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INVESTIGATION OF SCIENCE TEACHERS' TOPIC-SPECIFIC
PEDAGOGICAL CONTENT KNOWLEDGE REGARDING CLIMATE,
WEATHER AND SEASONS: FROM THE DUAL PERSPECTIVE

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

KÜBRA SAĞBİLGE

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FOR
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ABSTRACT

INVESTIGATION OF SCIENCE TEACHERS' TOPIC-SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE REGARDING CLIMATE, WEATHER AND SEASONS: FROM THE DUAL PERSPECTIVE

Sağbilge, Kübra
Master of Science, Science Education in Mathematics and Science Education
Supervisor : Prof. Dr. Ceren Öztekin

February 2022, 621 pages

This study aimed to investigate experienced science teachers' subject matter knowledge (SMK) containing syntactic and substantive knowledge and pedagogical content knowledge (PCK) regarding the seasons, weather and climate addressing the dual perspective. In this single case study, three science teachers who worked on public schools constituted the sample. Data were gathered via pre-interview, post-interview, classroom observations and teacher documents.

Findings regarding teachers' substantive knowledge indicated that they were knowledgeable about the basic concepts of seasons, weather and climate compared to climate change, global warming and greenhouse effect. Their syntactic knowledge, however, were found as deficient. Teachers' PCK regarding science teaching orientations were found as teaching curriculum objectives and preparing students to high school entrance exam. They were aware of all objectives, horizontal relations, and vertical relations in curriculum. The concept of dual perspective also was mentioned as affective goals; in various degrees, they addressed informing students about environmental problems, and being action competent citizens toward preventing these problems (i.e., dual perspective as an objective). They were knowledgeable regarding students’ prerequisite knowledge, and they noticed the some of students’ learning difficulties and misconceptions, but many have preferred teacher-centered methods to overcome them. Their knowledge of instructional strategies and assessment were generally limited to traditional methods. A professional development program should be designed to improve in-service teachers' PCK in which substantive knowledge is handled together with syntactic knowledge including seasons, weather and climate topic. Besides, teachers should be directed to raise students to become action competent citizens on behalf of the society.

Keywords: Pedagogical Content Knowledge, Subject Matter Knowledge, Dual Perspective, Experienced Science Teachers, Climate, Weather and Seasons

ÖZ

FEN BİLİMLERİ ÖĞRETMENLERİNİN İKLİM, HAVA VE MEVSİMLER İLE İLGİLİ KONUYA ÖZGÜ PEDAGOJİK ALAN BİLGİLERİNİN İKİLİ PERSPEKTİFTEN İNCELENMESİ

Sağbilge, Kübra
Yüksek Lisans, Fen Bilimleri Eğitimi, Matematik ve Fen Bilimleri Eğitimi
Tez Yöneticisi: Prof. Dr. Ceren Öztekin

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Bu çalışma, deneyimli fen bilimleri öğretmenlerinin mevsimler, hava ve iklim konularına ilişkin konu alan bilgileri ile pedagojik alan bilgilerini ikili perspektifi ele alarak araştırmayı amaçlamıştır. Bu tekli durum çalışmasında örneklemi devlet okullarında görev yapan üç fen bilgisi öğretmeni oluşturmuştur. Veriler, ön görüşme, son görüşme, sınıf gözlemleri ve öğretmen belgeleri aracılığıyla toplanmıştır.

Konu alan bilgilerine ilişkin sonuçlar, iklim değişikliği, küresel ısınma ve sera etkisine kıyasla mevsimler, hava ve iklim temel kavramları hakkında daha bilgili olduklarını göstermiştir. Bilimin doğasına ilişkin konu alan bilgileri ise eksik bulunmuştur. Pedagojik alan bilgilerine ilişkin sonuçlar, öğretmenlerin fen öğretimi yönelimlerinin müfredatla ilgili kazanımları öğretme ve öğrencileri lise giriş sınavına hazırlama olarak bulunmuştur. Tüm kazanımların, konunun müfredattaki yatay ve dikey ilişkilerinin ve ayrıca duyuşsal hedef olarak ikili perspektif kavramının farkında oldukları görülmüştür. Öğrencilerini çevre sorunları hakkında bilgilendirmeyi ve bu sorunları önlemeye yönelik eyleme yetkin vatandaşlar olmayı (yani ikili perspektif) ele aldıkları görülmüştür. Öğrencilerin ön koşul bilgileri

hakkında bilgi sahibi oldukları ve bazı öğrenme güçlüklerini ve kavram yanılgılarını fark ettikleri, ancak bunları aşmak için genellikle öğretmen merkezli yöntemleri tercih ettikleri görülmüştür. Öğretim stratejileri ve değerlendirme konusundaki bilgilerinin genellikle geleneksel yöntemlerle sınırlı olduğu bulunmuştur. Hizmet içi öğretmenlerin pedagojik alan bilgilerini geliştirmek için mevsimler, hava ve iklim konularını içeren bilimin doğası bilgileri ile birlikte konu alan bilgilerinin ele alındığı bir mesleki gelişim programı tasarlanmalıdır. Ayrıca öğretmenler, öğrencileri toplum adına eylemden yetkin vatandaşlar olarak yetiştirmeye yönlendirilmelidir.

Anahtar Kelimeler: Pedagojik Alan Bilgisi, Konu Alan bilgisi, İkili Perspektif, Deneyimli Fen Bilimleri Öğretmenleri, İklim, Hava ve Mevsimler

To My Mother, My Father and My Brother

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LIST OF ABBREVIATIONS

ABBREVIATIONS

PCK: Pedagogical Content Knowledge

PCKg: Pedagogical Content Knowing

TSPCK: Topic-Specific Pedagogical Content Knowledge

TSPK: Topic-Specific Professional Knowledge

SMK: Subject Matter Knowledge

CK: Content Knowledge

NOS: Nature of Science

MoNE: Ministry of National Education

CoRe: Content Representation

CHAPTER 1

INTRODUCTION

Teachers are described as the one who have an influential impact upon students' learning (Hanuscin, Lee, & Akerson, 2011; Hattie, 2012; Lumpe, 2007). In fact, in the late 19th century, early research, Lee Shulman (1986; 1987), started his leading research on teacher knowledge and noticed that the content of the exams or tests conducted to assess the competence of teachers focused mostly on the requirement for teachers to know subject matter knowledge, and concluded that teachers' subject matter knowledge has a primary role in being a qualified teacher (Shulman, 1986). As acknowledge by Shulman (1986), by the end of the 20th century, however, researchers have focused on pedagogical knowledge (e.g., management, evaluation) while assessing teachers. In this regard, Shulman (1986) defined the neglection of the emphasis on subject matter knowledge in teacher knowledge as a "missing paradigm" (p.6). Then, considering the pedagogy and content to be indistinguishable, he proposed the term pedagogical content knowledge (PCK), which includes content and pedagogy together and described it as;

> "the most useful forms of representation of those ideas, the most powerful analogies, illustrations, examples, explanations, and demonstrations-in a word, the ways of representing and formulating the subject that make it comprehensible to others." (Shulman, 1986, p.9).

According to above description, Shulman (1986) perceived the concept of PCK as containing things that lead to learning a topic difficult or easy, and he highlighted the necessity of teachers to possess knowledge regarding students' preconceptions and the methods that can be beneficial for rearranging their understandings. He also stated that subject matter knowledge contains syntactic and substantive structures depending on Schwab's idea (Schwab, 1978). According to Shulman (1986), while "The substantive structures are the variety of ways in which the basic concepts and principles of the discipline are organized to incorporate its facts, the syntactic structure of a discipline is the set of ways in which truth or falsehood, validity or invalidity, are established." (p.9).

In his another influential article entitled 'Knowledge and Teaching', Shulman (1987) focused on the combination of pedagogy and content, and described the PCK as "the blending of content and pedagogy into an understanding of how particular topics, problems, or issues are organized, represented, and adapted to the diverse interests and abilities of learners, and presented for instruction." (Shulman, 1987, p.8)

Accordingly, depending on Shulman's ideas, PCK contains two components; knowledge of learning difficulties and subject matter addressing knowledge of students' understanding, and knowledge of representation addressing knowledge of instructional strategies (Shulman, 1986; 1987).

Since Shulman's introduction of PCK, PCK's place in the related literature has received a great deal of interests by researchers (Nilsson, & Loughran 2012; Barendsen, & Henze, 2019; Bravo, & Cofré, 2016; Clausen, 2017; Coetzee, Rollnick, & Gaigher, 2020; Mavhunga, 2018; Norville, & Park, 2021; Park, & Chen, 2012; Pitjeng-Mosabala, & Rollnick, 2018; Teed, & Franco, 2014; Van Driel, De Jong, & Verloop, 2002; van Driel, Verloop, & de Vos, 1998) and it has been stated by researchers that PCK has a topic-specific nature (Hanuscin, de Araujo, Cisterna, Lipsitz, & van Garderen, 2020; Park, & Chen, 2012; van Driel, Verloop, & de Vos, 1998). Consequently, various PCK models were proposed such as Cochran, DeRuiter and King's (1993) PCKg model, Gess-Newsome's (1999) Integrative and Transformative PCK models, Gess-Newsome's (2015) PCK consensus model, Grossman's (1990) PCK model, Magnusson, Krajcik and Borko's (1999) PCK model, Park and Oliver's (2008a) Hexagon PCK model, Veal and MaKinster's (1999) Hierarchical Taxonomy of PCK model, Carlson and Daehler's (2019) Refined Consensus Model of PCK.

One of the earliest models were proposed by Grossman (1990). According to Grossman's (1990) model, teacher knowledge contains four knowledge areas which are "subject matter knowledge", "general pedagogical knowledge", "pedagogical content knowledge" and "knowledge of context". (See Figure 1.1).

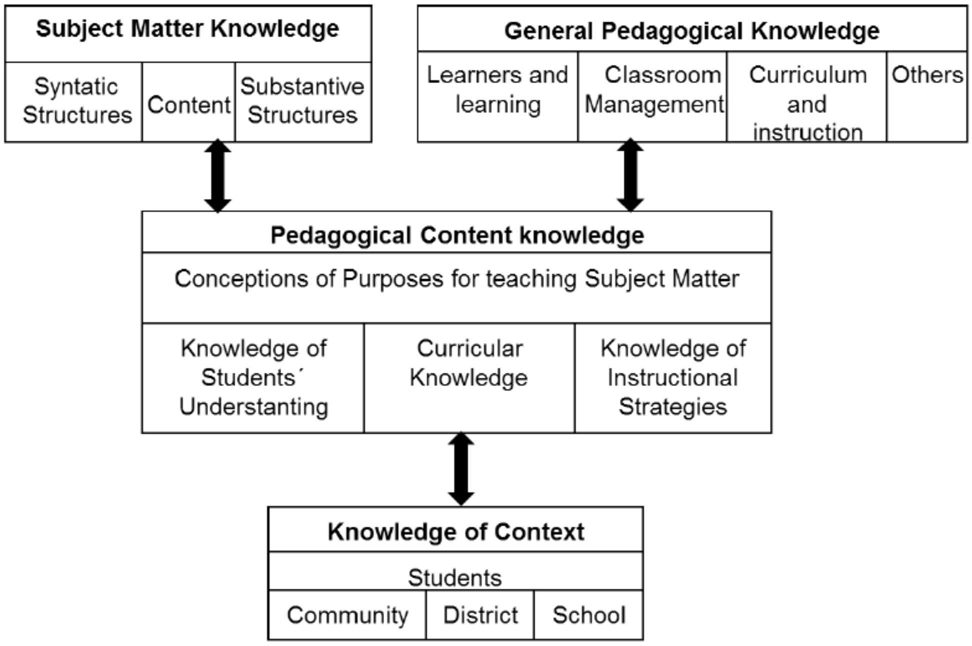


Figure 1.1 Grossman's PCK Model (1990, p.5)

As to Grossman (1990) model, while subject matter knowledge comprises of three components which are "substantive structures", "syntactic structures" and "content", general pedagogical knowledge involves three components defined as "classroom management", "learners and learning", and "curriculum and instruction". In Grossman's (1990) model, PCK has four components which are "knowledge of instructional strategies", "conceptions of purpose for teaching subject matter", "curricular knowledge" and "knowledge of students' understanding". Among PCK components, Grossman (1990) perceived the "conceptions of purposes for teaching" as overarching dimension. Lastly, knowledge of context covers four components specified as "community", "school", "students" and "district". In conclusion, Grossman (1990) model of PCK is considered as a transformative model, in which

PCK is generated through transformation of other three teacher knowledge areas (See Figure 1.1).

By criticizing Grossman's (1990) PCK model, later, Cochran et al. (1993), proposed their own PCK model by taking the constructivist approach into account (See Figure 1.2). Depending on constructivist approach, PCK is defined as active process and improve in time (Cochran et al., 1993). By defining the word 'knowledge' in the pedagogical content knowledge as "too static and inconsistent with the constructivist perspective" (Cochran et al., 1993, p.266), Cochran et al. (1993) put forward the term of pedagogical content knowing (PCKg). Accordingly, they described PCKg as integrated understanding of teacher's knowledge of subject matter, knowledge of environmental contexts, knowledge of students and knowledge of pedagogy.

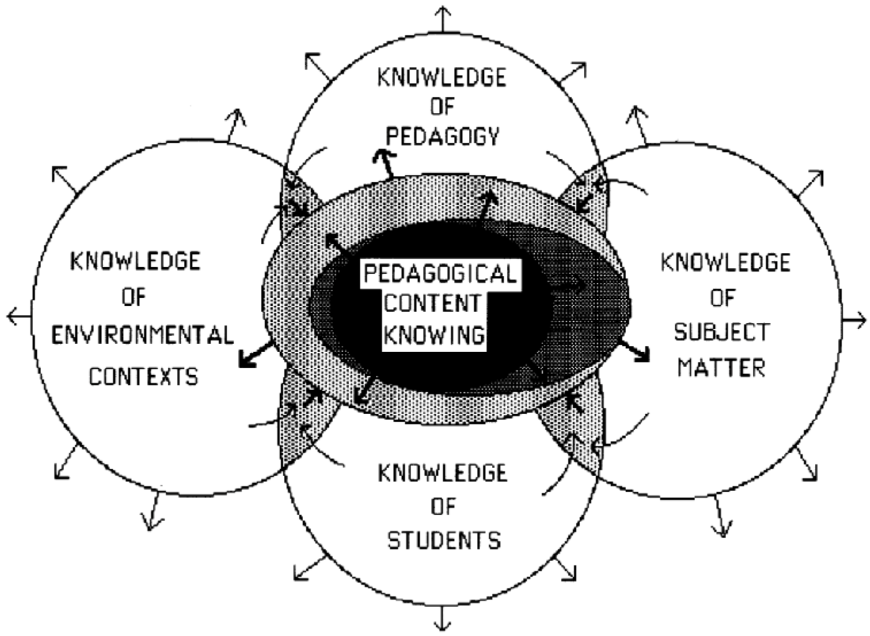


Figure 1.2 Cochran, DeRuiter, and King's PCKg Model (1993, p.268)

Cochran et al. (1993) stated that teachers' PCKg can improve when each component is integrated simultaneously and developed. Cochran et al. (1993) also mentioned that through experiences gained in time, the components of PCKg are likely to integrate better. Accordingly, the PCK model of Cochran et al. (1993) is an example for the integrative model because, as seen in this model, subject matter knowledge is not separated from PCK, but they are intertwined.

Noting that no hierarchical connection was established among the components in the former PCK models, Veal and MaKinster (1999) proposed two hierarchical taxonomy models related to PCK (See Figure 1.3 and 1.4). The first model depicted in Figure 1.3 which included four knowledge level: pedagogy, general PCK, domain specific PCK and topic specific PCK. As seen clearly from the model, these three kinds of PCK were hierarchically ordered from top to bottom.

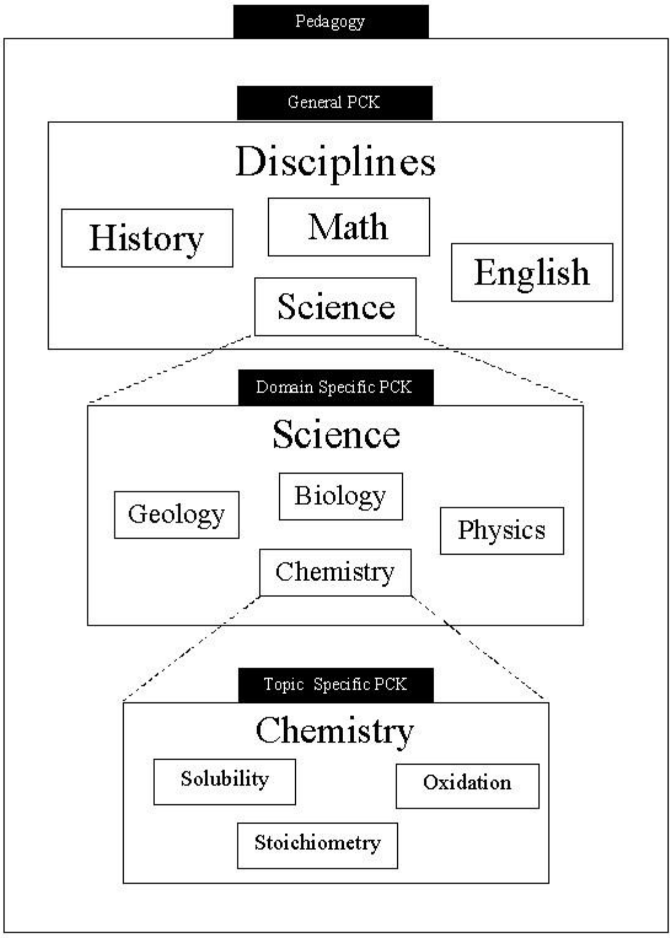


Figure 1.3 Veal and MaKinster's (1999) Hierarchical Taxonomy of PCK Model (p.7)

In this model, Veal and MaKinster (1999) stated that teachers need to develop their pedagogy forms the basis of this hierarchical taxonomy model. They defined the pedagogical strategies that teachers use (e.g., lecture, questioning, teaching methods) can be given as examples. First construct is defined as general PCK. According to Veal and MaKinster (1999), the general PCK is more specific knowledge, and for each discipline (e.g., English, science), the general PCK is specific. In comparison with general PCK, domain specific PCK as second construct is more specific knowledge since this type of PCK is related to domains included in the discipline (e.g., chemistry, biology in science). Lastly, as third construct, topic-specific PCK is most specific knowledge among these three types of PCK because topic-specific PCK cares with the topics found in the domain (e.g., chemical reaction topic in chemistry) (Veal, & MaKinster, 1999).

