardından besin zincirindeki bir halkanın çıkarılmasının zinciri oluşturan diđer canlıları nasıl etkilediđi tartışılacaktır. Öncelikle tüketicilerden biri çıkarılarak bu soru sorulacaktır. Öđrencilerin zinciri oluşturan bazı canlıların sayılarının artacađını bazılarının ise azalacađını tahmin etmeleri beklenir. Ardından zincirin ilk halkası (üretici) silinip sonuçları sorulacaktır. Tartışmaların ardından besin zincirinin tamamen yok olacađı çıkarımını yapmaları sağlanır. Bu noktada besin ađı kavramı da açıklanacaktır.

Üretici ve tüketici kavramları iyice açıklandıktan sonra tahtadaki besin zincirinin bu sefer besin piramidi olarak çizilmesi istenecektir. Ayrıştırıcıların yeri bu piramid üzerinde gösterilecektir.

Üretici, tüketici ve ayrıştırıcı kavramları öđrenciler tarafından kavrandıktan sonra kitaba geri dönölerek kitaptaki bu terimler ile ilgili açıklamalar okutulur.

Ardından çalışma kitabında yer alan “3. Etkinlik: Besin Ağı” yaptırılarak konunun iyice pekişmesi sağlanır.

Etkinliğin ardından üreticilere neden üretici denildiği, ne ürettikleri gibi sorular sorularak fotosentez konusuna giriş yapılır. Fotosentezin denklemi tahtaya yazılarak bitkilerin fotosentezde kullandıkları ve açığa çıkardıkları maddeler yazılır. Bu kavramlar üzerinde tek tek durularak her birinin önemi açıklanır.

Fotosentezin sadece bitkiler için değil bütün canlılar için önemi vurgulanır. Ardından çalışma kitabındaki “4. Etkinlik: Fotosentez Nerede Gerçekleşir?” ve “5. Etkinlik: Sorularla Fotosentez” etkinlikleri yaptırılır.

Sonuç

Dersin sonunda genel bir tekrar yapılır. Soru-cevap ile öğrencilerin eksik veya yanlış öğrenmeleri tespit edilmeye çalışılır.

BÖLÜM III

Ölçme-Değerlendirme • Bireysel öğrenme etkinliklerine yönelik Ölçme Değerlendirme • Grupla öğrenme etkinliklerine yönelik Ölçme Değerlendirme • Öğrenme güçlüğü olan öğrenciler ve ileri düzeyde öğrenme hızında olan öğrenciler için ek Ölçme-Değerlendirme etkinlikleri	Dersin işlenişi sırasında öğrencilerin sorulan sorulara verdikleri cevaplar, tartışmalara katılma düzeyleri ölçme değerlendirme amacıyla kullanılır.
Dersin Diğer Derslerle İlişkisi	-

BÖLÜM IV

Planın Uygulanmasına İlişkin Açıklamalar	-

L. Lesson Plan of Novice 1 (English Version)

PART I

Lesson	Science and Technology
Class	8
Unit /No	Living things and energy relations / 6
Topic	The energy flow in food chain
Time	40+40=80'

PART II

Students' Learning Objectives	Related to organisms in the food chains, students are able to; ▪ Infer those producers are at the beginning of food chains. ▪ State that producers produce simple sugars and oxygen by photosynthesis. ▪ List what is required for photosynthesis. ▪ Express photosynthesis with an equation. ▪ Discuss the importance of photosynthesis for living things. ▪ State that producers convert solar energy into usable energy by photosynthesis.
Students' Prior Knowledge	The students had already learned the fundamental concepts related to 'ecosystems,' 'food chains,' and 'food webs' in previous grades, as well as the environmental issues in our country and

	the world, in the 7th-grade learning area 'Living Beings and Life' and the unit 'Humans and the Environment'
Unit's Concepts and Symbols	Producer, consumer, decomposer, photosynthesis, chlorophyll, food chain, food web
Precautions (if there is)	-
Instructional Strategies and Techniques	Direct instruction, question-answer
Materials and instruments (students, teacher)	Textbook, Teachers Guidebook, Board, chalk
Teaching-Learning Activities	-
Summary	
Introduction At the beginning of the lesson, it will be emphasized that a new unit is going to be introduced, and the name of the unit will be written on the board. The topic headings of the unit will be read, drawing attention to what students will learn in this unit. Then, thought-provoking questions related to the overall theme of the unit will be read, and short discussions will be held with the students. At this stage, the answers to these questions will not be provided fully, but rather students will be encouraged to become more curious. During this question-and-answer session, the students' preparedness level will also be observed, and adjustments or abbreviations will be made in the development section of the lesson according to this level.	