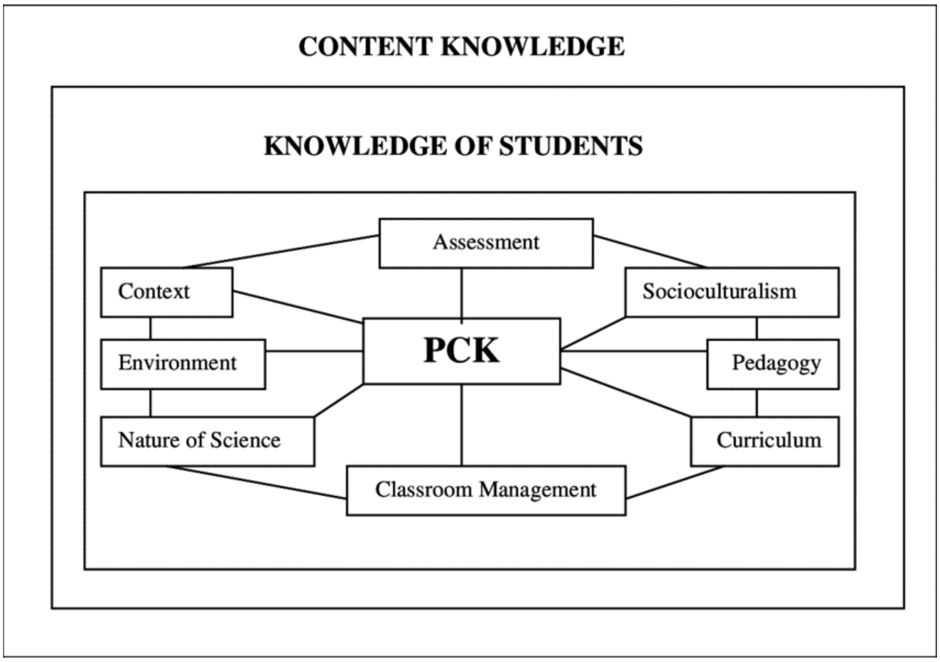


Figure 1.4 Veal and MaKinster's (1999) The Taxonomy of PCK Attributes Model from Bird's Eye View (p.10)

In their second hierarchical PCK model, Veal and MaKinster (1999) addressed the PCK development (See Figure 1.4). In this model, there are content knowledge, followed by knowledge of students, and then eight attributes, and PCK is placed at the center of these attributes. There is interrelatedness among the PCK's eight embedded attributes and they are not hierarchically placed, and may be developed throughout teachers' careers (Veal, & MaKinster, 1999). Accordingly, in case of the development of one attribute, another one may develop simultaneously (Veal, & MaKinster, 1999). Veal and MaKinster (1999) argued that firstly a strong content knowledge and secondly, a comprehensive knowledge of students are necessary for PCK's development, and stated that if the teachers are knowledgeable about the content, they can notice the misconceptions of students more simply. In addition, Veal and MaKinster (1999) stated that in case teachers are aware of knowledge of students in their teachings, their knowledge of eight attributes found in PCK can improve.

Another model was developed by Magnusson et al. (1999) by making some alterations in Grossman (1990) model (See Figure 1.5 and 1.6). While Figure 1.5 shows the teacher knowledge domain, Figure 1.6 displays the components of PCK. According to Magnusson et al. (1999), teacher knowledge consists of four knowledge domains which are pedagogical knowledge, knowledge of context, subject matter knowledge and pedagogical content knowledge (See Figure 1.5).

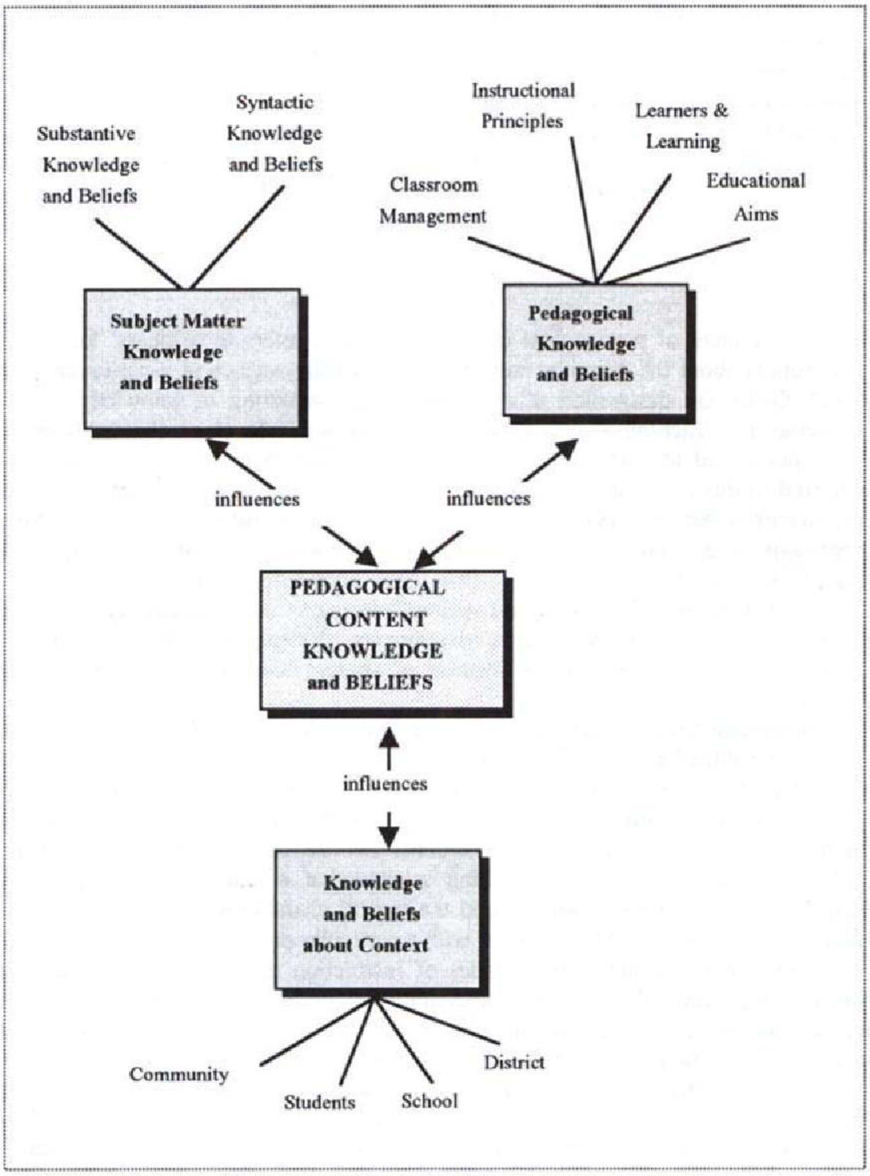


Figure 1.5 Model of Magnusson, Krajcik, and Borko (1999) Regarding the Relationships Among the Domains of Teacher Knowledge (p.98)

In Magnusson et al. (1999) model, pedagogical content knowledge, which is placed at the center, both impacts and is impacted by other three knowledge domains. Based on Magnusson et al.'s (1999) PCK model, Figure 1.6 shows five components contained in PCK: knowledge of instructional strategies, knowledge of science curriculum, knowledge of assessment, knowledge of students' understanding and orientation to teaching science. In order for teachers to be effective teachers, they should improve their knowledge regarding all the topics that are taught by them and all five PCK components (Magnusson et al., 1999).

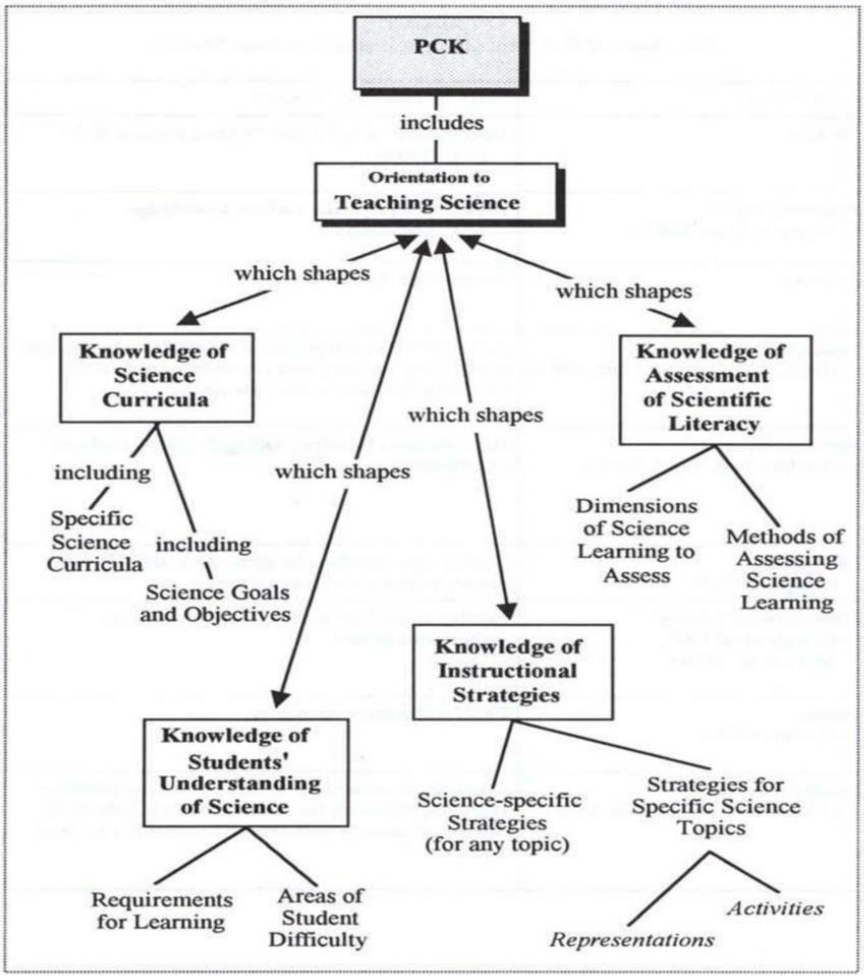


Figure 1.6 Magnusson et al.'s (1999) Model of PCK (p.99)

According to Magnusson et al. (1999), a general manner of conceptualization of teaching science is defined as orientation, which is located at the top of the model and affect the other four components. Knowledge of science curriculum involves goals and objectives and science curriculum (Magnusson et al., 1999). Knowledge of students' understanding contains areas of student difficulty and requirements of learning. The knowledge of teacher that is essential for students in order to understand particular concepts is defined as prerequisite knowledge and it contains knowledge regarding skills and abilities that may be necessary for students (Magnusson et al., 1999). The knowledge of teachers regarding the topics or concepts in science that are challenging for students' learning implies knowledge of areas of student difficulty (Magnusson et al., 1999). Knowledge of instructional strategies contains topic-specific strategies and subject specific strategies. The general approaches regarding implementation of science instruction is covered by subject-specific strategies (Magnusson et al., 1999). Teachers' knowledge regarding specific strategies which are beneficial with the purpose of providing students to understand particular science concepts is called knowledge of topic-specific strategies. Activities and representations are two categories found in knowledge of topic-specific strategies (Magnusson et al., 1999). Examples, analogies, illustrations and models could be the examples of representations (Magnusson et al., 1999). Activities which are able to be performed with the aim of providing students to understand particular relationships or concepts are covered by knowledge of topic-specific activities, and investigations, problems, simulations, experiments and demonstrations are the examples of topic-specific activities (Magnusson et al., 1999). "Knowledge of assessment" comprises of methods of assessment and dimensions of science learning to assess. In the scope of a specific topic, teachers' knowledge regarding the assessment of necessary aspects of students' learning is called knowledge of dimensions of science learning to assess (Magnusson et al., 1999). Knowledge of teacher regarding the ways which are able to be used for assessment of student learning in terms of crucial particular aspects in the scope of a specific topic is called knowledge of methods of assessment (Magnusson et al., 1999).

Gess-Newsome (1999) described two PCK models, integrative and transformative. In the integrative model (See Figure 1.7), the intersection of pedagogical knowledge, contextual knowledge, and subject matter knowledge results in the teacher's knowledge (Gess-Newsome, 1999). In other words, PCK is not a separate type of knowledge (Gess-Newsome, 1999). In the transformative model (See Figure 1.7), on the other hand, PCK exists separate (Gess-Newsome, 1999).

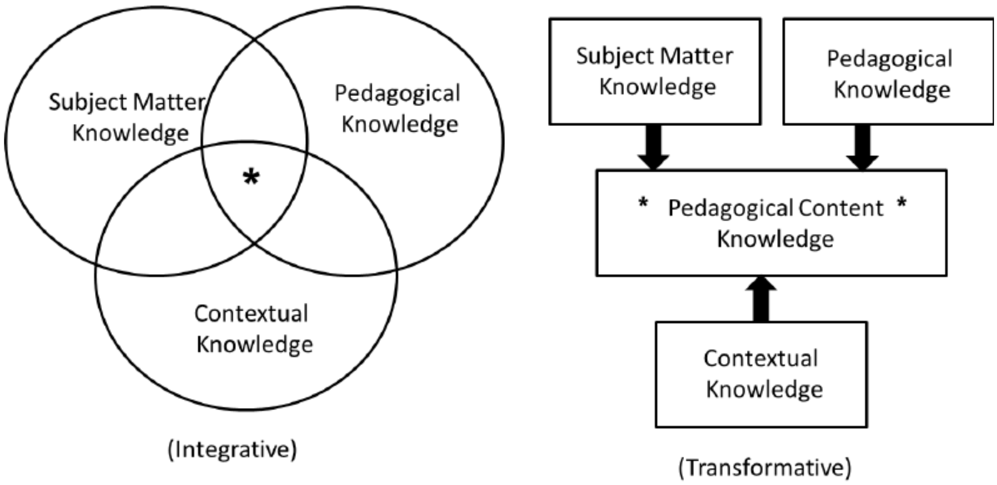


Figure 1.7 Gess-Newsome's (1999) Integrative and Transformative PCK Models (p.12)

While Cochran et al.'s (1993) PCKg model and Veal and MaKinster's (1999) Hierarchical taxonomy of PCK model are defined as integrative models, Magnusson et al.'s (1999) and Grossman's (1990) PCK models are defined as transformative models (Kind, 2009).

Park and Oliver (2008a) created hexagon PCK model by making some modifications depending on the findings of their multiple case study with three experienced chemistry teachers by studying on the five components of PCK model of Magnusson et al. (1999) (See Figure 1.8). Park and Oliver (2008a) found that PCK possesses knowledge-on-action and knowledge-in-action aspects, and by means of reflection, they were impacted from one another, and the development of PCK was occurred via reflection-on-action and reflection-in-action in certain teaching contexts. In their study, students (e.g., their responses, questions) were revealed as crucial effect upon the development of PCK, and their misconceptions were revealed to have crucial contribution to PCK (Park, & Oliver, 2008a). With different knowledge and teaching experiences, every teacher incorporates and improves their PCK components to enact PCK in teaching practice, and so, it was revealed that to a certain extent, PCK has idiosyncratic nature (Park, & Oliver, 2008a). Furthermore, in their study, teacher efficacy was revealed as an affective PCK component, and it played a role in terms of providing link between enactment and understanding which are the two dimensions forming PCK. Park and Oliver (2008a) added that in the model, all components affect each other continuously, and in a certain context, the components are integrated and enacted by teachers so that providing teaching to be influential.

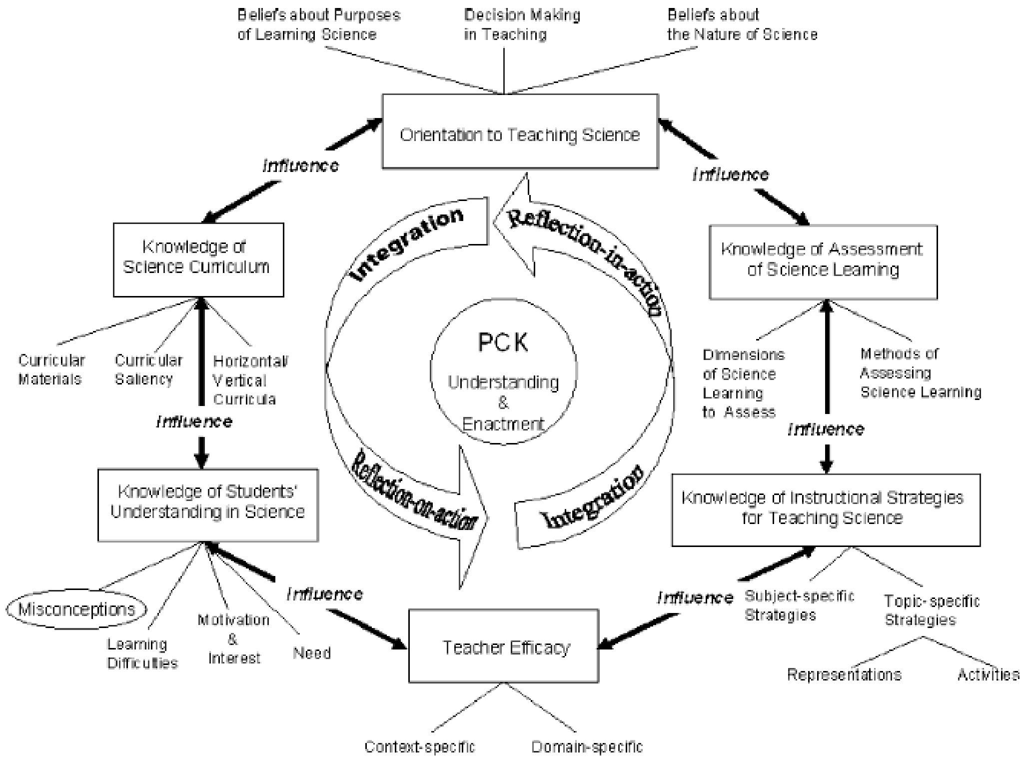


Figure 1.8 Park and Oliver's (2008a) Hexagon PCK Model (p.279)

One of the recent PCK models known as consensus model was developed by Gess-Newsome (2015). With the participation of many science educators from various countries, the PCK summit was held to further study on the PCK's construct. In consequence of the conversations and studies made within this PCK summit, the teacher professional knowledge and skill (TPK&S) model involving PCK was created (See Figure 1.9) (Gess-Newsome, 2015). While creating the model, Lee Shulman's and the research community's concerns (e.g., the negligence of context, the connection between student outcomes and PCK, and the negligence of goals and vision of teachers for education) were taken into consideration (Gess-Newsome, 2015). Gess-Newsome (2015) model stems from general teacher professional knowledge bases which involve knowledge of students, assessment, content, curricular and pedagogical knowledge. Teacher professional knowledge bases both affect and are affected from topic-specific professional knowledge. As filters and amplifiers, teachers' orientation and beliefs affect classroom practice and topic specific professional knowledge, and also, students' behaviors, beliefs and prior knowledge affect student outcomes and classroom practice (Gess-Newsome, 2015).

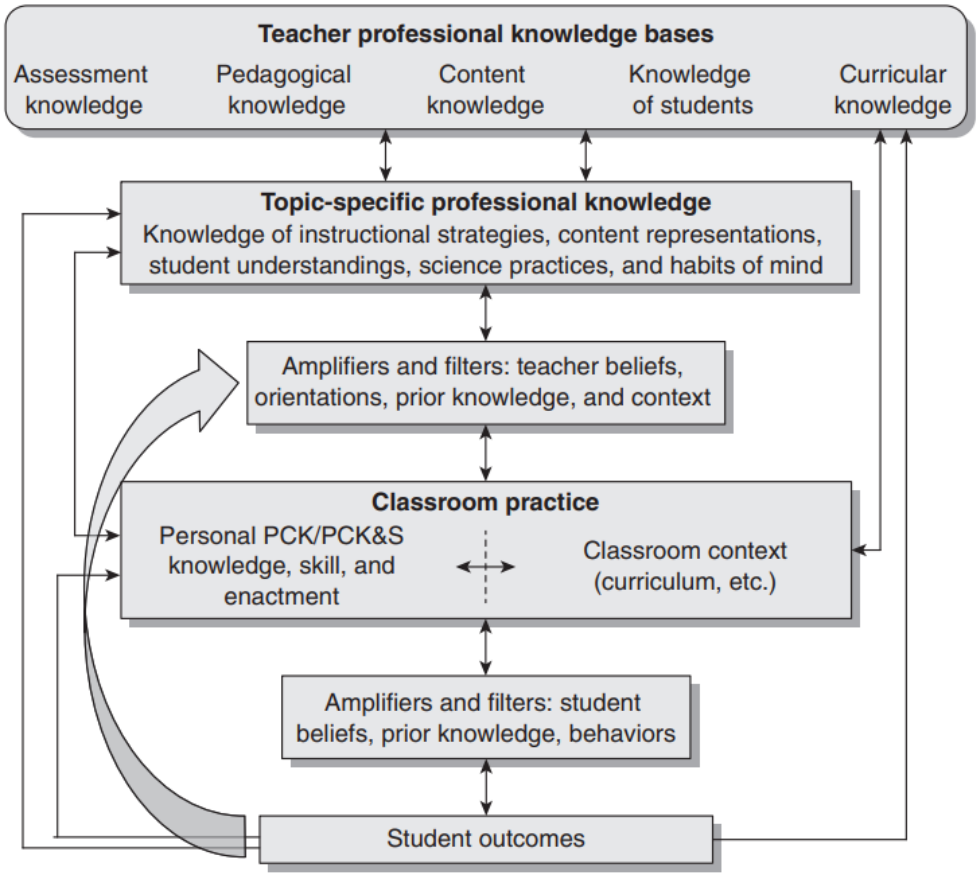


Figure 1.9 Gess-Newsome's (2015) PCK Consensus Model (p.31)

The most recent PCK model defined as the refined consensus model (RCM) was developed by Carlson and Daehler (2019) (See Figure 1.10). Another PCK summit was held with the participation of many science PCK and science teacher education researchers from various places in the world, and limitations that science PCK researchers thought about the Gess-Newsome's (2015) PCK consensus model were taken into account in the development of RCM of PCK (e.g., not showing the complex nature of PCK, difficulty in distinguishing between PCK&S and TSPK) (Carlson, & Daehler, 2019). Then, RCM of PCK has been developed as a result of important revisions on Gess-Newsome's (2015) PCK consensus model, along with Magnusson et al.'s (1999) PCK model and Shulman's (1986) definition of PCK (Carlson, & Daehler, 2019). Based on RCM of PCK, knowledge of students, assessment knowledge, pedagogical knowledge, curricular knowledge and content knowledge are contained in teachers' professional knowledge bases, and these knowledge bases are basis for PCK of teacher. Also, learning and teaching are impacted from the learning context such as student attributes (Carlson, & Daehler, 2019). As a key property, three different PCK realms which are personal PCK (pPCK), enacted PCK (ePCK) and collective PCK (cPCK) were remarked in this model (Carlson, & Daehler, 2019).

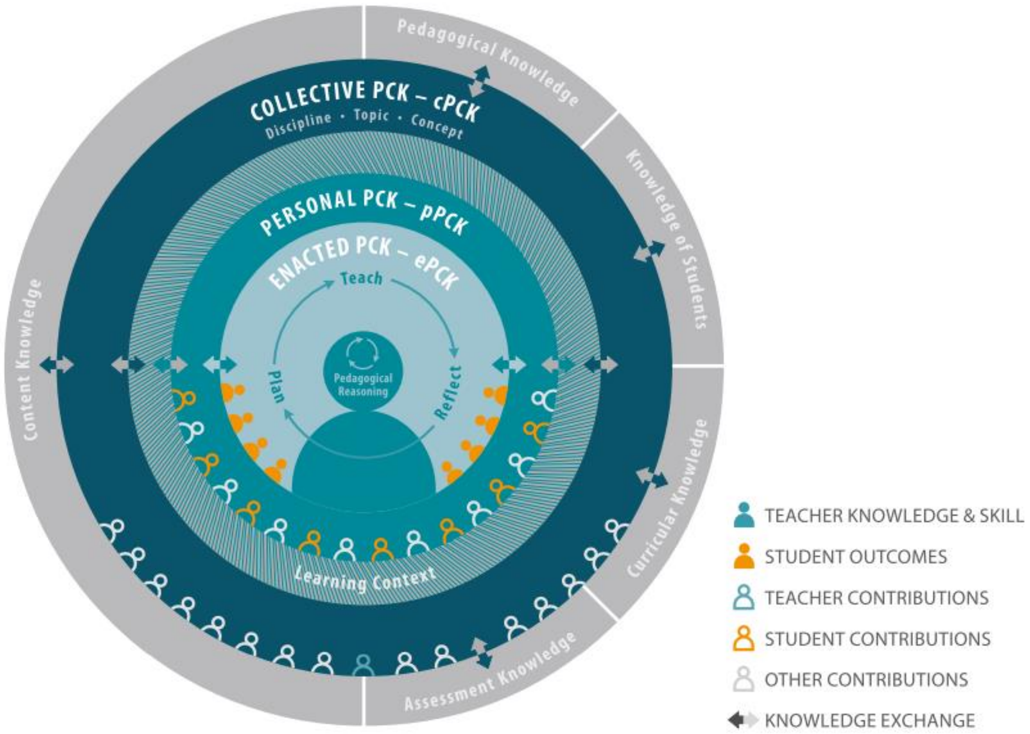


Figure 1.10 Carlson and Daehler's (2019) Refined Consensus Model of PCK (p.83)

As can be seen from the historical development of the PCK models described above, PCK appears to have a complex structure over the years and is a still developing and fruitful area to research (Abell, 2008; Bailie, 2017).

In the current study, Magnusson et al. (1999) model was adopted as a theoretical framework to investigate the experienced science teachers' PCK on the seasons, weather, and climate topics.

1.1 Significance of This Study

Current study is significant for many aspects. The first significance is the model used in the study. Among the others, model developed by Magnusson et al. (1999) has been found among the mostly used and cited model (Barendsen, & Henze, 2019; Coetzee, Rollnick, & Gaigher, 2020; Rollnick, 2016), and has been used for different purposes such as investigating the in-service or pre-service teachers' existing PCK, interactions between PCK components, relationship between SMK and PCK, and assessing developments of in or pre-service teachers' PCK. Besides, Magnusson et al. (1999) PCK model has been used in various topics from different disciplines (e.g., chemistry, physics, biology), which demonstrates the topic-specific nature of PCK.

The second significance was the inclusion of the all components of Magnusson et al. (1999) PCK model in the study. Available studies were rarely involving all components in their research. Playing an overarching role in teachers' PCK, orientation towards science teaching, for instance, was remained among the least examined components (Abell 2007; Aydın, & Boz, 2012; Friedrichsen, Van Driel, & Abell, 2011). It can be thought that investigating the science teachers' knowledge about all PCK components can provide clearer, detailed, and wide-ranging information with regard to their PCK. Furthermore, examining orientations toward science teaching is crucial because at the point of deciding on planning, implementation as well as reflection on teaching, this component is considered to have a central role on Magnusson et al. (1999) PCK model (Magnusson, Krajcik, & Borko, 1999). Thus, taking all components into consideration, current study assumed to provide detail and valuable information regarding science teachers' PCK and thus, contribute to the related literature.

Besides PCK, it is equally important to consider examining teachers' subject matter knowledge as a whole (Abd-El-Khalick, 2006). Therefore, in this study, both syntactic and substantive knowledge were investigated. Due to the PCK's topic-specific nature, the topic of seasons, weather and climate was preferred for this study as a substantive knowledge which constitute another significance. Briefly, this topic has an interdisciplinary nature and tie different disciplines together, like geography, earth science, biology, chemistry, and physic. Understanding of the seasons, for example, requires knowledge from astronomy (e.g., solar system), climate and weather, and physics (e.g., optic) (Sneider, Bar, & Kavanagh, 2011). Besides, as a complex system "Climate is an ideal interdisciplinary theme for lifelong learning about the scientific process and the ways in which humans affect and are affected by the Earth's systems." (NOAA, 2009, p.5). What is more, those topics are also commonly included in the national science, social science and geography curricula (MoNE Science, Social Science and Geography Curriculum, 2018). Accordingly, current study is thought to shed light not only on the science but also geography curricula and research on literature.

It is also necessary to mention that concepts of the seasons, weather and climate closely related to climate science literacy and scientific literacy, which was stated a purpose of the natural science curriculum (MoNE, 2018). As said by Sneider et al. (2011) in order for all students to become scientific literate individuals, the seasons concept is needed to be included in the topics that need to be taught to students. For example, they mentioned that through the topic of seasons, students can observe alterations occurred in the Sun's path within the year, establish hypotheses regarding the relations that alter between the Sun and the Earth within the year, and collect evidence regarding the changes occurred in climate. By this way, students can also have the opportunity to practice science process skills. Additionally, "Climate science literacy is a part of science literacy." (NOAA, 2009, p.3) and a climate-literate individual can meaningfully associate climate change and climate, grasp the essential principles of climate system of the Earth, as well as determine actions that might have an impact upon climate (NOAA, 2009). Hence, it can be considered the learning and teaching of seasons, weather and climate topic is important in raising scientifically literate and climate literate individuals. From this view, it is important to include 'dual perspective' in PCK studies, as did in the current study. As stated by Clausen (2017), teaching should aim to raise action competent students who understand the models, theories and concepts, called dual perspective. *"The concept of action competence includes the capacity to be able to act, now and in the future, and to be responsible for one's actions."* (Jensen, & Schnack, 1997, p.175) and the mixture of students' visions, knowledge/insight, action experience and commitment are defined as students' action competence (Jensen, & Schnack, 1997). For example, currently, environmental problems stemming from human actions (e.g., global climate change, global warming, carbon emission, deforestation) are threatening the Earth and individuals and society have various tasks and responsibilities to reduce the adverse effects of these problems. For instance, conducting a study in 46 countries within 6 continents, Sisco, Pianta, Weber, and Bosetti (2021) offer evidence that global activism events such as the global climate march have an impact on raising attention toward climate change in international field. In order to raise conscious individuals, it is important for teachers to integrate responsibilities of individuals to prevent or reduce those problems in to science courses. Seasons, weather, and climate is among the most appropriate topics to do this integration. Besides the concept of dual perspective was presented among both topic-specific objectives and specific objectives of the National science curriculum (MoNE, 2018). As a topic-specific objective, it was expressed that "it is aimed to gain knowledge and skills about global climate changes and their effects." (MoNE, 2018, p.47). Among the specific objectives of the curriculum that aims to develop students as scientific literate, some objectives refer to the dual perspective are as follows: "To recognize the interaction between the individual and the environment; to raise awareness of sustainable development in society, economy and natural resources.", "To arouse interest and curiosity related to the events taking place in nature and surroundings and to develop attitudes.", "To develop reasoning ability, scientific thinking habits and decision-making skills using socioscientific issues.", and "To provide to take responsibility for daily life problems and to use knowledge regarding science, science process skills and other life skills in solving these problems." (MoNE, 2018, p.9). However, considering the science education literature, it has been observed that there are relatively limited studies addressing the concept of dual perspective in the context of PCK. Few available studies, however, conducted with geography teachers rather than science teachers (e.g., Clausen, 2016; Clausen, 2017). To our best knowledge, no research was performed in Turkey to examine the science teachers' dual perspective. Hence, current study focused on to what extent science teachers integrate dual perspective in their science lessons. Their teachings of the seasons, weather, and climate topic were evaluated from the dual perspective. For this purpose, students' action competence including their knowledge, commitment, visions and action experiences were examined in attempt to increase our knowledge base regarding how science teachers touch upon the dual perspective throughout their lesson. Addressing the concept of dual perspective in science teachers' PCK, current study is also considered as significant, and is believed to increase teachers' awareness on above-mentioned issues further by examining the science teachers' syntactic knowledge (i.e., "the rules of evidence and proof used to generate and justify knowledge claims in the discipline." (Abell, 2007, p.1107)) embedded in the related concepts.

In addition, the seasons, weather and climate topic are among the topics that both students, and teachers possess various misconceptions. Several misconceptions have been reported in the related literature for students as well as teachers such as seasons (e.g., Atwood, & Atwood, 1996; Hsu, 2008; Starakis, & Halkia, 2013), weather and climate (e.g., Lambert, Lindgren, & Bleicher, 2012; Mandrikas, Stavrou, & Skordoulis, 2017), climate change (e.g., Herman, Feldman, & Vernaza-Hernandez, 2017; Papadimitriou, 2004), greenhouse effect (e.g., Khalid, 2001; Michail, Stamou, & Stamou, 2007), global warming (e.g., Khalid, 2001; Papadimitriou, 2004). From this point, current study is also considered to be significant.

Working with experienced science teachers is crucial since PCK is developed in time by gaining teaching experience (Cochran, DeRuiter, & King, 1993; Käpylä, Heikkinen, & Asunta, 2009; Hanuscin, Cisterna, & Lipsitz, 2018). Compared to beginning teachers, experienced teachers might have richer knowledge regarding instructional strategies such as activities, experiments, and metaphors which are influential to teach the specific topic (Grossman, 1990). Apart from, experienced science teachers' PCK may be more developed and their subject matter knowledge may also be good because they have been teaching topics for a long time. As highlighted by Abell (2008), there are relatively more studies conducted with novice teachers and pre-service teachers, compared to experienced teachers, including Turkey (Aydın, & Boz, 2012). Researcher emphasized that taking into account all of these, this study was preferred to conduct with experienced science teachers having more than ten years teaching experiences with the purpose of obtaining rich PCK findings.

Last significance is that using multiple data collection tools to elucidate the teachers' complex nature of PCK. In PCK literature, construct of PCK is defined as complex (Coetzee, Rollnick, & Gaigher, 2020; Nilsson, & Loughran, 2012) and hidden or tacit (Kind, 2009). Through multiple data collection sources (i.e., pre-post PCK-interview, teacher documents, classroom observations), comprehensive and rich information was obtained about experienced science teachers' PCK.

1.2 Statement of the Problem

In this study, with using Magnusson et al. (1999) model of PCK involving all five components, three experienced science teachers' PCK and SMK (i.e., substantive and syntactic knowledge) related to the seasons, weather, and climate topic were investigated with taking the dual perspective into consideration. Accordingly, related research questions and sub-research questions were presented in the below:

1. What is the subject matter knowledge of science teachers related to the seasons, weather, and climate topic?

1.1. What is the substantive knowledge of science teachers related to the seasons?

1.2. What is the substantive knowledge of science teachers related to the weather?

1.3. What is the substantive knowledge of science teachers related to the climate, climate change, global warming, and greenhouse effect?

1.4. What is the syntactic knowledge of science teachers related to nature of science?

2. What is the pedagogical content knowledge of science teachers related to the seasons, weather, and climate topic?

2.1. What is the orientation toward science teaching of science teachers related to the seasons, weather, and climate topic?

2.2. What is the knowledge of curriculum of science teachers related to the seasons, weather, and climate topic?

2.3. What is the knowledge of students' understanding of science teachers related to the seasons, weather, and climate topic?

2.4. What is the knowledge of instructional strategies of science teachers related to the seasons, weather, and climate topic?

2.5. What is the knowledge of assessment of science teachers related to the seasons, weather, and climate topic?

3. To what extent is science teachers' instruction reflect dual perspective in seasons, weather, and climate topic?

1.3 Definition of Important Terms in This Study

Pedagogical Content Knowledge (PCK): Magnusson et al. (1999) defined PCK as understanding of teacher's regarding the way assist students to understand specific content.

> “It includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction.” (Magnusson et al., 1999, p.96).

Orientation Towards Science Teaching: For a specific grade level, knowledge and beliefs of teachers about the goals and purposes for science teaching is defined as orientations towards teaching science (Magnusson et al., 1999).

Knowledge of Science Curriculum: Knowledge of science curriculum includes two dimensions which are specific curricular materials and programs, and mandated goals and objectives (Magnusson et al., 1999). Knowledge of teachers regarding the objectives and goals in the topic that is taught to the students is covered in knowledge of goals and objectives (Magnusson et al., 1999).

Knowledge of Students’ Understandings: Knowledge of students’ understanding of science involves two dimensions which are knowledge of areas of student difficulty and knowledge of requirements for learning (Magnusson et al., 1999).

Knowledge of Instructional Strategies: Knowledge of instructional strategies involves two dimensions which are knowledge of topic-specific strategies and knowledge of subject-specific strategies (Magnusson et al., 1999).

Knowledge of Assessment: Knowledge of assessment in science involves two dimensions which are knowledge of methods of assessment and knowledge of dimensions of science learning to assess (Magnusson et al., 1999).

Subject Matter Knowledge (SMK): “Shulman’s view of SMK was derived from the work of Schwab (1964), who defined two types of subject matter knowledge:

substantive and syntactic. The substantive structure of a discipline is the organization of concepts, facts, principles, and theories, whereas syntactic structures are the rules of evidence and proof used to generate and justify knowledge claims in the discipline." (Abell, 2007, p.1107). The nature of science understanding means syntactic knowledge (Abd-El-Khalick, & BouJaoude, 1997). In this study, as a syntactic knowledge, experienced science teachers' knowledge regarding nature of science was obtained.

Dual Perspective: The teaching that supports students to grow up as action competent citizens together with learning the models, theories and concepts is indicated by the dual perspective concept (Clausen, 2017).

Seasons: The revolution of the Earth around the Sun and the tilt of the Earth's rotation axis form the seasons (Sung, & Oh, 2018).

Weather: The current state of meteorological elements (i.e., wind, temperature, atmospheric pressure, precipitation, humidity) that changes daily in a short-time (Shepardson, Roychoudhury, Hirsch, Niyogi, & Top, 2014).

Climate: The averages of meteorological elements (i.e., atmospheric pressure, temperature, precipitation, humidity, wind) in the long-term might be called climate (Shepardson et al., 2014).

CHAPTER 2

LITERATURE REVIEW

The purpose of this study is to investigate the in-service science teachers' PCK and SMK (i.e., substantive knowledge and syntactic knowledge) regarding seasons, weather and climate addressing the dual perspective. In the literature review part, at first, previous research on PCK and SMK conducted with teacher candidates and teachers were reported under five sub-titles; research on Earth science, research on biology field, research on chemistry field, research on physic field and research on PCK for NOS. Secondly, previous research on substantive knowledge related to the understanding of seasons, weather and climate concepts were reported under two sub-titles; research conducted with teachers and research conducted with students.