Development

After providing a general overview of the unit and assessing students' prior knowledge, the first topic of the unit, 'Energy Flow in the Food Chain,' will be introduced. To inform the students about the objectives, the key concepts of the unit will be presented initially. Then, students will be asked to draw a food chain on the board, based on what they learned in the 7th grade about the 'food chain' concept. If there are any errors in the drawn food chain, the students will be encouraged to identify them first. Subsequently, each link of the food chain will be examined individually, emphasizing the importance of the first link.

Students will be asked to categorize the living organisms in the food chain as 'producers' and 'consumers.' Emphasis will be placed on the concept of producers, and guiding questions will be directed to help students discover the importance of producers. Next, the concept of consumers will be explained, followed by a focus on decomposers. After explaining these three concepts, students will be asked what the arrows in the food chain on the board represent. Following the discussion, it will be explained that these arrows represent energy transfer.

Once the students have grasped the concepts of producers, consumers, and decomposers, explanations from the textbook related to these terms will be read to them. Then, the students will be given the 'Activity 3: Food Web' in the workbook to reinforce the topic.

After the activity, students will be asked questions such as why producers are called producers and what they produce, leading to an introduction to the topic of photosynthesis. The equation of photosynthesis will be written on the board, and the substances plants use and release during photosynthesis will be listed. Each of these concepts will be explained separately, highlighting their importance.

At the end of the lesson, a general review is conducted. Through a question-and-answer session, an attempt is made to identify students' deficiencies or misconceptions in their learning.

Conclusion

At the end of the lesson, a general review is conducted. Through a question-and-answer session, an attempt is made to identify students' deficiencies or misconceptions in their learning.

PART III

Measurement-Assessment • Assessment and Evaluation for Individual Learning Activities • Assessment and Evaluation for Group Learning Activities • Additional Assessment and Evaluation Activities for Students with Learning Difficulties and Students with Advanced Learning Pace	During the course of the lesson, the answers students give to questions asked and their level of participation in discussions are used for assessment and evaluation purposes.
Relations with other Disciplines	-

PART IV

Explanations regarding implementation the plan	-

M. Lesson Plan of Novice 2 (Turkish Version)

DERS PLANI

BÖLÜM I

Dersin adı	Fen ve Teknoloji
Sınıf	8
Ünitenin Adı/No	Canlılar ve Enerji İlişkileri
Konu	Besin zincirinde enerji akışı
Süre	80 dk

BÖLÜM II

Öğrenci Kazanımları /Hedef ve Davranışlar	Besin zincirinin başlangıcında üreticilerin bulunduğu çıkarımını yapar. Üreticilerin fotosentez yaparak basit şeker ve oksijen ürettiğini belirtir. Fotosentez için nelerin gerekli olduğunu bilir.
Öğrencilerin Önbilgileri	Ekosistemler, besin zinciri, besin ağları
Ünite Kavramları ve Sembolleri	Üretici, tüketici, ayrıştırıcı, fotosentez, klorofil
Güvenlik Önlemleri (Varsa):	
Öğretme-Öğrenme-Yöntem ve Teknikleri	Soru-cevap, besin zinciri oluşturma
Kullanılan Araç, Gereçler (Öğrenen, öğrenci)	Öğretmen, öğrenci, tahta, ders kitabı, defter, küçük kağıtlar
Öğretme-Öğrenme Etkinlikleri	Besin ağı oluşturma Fotosentez denklemi oluşturma
Özet	
Giriş	

Öğretmen derse girişte üretici, tüketici, ayrıştırıcı, fotosentez, klorofil bu konunun anahtar kavramları ile ilgili ne bildiklerini öğrencilere tek tek sorulur. Başta onlara cevap vermeden düşünceleri alınır. Eğer yanlışlar varsa diğer öğrencilere de söz verilerek doğru açıklama yapılması sağlanır.

Gelişme

Öğrencilere ders kitabın da yer alan besin zinciri ile ilgili verilen resim incelenir. Resim incelenirken. Resmin üzerindeki besin zinciri ile ilgili kavramlar okutularak ve okunan kavramlar üzerinde öğrencilerle birlikte yorumlar yapılır. Ardından resim ile ilgili öğrencilere aşağıdaki sorular yöneltilerek onlardan cevaplamaları beklenir. Doğru cevaplar öğrencilere direk verilmez onların bulması sağlanır.