2.1 PCK and SMK Research Conducted with In-service and Pre-service Teachers

Research on PCK has occupied a prominent place in the science education literature and researchers interested in identifying pre- and in-service teachers' PCK and SMK about different areas, such as Earth science (e.g. Akerson, 2005; Clausen, 2017; Henze, van Driel, & Verloop, 2008; Kaya, 2009; Teed, & Franco, 2014), biology (e.g. Bravo, & Cofré, 2016; Käpylä et al., 2009; Park, & Chen, 2012; Şen, Öztekin, & Demirdöğen, 2018), chemistry (e.g. Aydın, Friedrichsen, Boz, & Hanuscin, 2014; Mavhunga, & Rollnick, 2016; Pitjeng-Mosabala, & Rollnick, 2018), physic (e.g. Mazibe, Coetzee, & Gaigher, 2018; Rollnick, 2016).

Above mentioned research has been handled in different ways. While many research focused on individual PCK components, others focus on interactions among those components or on the impact of SMK on PCK, still others tried to find way to develop pre- and in-service teachers' PCK. Another line of research is interested in investigating participants' PCK for NOS (e.g., Demirdöğen, 2012; Demirdöğen, Hanuscin, Uzuntiryaki-Kondakci, & Köseoğlu, 2016; Wahbeh, & Abd-El-Khalick, 2014). It is seen that most of that research have been conducted by using qualitative methods; researchers generally collected data by means of interviews, Content Representation (CoRe) and classroom observations. In their studies, researchers, generally preferred Magnusson et al. (1999) model as a framework.

2.1.1 Research on Earth Science Topics

In this part, previous research have been conducted with both in-service and pre-service teachers' PCK and SMK about Earth science topics such as weather formation and climate (e.g. Clausen, 2016; Clausen, 2017), climate change (e.g. Plutzer, & Hannah, 2018; Teed, & Franco, 2014; Wise, 2010), global warming (e.g. Kutluca, 2021), ozone layer depletion (e.g. Kaya, 2009), sustainable development (e.g. Tiras, Öztekin, & Sen, 2017), air (e.g. Nilsson, & Loughran, 2012), causes and process of tropical cyclone (e.g. Lane, 2009; Lane, 2015a), solar system and the universe models (e.g. Henze, van Driel, & Verloop, 2008) and astronomy (e.g. Akerson, 2005) were reported. While some of these studies examine individual PCK components, other focus on relationship between those components or impact of SMK on PCK, and others focus on development of PCK.

Regarding weather formation and climate, Clausen (2016, 2017) conducted two studies with Danish geography teachers to reveal their PCK by taking dual perspective into consideration. Recalled that teaching involving students to be action competent citizens and learning about theories, models and concepts is called dual perspective (Clausen, 2017). In the first study, Clausen (2016) focused on changes in schooling context, and explored the Danish geography teachers' self-reported topic-specific professional knowledge (TSPK) (N=55), and he also explored the effects of external changes in Danish educational system on Danish geography teachers' PCK utilizing Gess-Newsome (2015) PCK Model. The data were collected through the survey in which open-ended questions related to the most crucial content areas and most crucial learning goals on teaching the weather formation and climate change were directed to the participants. Then, participants' responses to TSPK were categorized under five categories; "Knowledge about weather and climate", "Human interaction with nature" (e.g., the burning of fossil fuels leads to climate change), "Action competence" (e.g., students' attitude toward climate change), "Skills/practical work" (e.g., the student's gain of skills through teaching about climate and weather), "Other" (p.11). For example, regarding content and learning goal, *knowledge* related to weather and climate were determined as the most crucial content and learning goals followed by "Human interaction with nature" (p.11), and "Action competence" (p.11). The findings also revealed that teachers gave less importance on the practical work for teaching the related topic, which may create an obstacle for students to be an action competence citizen. Researcher attributed the little emphasis on practical work to the fact that this took a lot of time in classes, that the teachers had incomplete skills and knowledge to perform this and that the final exams could not evaluate the students' practical skills due to being multiple choice. Researcher concluded that the changing in the schooling system may affect the teachers' selection of content and also, may have caused them to more emphasize the *"knowledge"* category related to content and learning goal related to weather formation and climate change.

In the second article, Clausen (2017) conducted a case study to investigate the Danish geography teachers' PCK, teachers' professional knowledge bases (TSPK) and topic-specific professional knowledge (TPKB) were examined within the Gess-Newsome' PCK consensus model. Four experienced geography teachers from different lower-secondary schools (grade 7-9) constituted the sample similar to 2016 study. The data were obtained through classroom observations, video recordings and semi-structured interviews. Overall findings showed that each teacher's PCK were different, and they preferred to use different instructional strategies in their classroom practice, and that teachers' beliefs and orientations were compatible with their enacted PCK. For example, 13 years' experienced geography teacher stated that she possessed weak TSPK regarding weather formation, that understanding of the sub-topic of weather formation is difficult for students, and that preferred to use short-video sequences to teach difficult topic like weather formation. She also designed inquiry-based lab work related to weather maps and hydro-term figures. 19 years' experienced teacher on the other hand considered the climate change and weather formation topic as difficult and interesting. He thought that this topic is value laden (i.e., being absence of precise results). Whereas he said that he uses student centered approach to make students active, he used both teacher and student-centered approach (e.g., small experiment, classroom discussion) in the lesson. In the classroom observation, as he reported, he taught the lesson by giving examples from daily life. He performed his teaching with emphasizing the action competent citizen and for example, he asked that "What can you do, to reduce electricity consumption?" (p.6). 30 years' experienced teacher considered that doing experiment is difficult because of time limitation and appropriate instructional strategies. In the classroom observation, she created a student-centered environment and ask questions regarding the effects of climate change for human's life. Overall, she taught her lesson based on both knowledge of concepts and growing students as action competent citizen. 5 years' experienced teacher considered that it is necessary to learn models and graphs (e.g., water cycle) due to content of exams. In the classroom observation, he designed the group work and created an environment where students prepared reports regarding the climate change issues. He mentioned about solutions for emissions of greenhouse gas, but he did not integrate the action competent citizen issues into his teaching practice. Lastly, the findings showed that each teacher touched upon the dual perspective in their classroom practice, nonetheless they did not give importance for students' action experiences.

In the context of causes and process of tropical cyclone, Lane (2009) investigated experienced geography teachers' knowledge of students' (Year 9/10) misconceptions, the methods that used for evaluating students' prior knowledge and the ways of addressing the students' common misconceptions in the classroom practice based on Shulman's (1986) PCK dimensions in Sydney. The data were obtained from two geography teachers, one with five years and the other with fifteen years teaching experience, by the observation of the lesson, semi-structured interviews and besides video stimulated recall session. Lane (2009) concluded that experienced geography teachers' beliefs, professional practice and knowledge that represented their PCK were in a complex relationship and that each teachers' knowledge about students' common misconceptions. For example, more experienced teacher possessed more comprehensive knowledge and use of strategies, such as asking probing questions, implementing simulation activity, multiple choice quiz, and class competition related to identify students' misconceptions as compared to less experienced teacher who preferred to use brainstorming. In particular, less experienced teacher mentioned about some concepts related to the process of tropical cyclone formation (e.g., low pressure), directed to the concepts that the students were interested in (e.g., human impacts on tropical cyclones) in her teaching practice, addressed the students' confusing ideas as students' common ideas and beliefs (e.g., high pressure) and used brainstorming to provide students to participate to the lesson. But underestimated the students' wrong or irrelevant ideas that emerged during brainstorming as well as students' questions. During the lesson, she emphasized and eliminated the students' alternative conception by demonstrating pictures related to tropical storms (e.g., hurricane, typhoon) however, more experienced teacher was aware of the key concepts that students should know and students' common beliefs related to tropical cyclones and their learning difficulties. He performed several methods with the purpose of learning students' beliefs with respect to causes and process of tropical cyclone (e.g., performing multiple choice quiz, asking probing questions). He performed the class competition and simulation activity with the aim of addressing students' alternative conceptions.

In a separate study of Lane (2015a), which is a part of a larger study, experienced geography teachers' knowledge regarding students' common alternative conceptions and epistemological beliefs toward teaching and learning with respect to causes and process of tropical cyclone were investigated. Magnusson et al. (1999) Model of

PCK was used and knowledge of students' understanding and orientation toward science including epistemological beliefs about teaching and learning were examined. The data were collected from sixteen experienced secondary geography teachers whose teaching experiences were ranged from 5 to 35 years with using same data collection tools used in his previous study (Lane, 2009). The findings indicated that four teachers possessed detailed and comprehensive knowledge of students' ideas as well as areas of difficulties and also, extended their ideas with giving specific examples, which represented constructivist epistemological beliefs category. Overall, whereas teachers who belonged constructivist epistemological beliefs category were aware of the students' common alternative conceptions (e.g., have difficulty in understanding cyclones and tornadoes) in detail, teachers who belonged partially constructivist and transmissionist epistemological beliefs gave not importance to diagnose students' conceptions and therefore, they have limited PCK of students' ideas. Lane (2015a) concluded that teachers' knowledge of students' ideas was strongly associated with each their epistemological beliefs about teaching and learning.

Studying with pre-service science teachers, Kaya (2009) conducted a study with the aim of investigating their SMK, PCK, relationship between SMK-PCK and intra-relationship and inter-relationship among PCK components in ozone layer depletion context. Magnusson et al. (1999) PCK model was used and the four components of PCK, except from orientation toward science, were examined. The data were obtained through five item open-ended survey and besides semi-structured interviews. The open-ended survey was applied to two hundred sixteen pre-service science teachers whose ages between 21-23. For semi-structured interview, however, seventy-five pre-service science teachers were chosen according to their SMK level to investigate relationships among their PCK. While Pearson correlation was used to analyze the intra-relationship and inter-relationship among PCK components and also, MANOVA was used to analyze the effect of their SMK level on PCK. The categories which are appropriate, plausible and naïve were used to categorize responses of participants. According to the findings related to open-ended survey, participants' success rate was found to be low level which is nearly thirty-six percentage. Among five items found in the open-ended survey, participants possessed better knowledge related to the consequences of ozone layer depletion as well as nature of ozone layer. But acid rain, ozone layer depletion and global warming were inaccurately linked among each other by many participants. Half of the seventy-five participants' knowledge related to four PCK components were found plausible and a quarter of participants knowledge related to curriculum, instructional strategies and students' understandings were found appropriate. The results of Pearson correlation indicated that participants' PCK involving all components and SMK were significantly correlated with each other. The results of MANOVA analysis indicated that the intra-relationship among PCK components were correlated significantly with each other, but this was not found between other PCK components and knowledge of assessment. The researcher concluded that SMK and knowledge of assessment were correlated significantly with each other. Yet it was found to be poor correlation when compared to other relationships. Researcher explained that there is one lesson about the assessment in Turkey and there is no course that gives students the opportunity to apply their assessment knowledge. Findings further demonstrated that participants' PCK level show variation relying on their SMK level with respect to ozone layer depletion topic. Researcher concluded that the reasons of this result may be originated from the science teacher education program in Turkey since in the first subsequent two years, Turkish pre-service science teachers obtain majority of their SMK from science and laboratory lesson (Kaya, 2009). The courses related to SMK and PCK in Turkey to have been given at separate times and this situation is an obstacle for pre-service science teachers to improve their PCK.

In a relatively recent study, Tiras, Öztekin and Sen (2017) carried out a study for exploring pre-service science teachers' (N=3) SMK and PCK with respect to sustainable development. The data were collected through interview and then, analyzed by deductively. Magnusson et al. (1999) PCK model was used and the four components of PCK were examined except from orientation toward science teaching. Based on the findings, it was revealed that pre-service science teachers had a deficient knowledge related to sustainable development, for example, they were not aware of the purpose of the education for sustainable development and the human aspect of sustainability. Their knowledge of curriculum was found to be lack because they were not aware of the objectives, place of the sustainable development in the curriculum, its' vertical and horizontal relations. They had a lack of knowledge related to students' understandings because they did not express any students' misconceptions regarding sustainable development. The findings also indicated that they possessed background knowledge related to assessment and instructional strategies as opposed to other components of PCK. For example, they indicated that they assess not only students' content knowledge but also their behaviors and discussion skills toward sustainable development. They mentioned about the alternative assessment methods to assess students' understandings (e.g., concept maps, projects). They mentioned about the student-centered teaching strategies (e.g., problem-based learning, 5E learning cycle), topic-specific representations (e.g., simulations, metaphors) and also activities.

Some researchers turned their attention to develop science teachers' PCK (Barnett, & Friedrichsen, 2015; Bravo, & Cofré, 2016; Chan, & Yung, 2018; Henze, van Driel, & Verloop, 2008; Nilsson, & Loughran, 2012; Pitjeng-Mosabala, & Rollnick, 2018; Teed, & Franco, 2014; Van Driel, De Jong, & Verloop, 2002; van Driel, Verloop, & de Vos, 1998). For example, Teed and Franco (2014) conducted a study to develop in-service science teachers' (N=18) CK, PCK and their confidence related to weather, climate and climate change. Hence, they developed Earth science summer workshop followed by follow-up program regarding climate change over geologic time. Teachers participated in the Earth science summer workshop regarding climate change on geologic time through three weeks and each week's topic were different from each other ("causes of climate and weather, geologic time and changes in the Earth system" "anthropogenic climate change")". For example, first week participants were divided into five groups and each group was assigned for teaching different topic such as ocean, sunlight, latitude and tilt, biomes. Then, each participant involved in new groups and explained the topic they learned in their own groups to the other group members. For developing their PCK, each group was asked to construct CoRe related to their assigned topic. In the second week, participants went to a field trip to collect fossils (e.g., ancient marine organisms), which enabled them to understand the geologic timescale concept and the biological and environmental changes. They were requested to perform time-line worksheets created by Teed and Wright (2014) related to scale of geologic history. Lastly week participants created a lesson plan with the new knowledge that gained during the Earth science summer workshop. The participants were subject to content knowledge pre- and post-test at the first day and final day of the Earth science summer workshop. Then, in the follow-up program, participants completed and implemented their lesson plans to K-8 and high school students in the classroom and then, they made discussion on the questions found in the pre-post content knowledge test. The pre- and post-test scores revealed that teachers' CK developed through the Earth science summer workshop. The findings also revealed that participants' pedagogical preparations and attitudes towards teaching climate change increased.

Air is another earth science topic studied by Nilsson and Loughran (2012) who focused on the PCK development of Swedish pre-service science teachers (N=34) during science teacher preparation program. The Magnusson et al. (1999) PCK model was used. Participants were asked to prepare 2 CoRes and to teach one of the following topics including volcanoes, sound, water, floating and sinking and air for teaching. Among these, the air topic was mostly preferred topic and therefore, the data regarding the air topic was analyzed. At first, in science method course, PCK and followed by CoRe tool which is used toward describe PCK aspects were presented. While the first CoRe considered as a pre-test (CoRe 1) for teaching in Science Learning Centre within the science methods course, second CoRe evaluated as a post-test for school practicum experience. According to the findings, participants' responses for CoRe 2 (post-test) were more detailed and expanded as compared to CoRe 1 (pre-test) in terms of several dimensions such as "What Do You Intend Students to Learn About this Idea?" (p.709), "Why is it Important for Students to Know this?" (p.710), "What Else Do You Know About this Idea" (p.710), "Difficulties/Limitations Connected with Teaching this Idea" (p.711). One of the participants realized in her CoRe 2 that the fact that air could take up space is difficult to understand by the many students, and thereby, she thought that experiments and discussions about air topic should be done. Another participant considered in her CoRe 1 that students should learn the air topic due to its relation to their daily life, but CoRe 2, she improved her understanding that students are able to learn the necessity of air for living things through learning air topic. Another participant considered in CoRe 1 that students might have difficulty in defining the concept of gas. But in CoRe 2, he expressed his thoughts in more detail, for example, the concept of air can be difficult for students to understand because it is an abstract concept. In general, teachers developed their thoughts on the balance of their own content knowledge and the information that the students should learn and they started to question more on this issue. Overall results showed that participants' PCK developed because of their gaining teaching experience from their classroom practice.

In another development study, experienced science teachers' development of PCK related to "Models of the solar system and the universe" was explored by Henze, van Driel and Verloop (2008) through conducting a longitudinal study utilizing Grossman (1990) and Magnusson et al. (1999) PCK model. Nine Dutch experienced science teachers whose teaching experiences were between 8 and 26 years attended in the study. The four components of PCK, excluding orientation toward science, were examined. Teachers completed their teachings regarding models of the solar system and universe, and then, the semi-structured interviews were utilized as data sources that performed in three subsequent years, and two types of PCK were created by researcher in consequences of interview analysis. In short, in first year, it was found that whereas Type A- PCK represented the concentrating on the model content, Type B PCK represented the concentrating on model production, model content as well as considering the nature of models. Teachers having Type A PCK were found to be aware of the influential teaching strategies and materials so that students can understand the models related to solar system yet they had not particular knowledge related to students' understandings. They knew assessment strategies for evaluating students' understanding related to models (e.g., presentations, exams) and they had a view of the combination of instrumentalist and positivist, which represented their knowledge of curriculum. Teachers having Type B PCK, were aware of the influential teaching strategies that can challenge students and encourage their learning related to model production, model content and thinking about the nature of models. They were aware of the assessment strategies (e.g., debating activities, modelling, portfolios), and the students' particular learning difficulties, deficiency toward modelling activities and model content and their motivation. They were aware of the way of constructing hypothesis and testing it, descripting and visualizing the phenomena related to model production, model content and thinking about the nature of models, which represented their knowledge of curriculum. The findings related to Type A and B PCK model showed that throughout the 3-year periods, there was improvement in teacher's knowledge of instructional strategies because teacher examined students' reports and written exams' results. This situation also implied the relationship among teacher's knowledge of assessment, instructional strategies and students' understanding. However, it was not found any significant improvement in teacher's knowledge about goals and objectives in both PCK model. While the interaction among the components in Type A PCK model was static, there was dynamic interaction among the components in Type B PCK model. Henze et al. (2008) concluded that teachers' beliefs and general pedagogical knowledge were congruent with development of both Type A and B PCK, and that teachers' initial pedagogical views and epistemological views regarding the models of the solar system and universe were associated with their development of PCK.

Another line of research is interested in comparing in-service and pre-service teachers (Akerson, 2005). She investigated how elementary teachers' cope with the incomplete science content knowledge related to astronomy unit in USA and factors affecting teachers' coping with the incomplete science content knowledge. Two experienced elementary teachers, one with 24 years and the other with 10 years of teaching experience, taught the astronomy topic through science activities and one intern (pre-service) teacher enrolled in one of the teachers’ teaching in the context of astronomy instruction. The data were obtained from participants via detail classroom observation that were video- and audio-recorded. According to the findings, experienced teachers were found to compensate their incomplete knowledge in astronomy by listening their students’ questions and ideas, reading non-fiction trade books, and current events and sharing it with students. For example, experienced teachers also tried to improve their students’ knowledge related to astronomy by asking questions, doing discussion, eliciting students’ ideas and then, designing the lesson with focusing on students’ ideas, debriefing of lessons. One of the teachers (24 years) determined students’ ideas related to galaxies through creating a discussion environment. When she listened her students’ ideas, she recognized that she should need to learn more knowledge relate to galaxies and read more to become informed about the galaxies. She also recognized that one student had incorrect idea related to causes of day and night and then, designed her lesson to address students’ ideas by using the models of the Earth, sun and moon and explained by asking questions to direct students toward correct concept. Pre-service teacher, by contrast, possessed only pedagogical concern regarding her teaching and cared with her deficiency toward learning the astronomy. Stated differently, she did not focus on students’ learning and ignored the factors that encourage herself toward developing her knowledge related to such as students' misconceptions during her teaching. For example, although she wanted to provide students to learn the astronomy topic by performing hands-on activity, she did not succeed because she had lack of knowledge regarding astronomy.

To conclude, this section reviewed and reported the previous research on Earth science topics. As seen from the reported research above, it can be concluded that the experienced teachers’ PCK appears to more developed compared to pre-service or less experienced teachers. In addition, in-service, or pre-service teachers’ PCK were developed with the implementation of various intervention studies (e.g., workshop). Apart from Earth science, PCK studies were also conducted by other domains of science. In the next section, prior research on biology topics were presented.

2.1.2 Research on Biology Topics

In this section, previous research was conducted with both in-service and pre-service teachers on biology topics such as evolution and natural selection (e.g. Barnett, & Friedrichsen, 2015; Bravo, & Cofré, 2016; King-Heiden & Litster, 2019; Lucero, Petrosino, & Delgado, 2017; Tekkaya, & Kılıç, 2012; Veal, & Kubasko, 2003), photosynthesis (e.g. Käpylä et al., 2009; Park, & Chen, 2012), plant growth (e.g. Käpylä, et al. 2009), ecosystems (e.g. Tıraş, 2019), biogeochemical cycles (e.g. Yılmaz Yendi, 2019), genetic (e.g. Mthethwa-Kunene, Onwu, & de Villiers, 2015), heredity (e.g., Park, & Chen, 2012), cell division (e.g. Şen et al., 2018), DNA/Protein synthesis (e.g. Barnett, & Friedrichsen, 2015) and polymerase chain reaction (e.g. Chan, & Yung, 2018) were reviewed and reported.

As seen cited literature, some researchers interested in teachers' or preservice teachers' PCK on two different topics. For example, Käpylä et al. (2009) investigated the impact of CK on PCK on photosynthesis and plant growth topic using Magnusson et al. (1999) PCK model. The study examined four PCK components including knowledge of curriculum, learner, teaching methods and orientation toward teaching. The sample was comprised of twenty Finnish prospective biology and prospective primary teachers who were selected depend on different levels of CK; ten secondary prospective biology teachers were named as content expert, and ten prospective primary teachers were named as content novice. The data were gathered by prospective teachers' lesson plan, interview and questionnaire. Overall results indicated that as opposed to primary prospective teachers, prospective biology teachers possessed better content knowledge and less misconceptions related to photosynthesis and plant growth topic as well as knowledgeable about the relationship between plant growth and photosynthesis and that there is a positive connection between PCK and CK. The findings also indicated that while prospective biology teachers were tended to implement more direct activities (e.g., field work, examining plant structure), prospective primary teachers have a tendency to implement more indirect activities (e.g., drama, small group discussion). As opposed to prospective biology teachers, prospective primary teachers were less aware of the conceptual difficulties of students due to having misconceptions. In comparison to prospective primary teachers, prospective biology teachers addressed more crucial topics found in the biology curriculum. Prospective primary teachers who were labelled as content novice embraced the constructivist orientation, that is, they have more tendency to teach lesson based on student-centered. In contrast, prospective biology teachers who were labelled as content expert embraced the conceptual teaching orientation, that is, their teaching were more tended to teach lesson based on teacher-centered.

Likewise, Park and Chen (2012) investigated the high school biology teachers' (N=4) PCK in photosynthesis and heredity topics in terms of interaction among the all PCK components within the framework of Pentagon Model (Park and Oliver, 2008b). The data were gathered by lesson plans, classroom observations, instructional materials, video-recorded lessons, semi-structured interviews including pre-post observation and background interview, students' work samples such as posters, lab reports. Depending on the collected data, PCK maps were created for each teacher's PCK regarding both topics. The findings indicated that differences were observed between the teachers' PCK maps for photosynthesis and heredity. Results showed that PCK has topic-specific nature that depends on how the components are interacted with each other. Researchers concluded that deficiency of harmony among the components may cause difficulties in the development of PCK (Park, & Chen, 2012). For instance, three teachers' PCK maps related to heredity showed less coherence compared to photosynthesis. Among these three teachers, one teacher expressed that because there are more concepts that need to be explained about heredity and thereby, heredity topic is more difficult to teach. This teacher while preferred rote learning instead of experiments in heredity, preferred inquiry-based teaching method and experiment in photosynthesis. Another finding indicated that knowledge of instructional strategies and knowledge of students' understanding are more interacted with other components and also, the interaction between them to be found as strong compared to other interactions. Among the other components, the knowledge of curriculum was found to be interacted less with other components. Researcher attributed those finding to the teachers' limited curriculum knowledge related topics. It was found that knowledge of assessment has most connections with knowledge of instructional strategies and students' understanding. Lastly, Park and Chen (2012) reached a conclusion that his orientation restrained the linking his knowledge of instructional strategies with other PCK components (e.g., knowledge of students). For instance, the teacher who embraced the didactic orientation taught the topic with didactic way (e.g., being knowledge transmitter) and so was not aware of the misconceptions of students.

Barnett and Friedrichsen' (2015) focus on concepts of DNA/Protein Synthesis and evolution. They conducted an intrinsic case study in order to identify secondary biology mentor teachers' who have 25 years teaching experiences strategies that used for development of one pre-service teacher's PCK based on situated learning theory and, educative mentoring. All components of Magnusson et al. (1999) PCK model was used. The data were gathered in the mentor teacher's classroom by means of semi-structured interviews and the daily meetings occurred between pre-service teacher and mentor, as well as field notes regarding weekly conversions between mentor and pre-service teacher. According to the findings, pre-service teacher's orientation toward science teaching was developed by several mentor strategies. To illustrate, mentor enabled pre-service teacher to assess himself to realize the consistency between his beliefs about students' learning and his teaching practice. Comparing the student-centered teaching strategies with teacher-centered one, teacher tied to direct him to student-centered teaching strategies. The mentor teacher aimed to develop pre-service teacher's knowledge of instructional strategies through mentioning her past experiences related to instructional strategies including strengths and weaknesses she used before (e.g., a paper DNA model), which encourage pre-service teacher to think critically about the instructional strategies he will use. By showing the old test-items implemented in past years and making discussion on prevalent misconceptions emerged from students' responses, the teacher intended to develop students' understanding. To develops pre-service teacher's knowledge of assessment, she implemented several strategies. For instance, mentor enabled pre-service teacher to examine critically the past exams and think on the regulation of exam questions to evaluate understanding of students in a better way. Lastly, it was found that pre-service teacher's knowledge of curriculum was also aimed to develop with helping of making discussion related to the how the concepts (e.g., teaching adaptations) in the DNA/Protein Synthesis unit should be ordered. Thus, Barnett and Friedrichsen (2015) concluded that pre-service teacher's PCK about DNA/Protein Synthesis developed with the implementation of different educative science mentor strategies.

Another study examined experienced biology teachers' PCK as well as development of PCK with respect to teaching of genetic topic in Swaziland secondary schools (Mthethwa-Kunene, Onwu, & de Villiers, 2015). Four experienced Grade 11-12 biology teachers whose teaching experiences were range between 5 and 22 participated in study. The multiple case method that is included in qualitative methodology was adopted for the study. Video-recorded classroom observations, concept maps, audio-recorded pre-post lesson interviews, post-lesson teacher questionnaire and document analysis (e.g., lesson plans of teachers) were utilized to collect data. The results of concept maps revealed that they have sufficient level of curriculum content knowledge regarding genetic. All teachers used conditional, declarative and procedural CK, but declarative CK was preferred commonly by teachers to describe concepts of genetic such as allele, genes, chromosome. Teachers performed several topic-specific instructional strategies such as analogies, questioning, peer teaching, homework assignments. The findings related to questionnaire indicated that teachers have not possess adequate knowledge regarding students' preconceptions as to genetic and they did not design their lessons based on students' preconceptions regarding genetic. As a common example of students' learning difficulties, all teachers mentioned they confused meiosis and mitosis to each other along with concepts of gene and chromosome. Teachers considered that the learning difficulties of the students may be due to the abstract nature of the genetic. In addition, in the post-reflection, teachers stated that their PCK could be developed and redefined through participating in in-service professional development biology workshops, taking disciplinary courses at the university and also, applying post-lesson reflections.

Recently, Chan and Yung (2018) conducted a case study to explore the experienced biology teachers' development of PCK in polymerase chain reaction topic which is recently included in New Senior Secondary 6th Grade Curriculum (aged 17-18) in Hong Kong context. Magnusson et al. (1999) PCK model was used. The sample was comprised of two experienced high school biology teachers who possessed sufficient level of SMK related to polymerase chain reaction. The data were obtained through field notes, classroom observations, semi-structured interviews (e.g., stimulated recall) and classroom artefacts and analyzed in qualitative way. The findings of the study showed that both although differences between biology teachers' planning lesson plans was observed, their previous teaching experiences provided information about the ways how teachers plan their lessons. For example, teacher having six years teaching experiences designed his lesson with examining content knowledge related to polymerase chain reaction superficially. He asked questions to the students with the aim of revealing their prior knowledge and encouraging them to make relationship between their prior knowledge and polymerase chain reaction topic. He did not, however, pay attention to students' learning difficulties and assessment for students' learning while planning his lesson. Moreover, he considered that the DNA replication topic that students learned before is easy and therefore, they have not difficulty in understanding, but it was observed that they had difficulty in understanding DNA replication. Another teacher having fourteen years teaching experience designed his lesson noticing students' learning difficulties, misconceptions and prerequisite knowledge. For instance, he considered that students have deficient prerequisite knowledge and may have misconception about DNA denaturation and therefore, drew a diagram related to DNA denaturation. He also assessed students through quiz including test items to understand whether students' confusion about protein denaturation and DNA were eliminated. Researchers concluded that SMK, according to how the teacher handles it, either supports or prevents the development of PCK.

Şen (2014) conducted a multiple case study with experienced science teachers and explored their CK and PCK on cell division by using all components in Magnusson et al. (1999) PCK model. Three experienced science teachers whose teaching experiences were 8, 9 and 11 years from different private schools participated in the study. Audio-recorded PCK pre-post interviews and substantive content knowledge pre-interview, classroom observations and teacher documents as visual and personal documents such as written exams, teacher drawings were utilized as data sources. Findings revealed that teachers had lack of knowledge and also misconceptions regarding cell division topic, such as mechanism of asexual reproduction, sexual production and genetic transferring. Teachers were aware of the related objectives, horizontal relations (e.g., genetics, meiosis, mitosis) and vertical relations (e.g., reproduction, growth and development) of the cell division topic as well as students' misconceptions (e.g., the differences between in separation of sister chromatids and homolog chromosomes), learning difficulties (e.g., cell division of plants, comparison between meiosis and mitosis) and prerequisite knowledge (e.g., cell, growth and development, organelles). They were also found as informed about the place of curriculum, limitations and misconceptions stated in the curriculum related to cell division topic. However, they also violated the curriculum objectives by mentioning about chiasmata and tetrad. Teachers stated that they only assessed students' conceptual understanding using traditional assessment methods (e.g., questioning) only. By using same sample, and data collection tools, Şen et al., (2018) investigated the relationship between CK and PCK. The teachers were labelled as curriculum-led teacher, content-novice teacher and content-expert teacher depending on their level of CK. It was found that teacher who labelled as content-expert possessed several drawbacks related to knowledge of curriculum. Teacher who has strong CK reported to be more knowledgeable about knowledge of students' difficulties, and topic-specific teaching strategies, for instance, curriculum led and content-expert teacher utilized more topic-specific strategies than content-novice teachers. No clear relationship between CK and knowledge of assessment, however, was found. Şen et al. (2018) concluded that CK supported only the knowledge of instructional strategies and knowledge of students' understanding components of the PCK and that the effect of CK on knowledge of assessment and knowledge of curriculum remained to be quite complex.

In the context of evolution, Veal and Kubasko (2003) designed a case study and compared the domain specific PCK of in-service and pre-service geology and biology teachers (N=12). Audio recorded semi-structured interviews, classroom observations, field notes, unstructured conversations and documents such as assignments, journals were used as data sources. Overall results showed that there are differences between pre-service and in-service biology and geography teachers in terms of handling the evolution topic. For example, in comparison with in-service teachers, pre-service geology and biology teachers preferred to implement traditional teaching strategies for teaching of the evolution because of their deficiencies related to the topic-specific activities and background of students. Yet experienced biology and geology teachers preferred to implement discussion method. For teaching of the evolutionary concepts, while the biology teachers made use of discussions regarding the evolution, the geology teachers made use of the fossil record. As compared to geology teachers, biology teachers used more activities (e.g., bead activity) and analogies in the classroom practice. Compared to the geology teachers, biology teachers were more knowledgeable related to the knowledge of students such as misconceptions as to the evolution topic. The vocabulary used by the geology and biology teachers while teaching the evolution showed variation. While biology teachers used the concepts such as theory, DNA, evidence, natural selection, geology teachers used the concepts such as Earth's history, slow change, erosion. Researcher concluded that although the content of the evolution topic show similarity, geology and biology are different domains and so geology and biology teachers' teaching approaches regarding the evolution topic are different. This indicated the differences between their domain specific PCK upon evolution.

Another research on evolution and natural selection was carried out by Lucero, Petrosino and Delgado (2017) to investigate the relationship between biology teachers' knowledge of students' conceptions and their SMK through Magnusson et al. (1999) PCK model in USA. The data were gathered from four high school biology teachers having 7, 3, 2 years and 1 semester teaching experiences together with their three hundred thirty-nine students (aged between 9 and 12) by means of video-recorded classroom observations, interviews, teachers' and students' responses to Conceptual Inventory of Natural Selection (CINS) and teachers' predictions regarding students' most common alternative conceptions on CINS. The CINS results showed that the range of teachers' SMK level were between the value of 65% and 80%. While some CINS concepts were easier to give correct answers for teachers (e.g., natural resources), some CINS concepts were more difficult for teachers (e.g., change in a population). Another finding indicated that majority of teacher predicted students' alternative conceptions correctly. Teachers tried to address their students' alternative misconceptions through asking them examine their textbooks to find the scientifically correct definition, and they also addressed scientists' ideas with the aim of getting attention of students to the lesson. Lucero et al. (2017) concluded that knowledge of students' conceptions was found to be not dependent on teachers' SMK because teachers' prediction accuracy patterns on CINS were similar to each other.

In the context of human evolution Bravo and Cofré (2016) conducted a multiple case study to explore the development of secondary biology teachers' (N=2) PCK by means of Professional Development Program (PDP). The four components of Magnusson et al. (1999) PCK model were used. Two biology teachers were worked collaboratively in the PDP, aiming at to develop their understanding about evolution, NOS and also how to apply their knowledge to their teaching practice. PDP included several parts; updates of content regarding human evolution, design of lesson plan followed by implementation of the lesson plan. Then, the applied lesson plans were video-recorded in the classroom environment. The data were gathered through first interview prior to PDP, which revealed their first CoRe, followed by group interview after the implementation of lessons. These teachers were applied to individual stimulated recall interview, providing them to state their thoughts regarding their teachings upon human evolution, which revealed their last CoRe. According to the findings, Bravo and Cofré (2016) concluded that teachers revised their thoughts about the way of teaching the evolution by examining their beliefs, self-efficacy, teaching strategies, and knowledge related to evolution throughout the PDP. The teachers' PCK developed in terms of their knowledge and beliefs regarding the teaching methods used for teaching the evolution as well as their knowledge regarding the students' misconceptions and learning difficulties. Another aim of the study is to explore the changes in teachers' knowledge related to evolution and NOS. Compared to before the PDP, after first part of PDP was completed, they became aware of the significance of interaction between the NOS understanding and teaching of evolution and, they acquired good knowledge related to them. Both teachers stated that their reflection on their teaching practice about evolution gave feedback about what they should be changed and improved in their teaching and thus, this situation improved their PCK.

Recently, Tıraş (2019) investigated experienced middle school science teachers' topic-specific pedagogical content knowledge (TSPCK) and substantive content knowledge in the context of ecosystem in the framework of Magnusson et al. (1999) model of PCK. The data were collected via semi-structured interviews, word association test, concept maps, classroom observations and draw, ecosystem test and analyzed with deductive and inductive coding. Briefly, Tıraş (2019) concluded that science teachers' knowledge related to PCK components, apart from knowledge of curriculum, and their substantive knowledge in the context of ecosystem were found to be deficient. The findings indicated that teachers had a lack of knowledge (e.g., flow of energy, confusing the concepts of ecosystem and community) and also had misconceptions about ecosystem concepts (e.g., not expressing the way of working of decomposers in nature). Although teachers expressed the schooling and subject matter goals as central goals and affective goals as peripheral goals in the interview, they emphasized only subject matter goals in the lesson. Teachers mentioned about the students' prerequisite knowledge (e.g., non-living things, living things), and learning difficulties (e.g., the confusing of speciation and population concepts), but did not mention about the student' misconceptions. Unlike from the interview, they used traditional teaching strategies (e.g., direct teaching, questioning), and preferred to show visuals (e.g., videos, pictures) regarding ecosystem in their teachings, but did not perform any activities. Teachers focused on assessing students' knowledge only about curriculum objectives related to ecosystem. Teachers assessed students' understanding during and at the end of the lesson through traditional assessment techniques (e.g., questioning), yet they were not aware of the alternative assessment techniques.