- Resimde hangi canlılar bulunmaktadır?
- Bu canlılar arasında gerçekleşen beslenme ilişkileri nasıldır?
- Buradaki besin zincirine örnekler verebilir misiniz?
- Bütün besin ağlarında ortak canlı grupları var mı?
- Bu gruplar neler olabilir?
- Bu grupları genel isimleri var mıdır?
- Bu gruplar arasında nasıl bir beslenme ilişkisi olmalıdır?

Öğrencilerin besin zinciri ile ilgili bu öğrendiklerinden sonra onlara küçük kağıtlar dağıtılarak onlardan birer besin zinciri oluşturmaları istenir. Öğrencilerin oluşturduğu besin zincirleri toplanır. Bu besin zincirleri tahtaya yazılır. Ortak yazılan hayvanlar birleştirilerek besin ağı oluşturulur. Böylece onların bir besin ağı oluşturmaları sağlanır. Ardından öğrencilere ders kitabındaki *besin ağı* etkinliği yaptırılır. Öğrencilere besin zincirinin ilk halkasına dikkat çekilir. Neden ilk halkasında üretici canlılar olduğu ve bu canlılara neden üretici denildiği sorulur? Öğrencilerden fotosentez yanıtı gelene kadar sorularla yönlendirilir.

Öğrencilere geçmişte öğrendikleri fotosentez konusu hatırlatılır. Tahtaya büyük bir yaprak çizilir. Bu yaprakta fotosentez olayı için neler gerekli, fotosentez

sonucunda neler oluşur? Fotosentezin yaprağın içindeki hangi kısmında gerçekleşir. Bunların hapsi yaprak üzerinde gösterilerek öğrencilere görsel öğeler kullanılarak öğretilir.

Öğrencilere klorofil hakkında bilgi verilir. Klorofil akıllarında kalıcı olması için fıstıklı dondurmanın renginin yeşil olmasını sağlayan içindeki klorofil maddesi olduğu dondurmanın içindekiler kısmına bakılarak gösterilir.

Sonuç

Fotosentez denlemi son kez tahtaya yazılarak. “*Fotosentez her ıřıkta yani yapay ıřıkta gerekleřir mi gerekleřirde hangi renk ıřıkta fotosentez en iyi hangi renk ıřıkta fotosentez en kt gerekleřir?*” sorusu yneltilerek ders bitirilir mi?

BLM III

lme-Deęerlendirme • Bireysel ęrenme etkinliklerine ynelik lme Deęerlendirme • Grupla ęrenme etkinliklerine ynelik lme Deęerlendirme • ęrenme glę olan ęrenciler ve ileri dzeyde ęrenme hızında olan ęrenciler iin ek lme-Deęerlendirme etkinlikleri	ęrencilerin dersteki katılımına baęlı olarak sre deęerlendirmesi yapılır
Dersin Dięer Derslerle İliřkisi	-

BLM IV

Planın Uygulanmasına İliřkin Aıklamalar	-

N. Lesson Plan of Novice 2 (English Version)

PART I

Lesson	Science and Technology
Class	8
Unit /No	Living things and energy relations / 6
Topic	The energy flow in food chain
Time	80 min.

PART II

Students' Learning Objectives	Related to organisms in the food chains, students are able to; ▪ Infer those producers are at the beginning of food chains. ▪ State that producers produce simple sugars and oxygen by photosynthesis. ▪ List what is required for photosynthesis.
Students' Prior Knowledge	Ecosystem, food chain, food web
Unit's Concepts and Symbols	Producer, consumer, decomposer, photosynthesis, chlorophyll
Precautions (if there is)	-
Instructional Strategies and Techniques	Direct instruction, construction of food chain
Materials and instruments (students, teacher)	Textbook, Board, papers, small piece of papers
Teaching-Learning Activities	-
Summary	
Introduction	

At the beginning of the lesson, the teacher individually asks the students what they know about the key concepts of this topic, such as 'producer,' 'consumer,' 'decomposer,' 'photosynthesis,' and 'chlorophyll.' Initially, their thoughts are collected without providing immediate answers. If there are any misconceptions, other students are also given a chance to speak, and correct explanations are encouraged to be provided.

Development

The students are asked to examine the picture related to the food chain in the textbook. While examining the picture, the concepts related to the food chain on the image are read and discussed with the students. Then, the students are directed to answer the following questions about the picture, and correct answers are not immediately given to encourage them to find the answers:

Which living organisms are present in the picture?

How are the feeding relationships between these organisms?

Can you provide examples of food chains in this picture?

Are there any common groups of organisms in all food webs?

What could these groups be?

Do these groups have general names?

What should be the feeding relationship between these groups?