Another recent study was carried out by Yılmaz Yendi (2019). She explored experienced in-service science teachers' PCK and SMK with respect to biogeochemical cycles within the context of sustainable development. Magnusson et al. (1999) PCK model was used and all components were examined. Three experienced science teachers whose teaching experiences were 21, 26 and 38 years participated in the study. Semi-structured interviews, video-recorded classroom observations, card sorting activity and teacher documents were used as data sources. Overall findings indicated that teachers' PCK and SMK related to biogeochemical cycles including hydrologic, carbon and nitrogen cycles within the context of sustainable development were found deficient. For example, regarding substantive knowledge, all teachers possessed lack of knowledge regarding aquatic carbon cycle, driving forces for cycle, and aquatic systems. Teachers having thirty-eight- and twenty-one years teaching experiences were found to ignore the producers that are cyanobacteria and algae in photosynthesis. Teacher having twenty-one years teaching experiences were not aware of the transpiration process in hydrological cycle and climatic factors, and had difficulty in understanding the differences between nitrifying bacteria and decomposers. Regarding PCK, while teachers having thirty-eight- and twenty-one years teaching experiences underlined the schooling and subject matter goals, teacher having twenty-six years teaching experience underlined the schooling and affective goals. All teachers knew the objectives, vertical relations (e.g., properties of elements and compounds), horizontal relations (e.g., photosynthesis) and the students' prerequisite knowledge (e.g., weather events) with respect to biogeochemical cycles. Compared to other teachers, teacher having twenty-six years teaching experiences used student-centered teaching methods (e.g. project-based learning) and benefitted from more representations (e.g., animations, daily-life examples, activities). All of them did not implement activities. As opposed to other teachers, teacher having twenty-six years teaching experiences mainly mentioned and used alternative assessment methods (e.g., concept map). Another purpose of the study is to explore the relationship that teachers establish between the sustainable development and biogeochemical cycles. All of them associated the sustainable development with carbon, nitrogen or hydrological cycles by mentioning about some dimensions of the sustainable development (e.g., political, economic, societal).

As reported, above mentioned studies interested in comparing topic and domain specific nature of PCK or examine individual PCK components, other focus on relationship between those components or impact of SMK on PCK, others focus on development of PCK. Next section, it was focused on the previous research on chemistry topics.

2.1.3 Research on Chemistry Topics

In this section, previous research was conducted with both in-service and pre-service teachers on chemistry topics such as chemical equilibrium (e.g. Mavhunga, 2018; Mavhunga, & Rollnick, 2016; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008; van Driel, Verloop, & de Vos, 1998), electrochemical cells and nuclear reaction (e.g. Aydın, Friedrichsen, Boz, & Hanuscin, 2014), macro-micro issues (e.g. Van Driel, De Jong, & Verloop, 2002), ion and how ions are formed (e.g. Nilsson, 2014), particulate nature of matter (e.g. Hanuscin, Cisterna, & Lipsitz, 2018; Pitjeng-

Mosabala, & Rollnick, 2018), the structure and properties of matter (e.g. Hanuscin, de Araujo, Cisterna, Lipsitz, & van Garderen, 2020) and states of matter and phase transitions (e.g. Ohle, Boone, & Fischer, 2015) were reviewed and reported.

Similar to other areas, some research on chemistry also focused on the relationship between PCK and SMK. For example, Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) studied with experienced South African teachers' (N=3) with the purpose of exploring the impact of SMK on PCK in teaching the amount of substance (i.e., mole) and chemical equilibrium with the adopting of Gess-Newsome (1999) model. In the case study, whereas two teachers participated to the workshop including instructional strategies related to mole, another teacher participated to the workshop related to chemical equilibrium, and then, all of them performed their teachings. The data were collected via pre-post interview, classroom observation and teacher documents, and analyzed via CoRe and PaP-eR. Four categories were emerged in both cases consequences of data analysis; SMK, curricular saliency, topic-specific instructional strategies and subject matter representations. For example, the findings related to mole case study indicated that both teachers underlined the procedural aspects of the mole concept, did not touch upon the conceptual aspects during their lessons. They mentioned about the calculations, formula and algorithmic exercises related to mole (e.g., number of moles) due to the public exam held at the end of the year and they did not establish the association between calculations and conceptual understandings. As a result, it was revealed that because teachers possessed limited understandings related to concepts of mole, their classroom practice were also limited. Related to chemical equilibrium case study, researcher concluded that teacher's SMK was strong because he established integration between context and knowledge of learner, and besides, his PCK was found to be highly developed. So, he transforms his SMK to new and powerful pedagogical practices in his teaching. For instance, his knowledge of curricular saliency was strong because he explained the absence of the chemical equilibrium in the syllabus and connections of it with other topics (e.g., acids, bases). He was knowledgeable related to students' understanding (e.g., misconceptions) because of his previous teaching experiences. For example, based on students' knowledge, he gave the phase of equilibrium, saturated solution as examples to provide students to understand chemical equilibrium concept.

Studying with the pre-service chemistry teachers (N=16), Mavhunga and Rollnick (2016) carried out a study to seek for development of their TSPCK, their science teaching beliefs and also the relationship between TSPCK and science teaching beliefs regarding chemical equilibrium through the intervention study in South Africa context. Gess-Newsome (2015) PCK model was used and all TSPCK components were examined. For teachers' TSPCK, while written class activities for each component, audio recorded classroom discussion and CoRe were gathered as qualitative data source, TSPCK instrument was implemented as pre- and post- test to obtain data quantitatively. Pre-service teachers' qualitative data regarding science beliefs was gathered by Teacher Belief Tool and open responses on statement with respect to beliefs related to sense of being a science teacher. The findings related to teachers' TSPCK showed that pre-service teachers' views for teaching of chemical equilibrium topic was developed, which implied that their TSPCK quality was developed as compared to before intervention. The findings related to teacher science beliefs through pre-test to post-test showed that there was a change in pre-service teachers' beliefs on the side of learner-centered beliefs (e.g., reformed-based beliefs). Another finding further revealed that it was found a complex interaction between teachers' beliefs and TSPCK. For example, while one group's TSPCK was developed after intervention, no change was occurred in their traditional beliefs about science teaching. Mavhunga and Rollnick concluded that teachers' beliefs and development of TSPCK are not depended to each other because when developed TSPCK were examined, the teachers' beliefs which are traditional and reformed based were observed together.

Another study on chemical equilibrium was carried out by Mavhunga (2018) with aim of the finding out the complexity of TSPCK (Park, & Oliver, 2008a) components that occur in planning of teaching the related topic through the intervention study. The sample was comprised of fifteen pre-service science teachers in final year of

Bachelor education. The intervention was implemented in chemistry methodology course to pre-service science teachers through more than six weeks and this intervention involved tutorial work as well as lecture. During the intervention, the TSPCK components were introduced, the five TSPCK components were matched to chemical equilibrium concepts (e.g., dynamic equilibrium) and following, they were discussed among them. After the intervention was finished, they completed expanded lesson plans and CoRes as an assignment for the methodology course. The data were gathered via CoRes constructed by pre-service science teachers and expanded lesson plans. In-depth qualitative analysis was used as a method for data analysis. The findings indicated that it was found lots of interactions which were existed to be idiosyncratic and complex formed by different combinations among TSPCK components and thereby, TSPCK and PCK possessed similar properties. Mavhunga (2018) stated that TSPCK episodes were created by pre-service science teachers through interactions among the components and these interactions that are special for every participant included diverse combinations of the components. While the most frequently used component was found to be curricular saliency, the least frequently used component was found to be conceptual teaching strategy. Another finding indicated that interactions among the components were found to be separable from each other and besides the interactions among TSPCK components can include interwoven formation or the combination of interwoven and linear formation. Lastly, the findings further pointed out that teachers' lesson sequence, summary of the most crucial CK and besides suggestions for conceptual teaching strategies bring about revealing most the complex interaction among TSPCK components.

Studying with in-service chemistry teachers, van Driel, Verloop and de Vos (1998) delved into their PCK development regarding chemical equilibrium in concern with representation of SMK and students’ understanding based on Shulman’s (1986) explanation through a workshop. Twelve chemistry teachers whose teaching experience are more than 5 years attended to the study, and they were involved in the workshop including meetings that were performed before, after and during the experimental course. In the first meeting, teachers implemented the assignments and chemical experiments in the chemistry textbooks, and then made discussion. Next meeting, they made discussion regarding their practical experiences and in the final meeting, they expressed their experiences regarding experimental course. Teachers performed the experimental course where students performed chemical experiments, participated into small group discussion and made assignments related to their existing conceptions in the first part of the workshop. The data were collected through the audio-recorded workshops, evaluative questionnaire and teachers' written answers on assignment during the workshop. Based on the findings, teachers considered that majority of students have difficulty in understanding the nature of dynamic conception of chemical equilibrium. Besides, majority of teachers have difficulty in understanding this topic. During the lesson, teachers recognized that they had lack of knowledge related to arguments regarding forward and backward reactions and also, their arguments were not strong to provide students to be convinced. Thereby, they preferred to use analogies to inform students related to this topic. Experimental course and workshops influenced teachers because teachers had more detailed knowledge regarding students' conceptions as well as obtained knowledge regarding students' learning difficulties and reasoning regarding chemical equilibrium. What is more, some teachers' knowledge related to representations (e.g., analogies) as well as strategies (e.g., argumentation, small-group discussion) showed improvement through workshop sessions. For example, they used discussion method to deal with students' difficulties related to occurring of opposite reactions simultaneously. van Driel et al. (1998) concluded that teachers' knowledge regarding the way of transforming of SMK as well as the way of associating the students' understanding to transformation of SMK raised, which implied that teachers' PCK developed.

In their other study, Van Driel and his colleagues (De Jong and Verloop (2002) conducted a qualitative in-depth study in order to explore the pre-service chemistry teachers' (N=12) development of PCK as well as the factors affecting the PCK development in the domain of macro-micro through one-year post-graduate teacher education program in first semester in Netherlands. Shulman's (1987) two PCK elements which are knowledge of instructional strategies incorporating representations of subject matter and knowledge of specific conceptions and learning difficulties of students were addressed in the study. Pre-service chemistry teachers who are from different universities were assigned two different mentors. In post-graduate teacher education program, participants were subject to first questionnaire related to PCK and SMK. Workshop was performed with two sessions in two different universities, and all participants and their mentors were subject to semi-structured interview. Lastly, participants were subject to second questionnaire related to PCK. They selected a topic (e.g., atoms, molecules) in chemistry curriculum and then, taught the selected topic. The data were gathered using of video-recorded workshop sessions, two questionnaire and semi-structured interviews conducting with mentors and participants through the related program and also, were analyzed in qualitative way. The results indicated that participants' knowledge of students' conceptions and learning difficulties developed because they frequently gave detail answers as opposed to first questionnaire. The interviews results indicated that majority of participants' PCK and some participants' SMK developed in different level. Moreover, university-based workshop, meetings with mentors and classroom teaching experiences which is the most influential factor are factors that affected their PCK development. It was stated that the different changes in their PCK can be due to teaching different topic for different classrooms and differences in mentors' impacts. Van Driel et al. (2002) expressed that PCK development is based on SMK substantially since PCK means that transforming SMK to make understandable for learners and therefore, in order to prevent deficiencies in the SMK of the participants, pedagogy, field experience and SMK should be integrated in science teacher programs.

Some research takes students' outcomes into consideration and investigated the effect of teachers' SMK or PCK on students' outcomes (e.g., Keller, Neumann, & Fischer, 2017; Ohle, Boone, & Fischer, 2015). For example, Ohle et al. (2015) conducted a study to investigate the relationship between students' outcomes including achievement, interest and teachers' CK regarding the teaching of states of matter and phase transitions within the Helmke's (2003) theoretical model in Germany. 4th grade classrooms' students (N=1326) and teachers (N=58) whose average teaching experiences were 17 years were involved in the study. The data were gathered by means of questionnaire, tests and video-recorded lessons through 12 months. The test regarding students' achievement and the questionnaire regarding students' and teachers' interest were implemented as pre-test, the test regarding students' achievement and the questionnaire regarding students' and teachers' CK were implemented as post-test. Based on the findings, it was found that students' achievement and interest related to physics were positively related to each other. It was found that, also, teachers' interest and CK regarding physics were positively correlated with each other, but have not influence on students' interest regarding physics. Another purpose of the study is to explore the impact of quality of instruction, including content structure and sequencing of learning process, on students' achievement as well as their interest in physics. Findings showed that the positive predictor of students' achievement was found as sequencing of learning process providing that the interest and CK of teachers are under control and performing the sequence of content conveniently (Ohle, Boone, & Fischer, 2015). In contrast, it was revealed that the students' achievement as well as interest were not affected by the content structure and Ohle et al. (2015) explained that this situation may be originated from showing variance in content structure types based on the complexity of topic in the lesson.

Hanuscin, Cisterna and Lipsitz (2018), as a part of longitudinal research program, conducted a study to investigate the elementary teachers' (N=18) initial PCK and differences among teachers' PCK in terms of teaching experience regarding the small particle model (SPM) of matter (5th grade level topic). CoRe, semi-structured interviews and lesson plan tasks were used to gather data. Researchers also created a rubric by adapting from Gess-Newsome, Taylor, Carlson, Gardner, Wilson, and Stuhlsatz (2017) as compatible with four components of Magnusson et al. (1999) PCK model including knowledge of curriculum, assessment, instructional strategies and learners' understanding with the aim of comparing teachers' PCK. Results showed that most of the teachers preferred to use curriculum materials and district supplied lesson plans template (e.g., 5E learning cycle), showing that their knowledge of curriculum were deficient. Teachers used visuals and hands-on activities as best teaching strategies for SPM of matter and 11 teachers showed some representations and models (e.g., simulations, role-playing). However, teachers did not use the instructional strategies and representations as specific to topic. All teachers aimed to assess students' learning with respect to show the particles of gases, liquid and solid. Six teachers paid attention to assessment related to students' understanding of SPM of matter, but they preferred to use general assessment methods (e.g., KWL charts). All teachers possessed general ideas related to student' knowledge related to SPM of matter and they were less knowledgeable related to students' skills and prerequisite knowledge. Another aim of the study is to compare the teachers' initial PCK. The result showed that it was found differences among teachers' PCK and readiness related to teaching SPM of matter topic depend on their experience level particular to grade level. More than a half of the teachers are experienced teachers, however, because the PCK has topic-specific nature, teachers' experience level related to particular grade level is important. These teachers have less teaching experience at fifth grade level, which means they are considered to be novice for teaching SPM of matter. Hanuscin et al. (2018) concluded that the expert teachers might improve their own PCK for specific science topic in particular grade level, but this does not mean that the teachers' PCK will develop for other science topics found in another grade levels as well.

In a recent study, Pitjeng-Mosabala and Rollnick (2018) investigated the development of novice unqualified graduate teachers' (N=14) whose ages between 21 and 29 PCK related to the particulate nature of matter in South Africa's classrooms through Professional Development Intervention (PDI). Gess-Newsome (2015) Consensus Model of PCK was used and all five components of TSPCK were examined. All teachers were involved in PDI programs for 10 months. In the first two weeks, content including such as particulate nature of matter was reviewed and

TSPCK was presented. Then, initial CoRe was constructed by teachers, and TSPCK and CK test were implemented as pre-test. Four teachers who were defined as case among all teachers completed their teaching related to particulate nature of matter. Final CoRes were constructed and at the same time, TSPCK and CK test were implemented as post-test for all teachers. Field notes, video-recording lesson and pre-post lesson observation interviews for four teachers and pre-post TSPCK and CK tests and CoRes for all teachers were utilized as data sources. The findings revealed that all teachers' CK level and majority of teachers' TSPCK level showed improvement from pre-test to post-test, but case study teachers showed a greater improvement than the non-case study teachers. For example, while one group of case study teachers did not express difficulties that they encountered while teaching the particulate nature of matter topic in pre-test, they indicated in the post-test that it might make teaching difficult for students to think that there are no empty spaces between the particles of solid. The reason why they changed their opinions was while teaching the lesson, they were able to notice the learning difficulties of the students by questions from students, and this situation showed that teachers benefitted from their teaching experience. It was noted that the curricular saliency and learner prior knowledge showed less improvement as opposed to other three components. Pitjeng-Mosabala and Rollnick (2018) concluded that teachers' experience and workshop involved in PDI lead to improve teachers' initial knowledge. Non-case study teachers' TSPCK showed less improvement in opposition to case study teachers since non-case study teachers involved in indirect teaching practice.

Utilizing the learning study, Nilsson (2014) explored the development of science teachers' PCK regarding ion and how ions are formed by means of Magnusson et al. (1999) PCK model. One science education researcher and three experienced secondary science teachers participated in the learning study. Another aim of this study was to identify the critical points that Grade 8 students need to learn and to improve their knowledge. Researcher supported the teacher in preparing and arranging lesson plans based on the critical points throughout the learning study for 10 weeks. In the learning study, the data were gathered by pre-test to post-test, stimulated recall interviews and video-recorded lesson plans with the aim of investigating students' understanding, teachers' PCK development as well as influence of that knowledge over their lessons. The findings indicated that students' understanding changed positively through the learning study. Teachers' self-understanding regarding objectives and purposes for teaching and their knowledge regarding interaction among the students' understanding, subject content and teaching developed. All teachers became conscious regarding the importance of knowledge of instructional strategies for students' understanding. Another result revealed that the learning study in which teachers and science education researcher worked together lead to change in their teaching. For example, teachers determined some concepts students have difficulty in understanding with examining students' pre-test results (e.g., the relationship between molecule and atom, confusing atom molecules with chemical elements). Then, teacher revised lesson plan and showed a concept map including concepts such as atom, chemical compound, metal, molecule to provide students to understand the relationship among these concepts. Nilsson recommended that for becoming informed regarding students' learning difficulties, teachers and students should make discussion on students' conceptions.

In Turkey, several studies were conducted by Aydin and her colleagues (e.g., Aydin, & Boz, 2013; Aydın, Demirdogen, Tarkin, Kutucu, Ekiz, Akın, Tuysuz, & Uzuntiryaki, 2013; Aydın, Friedrichsen, Boz, & Hanuscin, 2014). In one of the studies, Aydın et al. (2014) conducted a case study to investigate experienced chemistry teachers' topic-specific PCK corresponding to electrochemical cells and nuclear reactions topics. Modified version of Magnusson et al. (1999) PCK model was utilized with all five components. Two experienced teachers, one with 8 years and another one with 15 years teaching experiences, from the same high school constituted the sample. The data were gathered by means of classroom observations, card-sorting activity, field notes, audio-recorded semi-structured interviews and CoRe including interview questions, and data were analyzed inductively and deductively. The results indicated that both teachers possessed didactic orientation toward science for both topics, and used general teaching strategies for both topics (e.g., didactic teaching, questioning, discussion). While teachers preferred to perform teacher-centered and content-based teaching strategies for electrochemical cells, their teachings on nuclear reactions topic were less teacher-centered. Compared to nuclear reactions topic, teachers had highly integrated curriculum knowledge for electrochemical cells because they were aware of the objectives and suggestions found in the curriculum, sequence of topics, vertical relations (e.g., how to assign oxidation number) and horizontal relations (e.g., spectator ions). Teachers were more knowledgeable about the students' misconceptions, prerequisite knowledge and learning difficulties with respect to electrochemical cells as opposed to nuclear reactions. Teachers aimed to assess students' knowledge for both topics. However, more various assessment strategies (e.g., questioning, test, quiz) were used for electrochemical cells in comparison with nuclear reactions. Overall results indicated that teachers' PCK level were similar in general, yet their PCK regarding electrochemical cells and nuclear reactions topics were different from each other. This situation may be originated from differences between teachers' SMK level (e.g., high SMK for electrochemical cells), national curriculum program (e.g., the place of nuclear reactions topic at the end of the curriculum) and using different instructional strategies for each topic.