After the students learn about the food chain, they are given small papers and asked to create their own food chains. The food chains created by the students are collected, written on the board, and common animals are combined to form a food web. This way, they are encouraged to create their own food webs.

Next, the students are asked to perform a food web activity from the textbook. They are asked to put a tick mark on the first link of the food chain. They are questioned about why there are producer organisms in the first link and why they are called producers. The students are guided with questions until they provide the answer 'photosynthesis.'

The students are reminded of the photosynthesis topic they learned in the past. A large leaf is drawn on the board, and the necessary elements for the photosynthesis process on the leaf, and the results of photosynthesis are explained using visual elements to make the information memorable.

Information about chlorophyll is provided to the students. To make chlorophyll memorable, it is demonstrated that the green color of pistachio ice cream is due to the chlorophyll content in the nuts by looking at the ingredients of the ice cream

Conclusion

The photosynthesis equation is written on the board one last time. Then, the question is posed to the students whether photosynthesis occurs in all types of light, including artificial light, and if so, in which color light photosynthesis occurs most effectively and in which color light it occurs least effectively. The lesson ends with this question.

PART III

Measurement-Assessment • Assessment and Evaluation for Individual Learning Activities • Assessment and Evaluation for Group Learning Activities • Additional Assessment and Evaluation Activities for Students with Learning Difficulties and Students with Advanced Learning Pace	Process evaluation is carried out based on the students' participation in the lesson.
Relations with other Disciplines	-

PART IV

Explanations regarding implementation the plan	-

O. Lesson Plan of Expert 1 (Turkish Version)

DERS PLANI

BÖLÜM I

Dersin adı	FEN VE TEKNOLOJİ
Sınıf	8/C
Ünitenin Adı/No	CANILAR VE ENERJİ İLİŞKİLERİ
Konu	FOTOSENTEZ
Süre	40 + 40'

BÖLÜM II

Öğrenci Kazanımları /Hedef ve Davranışlar	- Besin zincirinin başlangıcında üreticilerin bulunduğunu - Üreticilerin fotosentez yaparak basit şeker ve oksijen meydana geldiğini - Fotosentez için nelerin gerekli olduğunu - Fotosentezin denkleme ifade edildiğini - Üreticilerin fotosentez ile güneş enerjisini kullanarak bilin enerjiye dönüştürdüklerini
Öğrencilerin Ön bilgileri	Canlıların geçmiş yıllarda öğrendiği Fotosentez Canlıların ve cansızların etkileşimi besin zinciri
Ünite Kavramları ve Sembolleri	Üretici - Tüketici - Ayrıştırıcılar - Fotosentez klorofil - Enerji
Güvenlik Önlemleri (Varsa):	—
Öğretme-Öğrenme-Yöntem ve Teknikleri	Anlatım - Soru - Cevap Beyin fırtınası Grup çalışması - Gösteri
Kullanılan Araç, Gereçler (Öğremen, öğrenci)	Ders kitabı, kesitli broşürler, bilim dergileri
Öğretme-Öğrenme Etkinlikleri	Grup çalışması Oyun sergileme

Özet

Giriş Öğrencilere anahtar kavramlar soru şeklinde yöneltilir öğrencilerin cevaplamaları istenir. (Üreticiler - Tüketiciler - Ayrıştırıcılar - Fotosentez - Klorofil Enerji) Açıklamalar yapılarak kavramlar pekiştirmeye çalışılır.

Gelişme Daha önce görevlendirilmiş öğrencilerin fotosentezle ilgili yapmış ve hazırlamış oldukları oyunu sergilemeleri sağlanır. Hazırlamış oldukları (Güneş, yaprak (klorofil), CO₂ ve O₂, H₂O, Besin (Basit şeker)) içeren broşür pektideki renkli kartonları sırasına göre Güneş ışığı altında yaprağın içine su ve karbondioksiti pambol eden öğrenciler yer alacak. Daha sonra CO₂ ve H₂O tüketilecek. Besin ve oksijen yer alacak bu durumu çocuklara soru şeklinde yöneltilecek ve fotosentez olayı kavratılmaya çalışılacak.