In this section, previous research on chemistry topics were reviewed and reported. Utilizing different PCK models, some of these studies examine individual PCK components, other focus on relationship between those components or impact of SMK on PCK, others focus on development of PCK or teachers' PCK regarding different topics and others focus on students' outcome (e.g., achievement). Following section focused on previous research on physic topics.

2.1.4 Research on Physic Topics

In this section, previous research was conducted with both in-service and pre-service teachers on physic topics such as graphs of motion (e.g. Mazibe, Coetzee, & Gaigher, 2018), semiconductors (e.g. Rollnick, 2016), density (e.g. Şen, & Öztekin, 2019), electricity (e.g. Keller, Neumann, & Fischer, 2017; Kind, 2016), electromagnetism (Coetzee, Rollnick, & Gaigher, 2020), force and motion (e.g., Suh, & Park, 2017), energy (e.g. Soysal, 2018), friction forces, simple machines, work and energy, (e.g. Çaylak, 2017) were reviewed and reported.

For instance, Kind (2016) investigated pre-service science teachers' science teaching orientations, beliefs about science as well as the consistency between them in the framework of Magnusson et al. (1999) PCK model in England context. Two hundred thirty-seven pre-service science teachers whose ages were between 21-25 from different disciplines including physic, chemistry, biology participated before attending teacher education program. The data were obtained through written questionnaire and three content-based vignettes including a simple circuit, plant growth via photosynthesis, chemical reaction topics. The results revealed that majority of pre-service science teachers' responses regarding science teaching orientations were related to conceptual change, didactic and academic rigor, but this situation varies within vignettes related to different disciplines. For example, whereas fifty eight percent of the responses toward physic vignettes and sixty percent of the responses toward biology vignettes were related to conceptual change, academic rigor or didactic, almost eighty percent of the responses toward chemistry vignettes were related to these orientations. Almost half of the responses referred to didactic orientation, which implied that they considered teachers as knowledge transmitter. For example, one of the physicists who embraced didactic orientation stated that "We can show that in a circuit, the flow must be constant…" (p.136). Another finding showed that most of the pre-service science teachers belonged naïve beliefs related to science, around thirty eight percent of them possessed partially informed beliefs, and fewer of them possessed informed beliefs. For example, a quarter of them considered science as understanding the "how the world works." (p.144), which represented naïve belief. It was concluded that there is imperfect consistency between beliefs about science and science teaching orientations because their relationships between them were found complex. For example, it was found that there is strong link among didactic, academic rigor and naïve belief about science, but the link among other categories of science teaching orientations and belief about science are either absent or limited.

By adopting the Mavhunga and Rollnick (2013) TSPCK model, Mazibe, Coetzee and Gaigher (2018) conducted a case study with physical science teachers (N=10) to compare their enacted PCK and reported PCK regarding graphs of motion in South Africa context. The five components of PCK (TSPCK) were examined in the study. The data were gathered by means of interviews, classroom observations and CoRe constructed by teachers. Teachers' classroom teachings related to graphs of motion were observed to obtain data with respect to their enacted PCK. The data were analyzed via two TSPCK rubric constructed by Mavhunga and Rollnick (2013) that evaluated the enacted and reported PCK. Teachers' enacted PCK and reported PCK were categorized under four categories which are basic, limited, exemplary and developing. The findings indicated that there are differences between teachers' enacted PCK and reported PCK, that is, generally their enacted PCK scores are lower than their reported PCK scores at least in terms of one PCK component. For instance, one teacher was aware of the students' learning difficulties (e.g., calculating the gradient of graphs) and elimination techniques related to graphs of motions and her reported PCK was defined as "developing", but she did not explain sufficiently in the classroom practice and therefore, her enacted PCK was defined as "basic". Another example is that another teacher's reported PCK regarding learners' prior knowledge was identified as "developing" because she knew the students' misconceptions related to confusion between acceleration and direction of velocity, and objects' position vector and its velocity. However, she only mentioned about the definitions of acceleration and velocity in the classroom practice and so, her enacted PCK was identified as "basic". Researchers concluded that teachers were not able to reflect their reported PCK to the classroom practice despite their pedagogical knowledge were rich in their reported PCK. Researchers suggested that in teacher training programs, there should be opportunities for pre-service teachers to apply their PCK to the classroom practice as well as learn the PCK and CK.

Rollnick (2016) investigated the development of CK, PCK and the relationship between them of high school science teachers' (N=7) whose teaching experiences were ranged from 4 to 20 years within the context of project work regarding semiconductors (Grades 10^{th}, 11^{th}) that is a new topic for the curriculum in South Africa. Gess-Newsome (2015) Model of PCK was preferred. Teachers who are part-time students were involved in the project work in which two supervisors including chemistry and physic educators guided teachers for 12 weeks and three meetings were performed, and each teacher created their own project. Supervisors introduced the constructing of concept maps and then, participants created their first concept map. CoRe was constructed by collaborative work of teachers and supervisors and following, teachers designed their first lesson plan followed by their second lesson plan after discussions about the first one. Then, teachers constructed their second and third concept map. The data sources were audio-recorded peer lessons, three concept maps, video-recorded lessons, project reports, lesson plans, journals and interviews. The analysis of all concept maps indicated that majority of teachers' CK developed. For example, whereas one of the teachers' first concept map contained few concepts related to semiconductors (e.g., N type, P type), her final map contained various concepts (e.g., mobile holes, p-n junction diode, doped, junction) and integrated elements related to pedagogy (e.g., np strategy). This example showed that the development in her CK is also seen in her PCK. Another finding is that teachers' awareness of students' prior knowledge, their assessments and using various representations showed that teachers' PCK level developed. For example, one of the teachers recognized the students' difficulties related to holes movement in semiconductor and thereby, she tried to overcome it through showing some representations (e.g., doped crystals) and performing role playing. Rollnick (2016) concluded that development of teachers' CK is closely associated with teachers' development related to thoughts on topic that is taught. Researcher also concluded that there is strong harmony between PCK and CK and it seems that when teachers' confidence with respect to their CK increases, CK and PCK progress in parallel

(Rollnick, 2016). Rollnick (2016) added that PCK and CK were developed with using of scaffolding approach for teaching of new topic.

In their study, Keller et al. (2017) focused on the effects of PCK and motivation on students' achievement and interest with respect to electricity, especially electric energy and power. They conducted a study with seventy-seven physic teachers whose teaching experiences were ranged from one to forty-one years and one thousand six hundred fourteen 10^{th} grade level students from secondary schools in Germany and Switzerland contexts. The data were gathered by means of questionnaire, test-instruments and video-recorded lessons. Pre-post design was used and the pre-test including teachers' PCK, motivation and students' achievement, enthusiastic teaching, interest were implemented before the teaching of electricity. The post-test including students' achievement and interest were implemented 6 weeks after the teaching of electricity. The cognitive activation was assessed through video-recorded lessons. Based on the findings, teachers' PCK level were found to be moderate. Students' interest was affected by teachers' motivation by way of enthusiastic teaching, but PCK of the teachers did not have a direct effect on the student's interest. Students' achievement was affected by teachers' motivation via cognitive action, yet motivation of the teachers did not have a direct impact on the student's achievement. Keller et al. (2017) concluded that students' outcomes, including achievement and interest, are affected from teachers' motivation and PCK differently, which means that one effect cannot replace another effect. Keller et al. (2017) suggested that for enhancing students' learning and growth in optimal level, teachers should become motivated as well as informed.

Research on physic topics have been done in Turkey context and one of them was carried out by Çaylak (2017). In his doctoral dissertation, he conducted a case study with one gifted students' teacher whose teaching experience was three years to delve into topic-specific pedagogical content knowledge on three physic topics including friction forces, work and energy, simple machines in 7^{th} grade level. Magnusson et al. (1999) PCK model was preferred and all components were examined. The data were collected through pre-post interview, classroom observation, card sorting activity and CoRe plan. The findings revealed that teacher possessed different goals and purposes regarding teaching science including affective, subject matter, affective and gifted education, but the subject matter goals were mainly highlighted in her teaching. She was aware of the objectives, the vertical (e.g., force concept, friction force) and horizontal relations (e.g., kinetic energy, potential energy). She knew the students' prerequisite knowledge (e.g., force, work, lever), and stated some their learning difficulties (e.g., the unit of force and motion) and misconceptions (e.g., the concepts of velocity and speed are same.). But she also possessed misconception (e.g., friction force and energy). She did not express subject specific strategies in interview and also, did not prefer to use in her lesson. However, she used topic-specific strategies (e.g., questioning, lecturing) and representations (models). She generally assessed students' conceptual understanding during and at the end of the lesson. She used both informal (e.g., questioning) and formal (e.g., multiple-choice tests) assessment strategies. Regarding teacher's conceptualization of PCK, looking at the interview and observation data, it was seen that the PCK maps related to these are different from each other. Teacher's planning and teaching of the friction forces, work and energy, simple machines topics were influenced from teacher's knowledge of enrichment curriculum and gifted students' characteristic (e.g., comprehending the topic quickly, not being convinced easily).

Recently, Şen and Öztekin (2019) explored the middle school science teachers' PCK, contextual knowledge as well as the effect of contextual knowledge on PCK related to density topic in terms of sociocultural perspective with adopting of the Magnusson et al. (1999) PCK Model. All components were examined. The two science teachers; one of them with twenty years and another one with one-year teaching experience from same schools constituted the sample. The classroom observation and two semi-structured interviews were performed to collect data. According to the findings, both teachers reported that student component (e.g., readiness level), school component (e.g., lack of material) as well as conditions of country component (e.g., dense curriculum) have effect on their teaching. Besides, novice teacher added community (e.g., family) and teacher components (e.g., experience). While experienced teacher reported schooling and subject matter goals, novice teacher reported schooling, affective and subject matter goals, yet the schooling goals were not mentioned by both during their teaching. Both teachers mentioned about the subject-specific strategies (e.g., experiment, demonstration), activities (e.g., problem-solving activity) and representations (e.g., visuals, drawings). However, the experiment was not performed during their teaching. They assessed students' content knowledge by using questioning method within the lesson time. Both teachers were aware of the objectives, vertical (e.g., mixtures, buoyancy) and horizontal relations (e.g., speed, ratio). Novice teacher, however, addressed advance knowledge that is out of the scope of the curriculum (e.g., change of density). Both stated the students' prerequisite knowledge such as properties of matter, and also reported students' difficulties. But novice teacher mentioned about students' misconceptions (e.g., heavy object sink). Another finding indicated that teachers' PCK can be shaped based on teachers' contextual knowledge. For example, if there is a lack of material related to the experiment that the teacher will do and the teacher is aware of this, teacher tries to deal with this problem by performing alternative activity. It was found that in some conditions, the negative impacts of contextual factors cannot be prevented (e.g., dense curriculum program) or PCK components are promoted with teachers' contextual knowledge.

Within this section, previous research on physic topics were addressed. As can be seen from the reported studies, while some studies in physics used different PCK models, some focused on few components or all components. While some addressed PCK development, others investigated how teachers' PCK impacts the students' outcomes. Next section, previous research on PCK for NOS were reviewed and reported.

2.1.5 Research on PCK for NOS

Subject matter knowledge consists of the syntactic knowledge and substantive knowledge and NOS represented the syntactic knowledge in the scope of this current study. “Typically, the NOS has been used to refer to the epistemology of science, science as a way of knowing, or the values and beliefs inherent to the development of scientific knowledge.” (Abd-El-Khalick, Bell, & Lederman, 1998, p.418). NOS, which has its own technical terms, topics and concepts, is defined as subject-specific content (Faikhamta, 2013). NOS understanding comprises of knowledge of justification of scientific knowledge and source and it is piece of the SMK of teachers and also, their syntactic knowledge of science at particular within the scope of diverse teacher knowledge domains (Hanuscin, Lee, & Akerson, 2011). Accordingly, another line of PCK research is PCK for NOS which have been received attention by the researchers. In this section, several research conducted with pre-service and in-service teachers on PCK for NOS such as (e.g., Abd-El-Khalick, & BouJaoude, 1997; Bektaş, Ekiz, Tüysüz, Kutucu, Tarkin, & Uzuntiryaki Kondakçı, 2013; Bilican, Cakıroglu, & Oztekin, 2015; Demirdöğen, Hanuscin, Uzuntiryaki Kondakci, & Köseoğlu, 2016; Matkins, & Bell, 2007; Şen, 2014; Wahbeh, & Abd-El Khalick, 2014; Yılmaz Yendi, 2019) were reviewed and reported.

One of the early research with respect to PCK for NOS was conducted by Abd-El-Khalick and BouJaoude (1997) in Lebanon. They carried out a study with science teachers in order to reveal their knowledge base that is assessed with regard to NOS, development knowledge, function knowledge and besides structural knowledge. For revealing teachers’ knowledge bases, they were requested to create their concept maps. For the topic of concept map, suitable topics such as temperature (physic), elements (chemistry) and digestion (biology) were chosen at different grade level. Then, clinical interviews were applied to teachers by asking whether they want to make adjustments on their concept map in case they needed to explain these concepts to the students at the different desired grade level. Also, they were asked the students’ alternative conceptions and everyday life examples related to topics on which concept maps are created. All of which revealed teachers’ knowledge of curriculum as well as knowledge of students’ understandings. Views on Science-Technology-Society (VOSTS) questionnaire was applied to reveal their NOS understandings. As data sources, structured concept maps created by teachers, modified version of VOSTS questionnaire and audio recorded clinical interviews were utilized. Based on the findings, majority of teachers' NOS understandings were found to be naïve. The vast majority of teachers considered that scientists follow one scientific method, which implied that they failed to notice the role of imagination and creativity in science. Majority of teachers possessed naïve views as to theory and law nature. Slightly more than seventy percent of teachers have not possessed adequate understanding as to subjective NOS. Almost more than a half teachers believed the scientific models as realities copy. Another finding demonstrated that teachers have not adequate knowledge regarding development, function and structure of their disciplines. Central concepts related to topics could not be expressed sufficiently in concept maps and also, there were basic associations between the concepts, which indicated that teachers had a lack of knowledge of curriculum. Teachers did not use any activities and have not enough knowledge about giving examples of daily life on the topics in the concepts that provides students to make association between their needs and science, which indicated that teachers had a lack of knowledge of instructional strategies. Teachers did not make the necessary changes in the concept maps they first created in order to enable their students to understand, and their knowledge of alternative conceptions was found to be not sufficient, which means that they have lack of knowledge of learners. Abd-El-Khalick and BouJaoude (1997) concluded that as regards all knowledge base, it was revealed that teachers have a lack of knowledge.

Regarding development of PCK for NOS, Matkins and Bell (2007) explored the effect of explicit NOS instruction embedded the context of global climate change, greenhouse effect and global warming on pre-service elementary teachers' understandings with respect to NOS, global climate change, global warming in USA. Fifteen pre-service elementary teachers having different bachelors whose ages were varied from 20 to 28 were involved in the study. In elementary science methods course, instructors performed several activities related to NOS such as providing discussion environment, performing mystery-tube activity, basic and integrated science process skills activities. The data were gathered via journal entries, modified version of VNOS (pre-post), assignments and interviews and analyzed with analytical induction. Findings showed that as opposed to pre-instruction views, participants' views related to NOS showed improvement in post instruction. For example, while participants' views related to creativity were not congruent with scientific explanation in pre-instruction, more than a half participant considered the role of creativity in data interpretation and experiments design in post instruction. While great majority of participants held misconceptions related to subjective NOS in pre-instruction, they were aware of subjectivity of scientific knowledge in post-instruction. Whereas all participants were unaware of the social and cultural NOS, a little more than a quarter of the participants were aware of the influence of social and cultural factors on scientific knowledge in post instruction. Another finding indicated that whereas participants were found to be hold lots of misconceptions related to global climate change, global warming and NOS in preinstruction (e.g., considering the greenhouse effect as law due to being proven knowledge), majority of participants' ideas related to these issues developed in post-instruction (e.g., expressing the greenhouse effect scientifically). Another aim is to investigate the effect of context embedded and explicit NOS instruction on their decision-making skills. Post-instruction findings indicated that more than sixty percent participants' decisions related to this issue were affected positively from their knowledge about NOS and global climate change, global warming. Matkins and Bell (2007) concluded that participants' informed decision making, views with respect to NOS and understandings related to sophisticated content related to global climate change and global warming are affected positively from context embedded and explicit NOS instruction.

Demirdöğen et al. (2016) conducted a case study to reveal complexities of pre-service chemistry teachers' (N=30) early development considering knowledge of assessment, science teaching orientations, knowledge of learners and instructional strategies. Also, they explored the development of their PCK regarding NOS through Research in Chemistry Education course with using Magnusson et al. (1999) PCK model. During this course, content-generic, content-embedded and additional activities were implemented to develop participants' NOS understandings. Moreover, activities related to components of PCK were implemented to develop their understandings of PCK for NOS. Participants were asked to choose a topic among chemistry topics (e.g., atom, mole) to prepare a lesson plan. The data were collected by means of interviews (pre-post), responses to open-ended questions, observations, reflection papers, reports, audio-visual materials, documents, VNOS-C questionnaire (pre-post) and lesson plans. The findings as to VNOS-C questionnaire applied before NOS instruction showed that participants had misconceptions regarding NOS aspects such as considering hierarchical relationship between law, hypothesis and theory. After NOS instruction, however, participants' NOS understanding developed, and the number of informed views increased. Participants' PCK for NOS showed improvement from knowledge level to application level in their design of the lesson plan, yet participants' all PCK components did not show improvement and the knowledge of instructional strategies and orientation components were found to be central in the integration among all components. Another finding indicated that for performing NOS teaching, enough beliefs and understanding of NOS were revealed to be essential for teachers. However, it was not found any association between participants' PCK for NOS and their NOS understandings because they preferred to integrate the NOS aspects, of which they were more knowledgeable, into their lessons. It was found that a teacher with a well-integrated PCK for NOS prepared lesson plans suitable for the teaching NOS and taught the NOS successfully. Demirdöğen et al. (2016) concluded that pre-service chemistry teachers were triggered for integrating NOS approach into their classroom practice within chemistry topic through NOS instruction pursued by PCK for NOS instruction.

Another research on development of the understanding of the NOS was carried out by Wahbeh and Abd-El Khalick (2014). They conducted a study to understand the impact of integrated NOS course on science teachers' (N=19) whose teaching experiences were varied between 1- and 30 years NOS understandings, instructional practices and planning in Palestine context. Another aim of the study is to understand the retention of NOS understandings and factors that provide teachers to integrate NOS into their classroom practice. First, teachers were involved into explicit-reflective NOS course integrated with learning-as-conceptual-change approach which includes several activities and metacognitive methods for six weeks. Six teachers were assigned to create a lesson plan including NOS integration for two-week period following to the NOS course because their most of NOS aspects were found to be informed. Then, their teachings were observed to understand whether they integrate NOS understandings. Semi-structured interview, pre-post-tests, reflection papers, VNOS-C questionnaire, classroom observations, teacher-generated artefacts and delayed-test were used to gather data. Overall results showed that participants NOS understandings developed to a large extent in virtue of participating into NOS course (e.g., creativity, subjectivity, tentativeness, social-cultural embeddedness). Also, VNOS-C questionnaire was applied at the end of 5 months and majority of participants were found to be retained their NOS understandings. Teachers integrated several NOS aspects including empirical, inferential, tentative, sociocultural embeddedness into classroom practice, however, they had difficulty in integrating some NOS aspects (e.g., theory and law nature, creativity). Moreover, they confronted with three difficulties during their teaching NOS; their lack of knowledge related to pedagogical expertise related to inquiry teaching approach for NOS teaching, their lack of knowledge with respect to some NOS aspects (e.g., theory and law nature, theory-ladenness) and their lack of CK for teaching NOS within the content (e.g., greenhouse effect). The factor that mediates teachers' translation of NOS understanding into their teaching practice were found as their newly learned NOS understanding that learned in the context of science and thereby, this situation was a factor that restrained their NOS understandings into different contexts.