Sonuç Fotosentez olayının gerekliliği (Üreticiler) olarak canlılar için önemi fotosentez yapılabilmeleri için gerekli olanlar ve sonunda meydana gelenler canlılar için önemi tekrarlanacak Fotosentezde kullanılanların ve elde edilenlerin kimyasal denklem olarak yazılması ve öğrenilmesinin sağlanması

$$6\text{CO}_2 + 6\text{H}_2\text{O} \xrightarrow[\text{Güneş ışığı}]{\text{Klorofil}} \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2$$

Karbondioksit + Su

BÖLÜM III**Ölçme-Değerlendirme**

- Bireysel öğrenme etkinliklerine yönelik Ölçme Değerlendirme
- Grupla öğrenme etkinliklerine yönelik Ölçme Değerlendirme
- Öğrenme güçlüğü olan öğrenciler ve ileri düzeyde öğrenme hızında olan öğrenciler için ek Ölçme-Değerlendirme etkinlikleri

Dersin Diğer Derslerle İlişkisi

1. Fotosentez yapılıması için hangi inorganik maddelere ihtiyaç duyarlar?
2. Fotosentez neye denir?
3. Ototrof ve heterotrof canlı ne demektir?
4. Yeşil bitkiler besinlerini yaparken aşağıdaki maddelerden hangisini kullanmazlar?
a) O_2 b) CO_2 c) H_2O d) Klorofil.
5. Fotosentez denklemlerini yazınız.

BÖLÜM IV**Planın Uygulanmasına İlişkin Açıklamalar**

P. Lesson Plan of Expert 1 (English version)

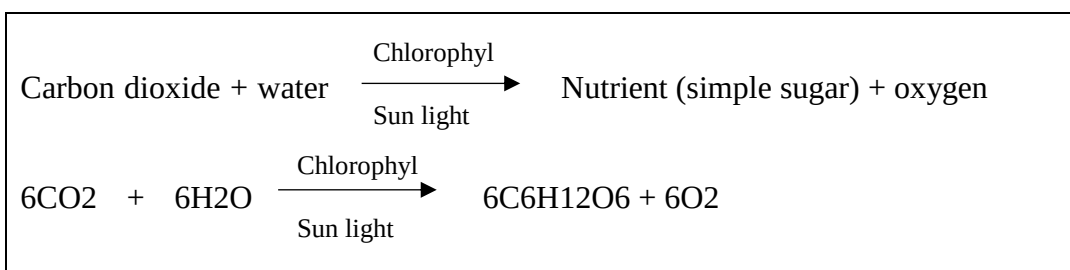
PART I

Lesson	Science and Technology
Class	8
Unit /No	Living things and energy relations / 6
Topic	Photosynthesis
Time	40 +40 min.

PART II

Students' Learning Objectives	• Infer those producers are at the beginning of food chains. • State that producers produce simple sugars and oxygen by photosynthesis. • List what is required for photosynthesis. • Express photosynthesis with an equation. • State that producers convert solar energy into usable energy by photosynthesis.
Students' Prior Knowledge	Organisms-they learnt in previous years-photosynthesis the interactions between living and non-living things food chain
Unit's Concepts and Symbols	Producer, consumer, decomposer, photosynthesis, chlorophyll, energy

Precautions (if there is)	-
Instructional Strategies and Techniques	Direct instruction, questioning, brain storming, group work, demonstration
Materials and instruments (students, teacher)	Textbook, brochures and science magazines
Teaching-Learning Activities	Group work Role-playing
Summary	
Introduction The students are directed to answer key concept questions. They are asked to respond to questions about producers, consumers, decomposers, photosynthesis, chlorophyll, and energy. Development The previously assigned students are allowed to showcase the game they have made and prepared about photosynthesis. They will present their prepared brochure-shaped colored cardboard cut-outs, including the sun, leaf (chlorophyll), CO₂, O₂, and H₂O as nutrients (simple sugars), in their respective order under sunlight. Students representing water and carbon dioxide will be inside the leaf, while those representing CO₂ and H₂O will exit. Students representing nutrients and oxygen will take their place. This formation will be presented to the children in the form of questions, aiming to help them understand the process of photosynthesis. Conclusion The importance of the process of photosynthesis for living organisms as producers will be emphasized. What is required for photosynthesis to occur and its resulting products will be reiterated, highlighting its significance for living organisms. Ensuring the chemical equation for the substances used and produced in photosynthesis is written and learned.	



PART III

Measurement-Assessment • Assessment and Evaluation for Individual Learning Activities • Assessment and Evaluation for Group Learning Activities • Additional Assessment and Evaluation Activities for Students with Learning Difficulties and Students with Advanced Learning Pace	What inorganic substances do they need to perform photosynthesis? What is photosynthesis called? What do autotrophic and heterotrophic organisms mean? Among the following substances, which one do green plants not use while making their food? a) O₂ b) CO₂ c) H₂O d) chlorophyll
Relations with other Disciplines	-

PART IV

Explanations regarding implementation the plan	-