By focusing on only tentative and theory and law nature aspects of NOS, Bektaş et al. (2013) conducted qualitative research to investigate PCK for NOS on particle nature of matter topic studying with pre-service chemistry teachers (N=7) through a practice teaching course. Magnusson et al. (1999) PCK model was used and the knowledge of instructional strategies, assessment and learners were included. In practice teaching course, participants received NOS instruction for three weeks. Then, they were requested to select at least one topic from the related particle nature of matter topics, prepare lesson plans and teach selected topic with NOS integration in the university course and placement school. The data were gathered through lesson plans, open-ended questions as pre-post, reflection papers about their teachings, video recorded classroom observation and audio recorded interviews. The findings indicated that pre-service teachers' NOS understandings developed with teaching experience gained through the practice teaching course. For example, while prior to practice teaching course, some participants were found to held a misconception of hierarchical relationship between theory and law, majority of participants' related NOS understandings showed improvement after the practice teaching course. Both prior to and after the practice teaching course, participants expressed the students' learning difficulties, their sources of misconceptions (e.g., textbook, teachers), yet their views related to students' learning difficulties became more detailed after the practice teaching course. After the practice teaching course, majority of the participants explained the instructional strategies (e.g., discussions, lecturing, demonstration) and how they implement the instructional strategies to integrate the related NOS aspects into the lesson. But prior to this course, participants' knowledge of assessment toward related NOS aspects in the context of particulate nature of matter were found to be deficient, and after this course, it was not observed improvement. Also, they did not assess students' understanding with respect to related NOS aspects in the context of particulate nature of matter because they asked questions either just related to the topic or NOS aspects. Bektaş et al. (2013) concluded that pre-service chemistry teachers' teaching related to NOS in the context of chemistry showed improvement and they were able to associate the particular chemistry content with NOS by means of classroom practice about content embedded NOS instruction through practice teaching course.

Based on contextualized explicit reflective NOS approach, Bilican, Cakıroglu and Oztekin (2015) conducted a study to investigate the development of pre-service science teachers' (N=7) NOS understandings. Explicit reflective NOS instruction was implemented in elementary science methods course through 10 weeks. For the first four weeks, decontextualized NOS activities which are content-generic activities were implemented with the aim of developing participants' NOS understandings. Followingly, contextualized NOS activities were implemented to enhance the effectiveness of this NOS instruction. Reading and activities related to history of science were implemented and readings scripts based on NOS aspects were used for enhancing participants' NOS understanding and teaching. Participants were requested to design and present five lesson plans for each history of science reading scripts in each week and followingly, group discussion was performed to enhance their NOS understandings. The data were gathered by means of VNOS-C questionnaire combined with semi-structured interviews applied before and after the elementary science methods course. The findings uncovered significant development in participants' NOS understandings. Whereas majority of participants views related to tentative and creative NOS were inadequate before the NOS intervention, all participants' views turned into informed view after the NOS intervention. After the NOS instruction, most of the participants' inadequate views related to subjective and empirical NOS turned into informed view. Before the NOS intervention, four participants view regarding inferential NOS were revealed as adequate, but after the NOS intervention, most participants' views altered from adequate to informed. At the end of the NOS intervention, all participants views' regarding sociocultural NOS (e.g., science is universal) and nature of theory and law (e.g., considering hierarchical relationship between law and theory) were changed from inadequate to informed. Bilican et al. (2015) concluded that decontextualized NOS activities and contextualized activities including rich science content enhanced the influence of explicit NOS instruction, which provided pre-service science teacher to hold informed views regarding NOS. Researchers also concluded that several pedagogical practices such as planning plans, presenting lesson plans, which were implemented in the context embedded NOS activities, enabled the pre-service teachers to evaluate their own NOS understandings and then, revise their NOS understandings to integrate the NOS into their lesson in a proper way.

In Şen’s study in 2014, he also investigated the NOS understandings of three science teachers with using VNOS-C questionnaire and classroom observation. The findings indicated that all science teachers had a lack of knowledge regarding NOS. For example, all science teachers’ views in terms of nature of theories and laws were revealed as naïve because they had a misconception of hierarchical order between law and theories. All science teachers believed that scientific knowledge could change, but they did not transfer their views to law, which showed that they possessed naïve views related to tentative NOS. All science teachers’ views related to socio-cultural NOS were found to be naïve because they did not notice the effects of social norms (e.g., culture) on science. While two teachers’ views related to subjectivity were found as inadequate, one teacher’s views related to subjectivity were found as informed. Whereas two teachers’ views related to empirical and inferential NOS were found as adequate, one teacher’s views related to empirical and inferential NOS were found as informed. Lastly, all participants expressed the role of creativity in science, but two of them had a lack of knowledge because they were unaware that creativity is used in every part of the scientific investigation. It was observed that science teachers did not integrate the NOS aspects to their classroom practice and Şen (2014) concluded that the deficient knowledge of science teachers about with respect to NOS aspects may prevent them from including the NOS aspects in their lessons.

Yılmaz Yendi (2019), in her study mentioned above, also investigated three experienced in-service science teachers’ NOS understandings through embedded VNOS-C questionnaire and classroom observation. The findings indicated that all science teachers possessed deficiency regarding NOS aspects. For example, all teachers’ understanding of tentative NOS were found as naïve because they stated that scientific knowledge can change without transforming this view to law and theory. All teachers’ understanding of nature of theory and law were found as naïve because they had a misconception as to hierarchical order between law and theory. Furthermore, in embedded NOS question, whereas they described the what the greenhouse effect is, they were unaware of the greenhouse effect as theory. All teachers' understanding of empirical NOS were deficient. For example, although two of them stated that with using observations and data, existence of global warming can be proved by scientists, they failed to notice that non-experimental techniques can be used to reach scientific knowledge. Majority of them had lack of knowledge regarding subjective NOS because they stated that reliability of scientific knowledge is destroyed via subjectivity or did not believe the subjective nature of scientific knowledge. Majority of them understandings of creative and imaginative NOS were found as deficient because they were unaware that creativity and imaginations are crucial in all phases of the scientific investigation. All teachers' understanding of sociocultural NOS were found as naïve because they failed to notice the effects of culture and society on science. But all teachers were aware of the inferential NOS because they expressed that the interpretations can be made by scientists depend on the evidences. For instance, one of the teachers said that scientists can form dinosaurs' models through benefitting from fossil evidences. Another finding indicated that science teachers did not integrate the NOS aspects to their classroom practice. Yılmaz Yendi (2019) concluded that science teachers' educational background (e.g., undergraduate, primary and secondary) may lead to teachers to hold naïve view with respect to NOS. Yılmaz Yendi (2019) also concluded that teachers' orientations for NOS teaching were deficient and thereby, PCK for NOS were not able to develop by them.

In general, previous research findings indicated that both pre-service and in-service teachers had naïve views and misconceptions related to NOS aspects and besides, they had difficulty in integration of NOS aspects into their science classroom practice. Related NOS studies were also intended to develop pre-service and in-service teachers' NOS views through various development programs such as integrated NOS course, explicit NOS instruction, contextualized explicit reflective NOS approach, content generic activities, content embedded activities.

In this section, previous research on PCK including PCK for NOS was reviewed and reported. Briefly, many research were conducted with pre-service and in-service teachers on different domains such as Earth science, biology, chemistry, physics about diverse topics. In these research, different PCK models were used, but Magnusson et al. (1999) PCK model was mostly used. Since PCK is topic specific, in the following section, research on in-service teachers and pre-service teachers' substantive knowledge, as a part of SMK, regarding seasons, weather and climate understanding and knowledge were reviewed and reported. Since teachers' awareness of students' misconception and learning difficulty are important component of PCK, in the following section, students' understanding of seasons, weather and climate understanding and knowledge were summarized as well.

2.2 Research on Substantive Knowledge Regarding Seasons, Weather and Climate Understanding

In this section, previous research on in-service teachers', pre-service teachers', and students' understanding and knowledge related to seasons, weather and climate concepts including climate change, global warming, ozone layer depletion, greenhouse effect, and acid precipitation were reviewed. In general, previous research demonstrated that they have lack of knowledge and possessed many misconceptions related concepts.

In this section, previous research on seasons, weather and climate understanding and knowledge were reviewed under two sub-titles; research conducted with students (e.g. Cepni, 2014; Henriques, 2002; Porter, Weaver, & Raptis, 2012; Shepardson, Niyogi, Choi, & Charusombat, 2011; Sung, & Oh, 2018) and research conducted with pre-service teachers and in-service teachers (e.g. Atwood, & Atwood, 1996; Boyes, & Stanisstreet, 1992; Dove, 1996; Khalid, 2001; Lane, 2015b; Michail, Stamou, & Stamou, 2007). First, research conducted with in-service teachers were reported and following, research conducted with pre-service teachers and students were reported separately.

2.2.1 Research Conducted with In-Service Teachers

In this section, previous research on seasons, weather and climate understanding and knowledge conducted with in-service teachers related to such as climate change (e.g., Herman, Feldman, & Vernaza-Hernandez, 2017), ozone layer (e.g., Daskolia, Flogaitis, & Papageorgiou, 2006; Michail, Stamou, & Stamou, 2007), greenhouse effect (e.g., Michail, Stamou, & Stamou, 2007), acid rain (e.g., Michail, Stamou, & Stamou, 2007) were reviewed and reported.

One of the early research conducted with in-service teacher belongs to Daskolia et al. (2006) who conducted a study to investigate kindergarten teachers' conceptual framework related to ozone layer depletion. The sample was comprised of one hundred fifty-nine in-service kindergarten teachers whose teaching experiences were generally between 8 and 10 years in Greece. The data were gathered through a written questionnaire including two parts; in the first part, a word association test regarding ozone hole was applied and in the second part, there are closed type questions to obtain knowledge related to their personal information and teaching practice. Participants wrote three hundred fifty-five words related to ozone hole that were categorized under twelve categories such as greenhouse effect, environmental destruction. The findings indicated that it was found a linear, simplistic and cause-effect schema in participants' conceptual frameworks with respect to ozone hole, and participants hold misunderstanding as well as misconceptions. For instance, participants associated the ozone hole with greenhouse effect and under greenhouse effect category, they mentioned about the concepts such as temperature rise, melting of ice, which implied that they confused ozone hole with greenhouse effect concepts. Mostly, participants linked the ozone hole to solar radiation and related words (e.g., ultraviolet radiation). The detrimental impacts of ozone hole on health of the people were emphasized excessively by frequently mentioning words under consequences to health category such as burns, skin illness, skin cancer-cancer. Participants associated the ozone hole with words regarding environmental pollution (e.g., contamination, acid rain), which indicated a misconception as to the relationship between ozone depletion and pollution. Participants linked the ozone hole to words related to environmental destruction (e.g., destruction of life) and various environmental problem (e.g., acid rain, drought, deforestation, soil erosion). Daskolia et al. (2006) stated that fundamentally the impact of the media and then the personal experiences of individuals and social coincides appear to enable teachers to have concepts about the ozone layer, acid rains and greenhouse effect. Researchers concluded that participants mostly highlighted the impact of the ozone layer depletion on human health and solar radiation because news related to ozone hole and its' negative impact on human health are frequently published in Greece media.

Michail, Stamou and Stamou (2007) explored the understandings of primary school teachers (N=155) with respect to greenhouse effect, acid rain and ozone layer depletion in Greece. The data were gathered via questionnaire including three sections; the first one was related to sources of teachers' knowledge related to these concepts, the second one was related to questions regarding aforementioned concepts and the third one was related to demographic information. According to the findings, respondents possessed misconceptions as well as lack of knowledge related to greenhouse effect, acid rain and ozone layer depletion. Related to acid rain, majority of the respondents considered the origin of acid rain as only human activities but ignore the impact of natural events. Related to ozone layer depletion, almost sixty percent of respondents were not aware of the role of CFCs and vast majority of the respondents were not aware of the role of aerosol in ozone layer depletion. More than half of the respondents did not indicate that the rate of skin cancer would be rise with increasing of ozone's hole. Slightly more than half of the respondents had an incorrect idea by considering association between rising of planet temperature and enhanced depletion of ozone layer and also, most of the respondents did not give completely correct answer related to the place of ozone. Related to greenhouse effect, slightly more than half of the respondents were unaware of the role of carbon dioxide as greenhouse gas causing greenhouse effect. Most of the respondents had a misconception as to cause effect relationship between greenhouse effect and ozone layer depletion, were not aware of the natural greenhouse effect and in parallel, considered the origin of occurring greenhouse effect as humans. But slightly more than sixty percent respondents correctly indicated that greenhouse effect is enhanced by destruction of forests. Another finding showed that respondents mostly stated the new magazines, television and newspaper as sources of their knowledge of environmental issues compared to discussion with friends, colleagues and family, specialized magazines, radio, NGO’s events, internet and seminars. Researchers concluded that the teachers described the greenhouse effect and acid rain as events based on human activities and stated that they disrupted the balance of nature and in this case, the dominant image of the teachers' ideas was named as “nature-as-balance metaphor”. Researchers also concluded that the teachers stated the media as the main source from which they received information about the environment, and the researchers considered that the wrong information and errors in the environmental media stories might lead to develop misconception in teachers.

Herman et al. (2017) conducted a cross-cultural study with Florida (N=102) and Puerto Rico (N=118) secondary science teachers, who asserted that they teach the climate change topic thoroughly, to investigate their conceptions with respect to climate change and teaching of climate change science. The data were gathered through survey which contains several prompts. The categories that are “correct”, “partially correct”, “incorrect” and “tautological” were used the assess participants’ description related to climate change. According to the findings, Herman et al. (2017) concluded that although teachers asserted that they teach the climate change topic thoroughly, they possessed abundant misconceptions related to climate change and also, differences in their CK levels of teachers that originated from differences in sample might lead to difference between Florida and Puerto Rico teachers. For example, seventeen percentage of Florida teachers and eighteen percentage of Puerto Rico teachers’ responses related to definition of climate change were labelled as incorrect. Most of both group teachers’ responses were labelled as partially correct. But four percentage of Puerto Rico teachers and fourteen percentage of Florida teachers correctly described the climate change. Another finding showed that teachers possessed lots of naïve views found in US public commonly related to causes of climate change. For example, majority of teachers in both groups were found to be hold the incorrect idea that the primary cause of the climate change is ozone layer depletion and is not cooling and heating of homes. Half of all participants incorrectly stated the using the insecticides and aerosol as secondary or minor causes of the climate change. But Puerto Rico teachers' ideas related to the causes of the climate change were found as less accurate as opposed to Florida teachers and US public. Majority of teachers' ideas related to climate science validity were found as incorrect or uncertain. For example, they believed the climate change as validated and scientifically tested, and climate change science should be depended on controlled experiments so that it is valid. All teachers' content coverage of climate change included its' effects such as on biodiversity, water resources, adaptations, sea and ocean levels, but majority of teachers little emphasized or did not emphasize teaching about climate change in terms of economic, social and political dimensions and also, alleviation of climate change. Herman et al. (2017) stated that the deficiency of emphasizing the political and social aspects of climate change in the secondary curriculum hinder students to make association climate change with their and other's daily life, and also participate in rational decisions to alleviate the effects of climate change. Herman et al. (2017) suggested that teachers should need to possess more detail science CK compared to knowledge where they learned in traditional university lesson for teaching climate change science in a sufficient level.

2.2.2 Research Conducted with Pre-Service Teachers

Research have been carried out with pre-service teachers on seasons, weather and climate understanding and knowledge related to such as seasons (e.g. Atwood, & Atwood, 1996), weather and climate (e.g. Lane, 2015b), climate change (e.g. Papadimitriou, 2004), ozone layer (e.g. Arslan, Cigdemoglu, & Moseley, 2012; Dove, 1996; Khalid, 2001; Papadimitriou, 2004), global warming (e.g. Arslan, Cigdemoglu, & Moseley, 2012; Boyes, & Stanisstreet, 1992; Ocal, Kisoglu, Alas, &

Gurbuz, 2011), greenhouse effect (e.g. Arslan, Cigdemoglu, & Moseley, 2012; Dove, 1996; Khalid, 2001; Papadimitriou, 2004; Ratinen, 2013), acid rain (e.g. Arslan, Cigdemoglu, & Moseley, 2012; Dove, 1996; Khalid, 2001) were reviewed and reported.

One of the early research was conducted with pre-service elementary teachers (N=49) belongs to Atwood and Atwood (1996). They conducted a study to investigate their conceptions with respect to causes of seasons in USA. The data were gathered via written and verbal part. At first, in written part, participants were asked to write their answers for that question "What causes the seasons for regions of the earth that experience winter, spring, summer, and fall?" (p.554) in science methods and materials course. In verbal part, participants were desired to select Earth model and then, use earth and sun models to show the causes of seasons with explaining verbally in the interview for two days. Participants' responses were classified as scientific conception, no response, alternative conception, unclear responses and incomplete explanation based on the scientific explanation of seasons. Both procedure findings indicated that participants possessed alternative conceptions concerning causes of seasons. The distance between the sun and earth was found as mostly cited alternative conception in both parts. Findings of the written part indicated majority of participants' answers were classified as alternative conception. For example, four participants thought the "the rotation of the earth on its axis" (p.557), four participants thought that "the way the earth is positioned on its axis; the part facing the sun is having summer" (p.557) and six participants thought that "the closeness of part of the earth due to the earth's tilt" (p.557) as causes of seasonal changes. In verbal part, great majority of participants' answers were classified as alternative conception. For example, whereas three participants thought "the sun revolves around the earth" (p.558) as causes of seasonal changes, six participants thought "the rotation of the earth on its axis" (p.558). Also, seven students thought "the direction of the earth's tilt changes as the earth revolves around the sun" (p.558), and four students thought "the pole of the hemisphere having summer is pointed almost directly toward the sun" (p.558) as the causes of seasonal changes. However, teachers asked questions about the models that students made during extension probe in this procedure and thereby, almost half of the students made correct adjustments to the earth and sun models they made. Atwood and Atwood (1996) concluded that students' alternative conception might not be held exactly because there was not coherence between two procedures in terms majority of students' specific alternative conception. It was found that extension probe focused on alternative conceptions applied to participants gave positive results related to their alternative conception and Atwood and Atwood (1996) concluded that much positive results may occur as a result of short trainings organized to eliminate mostly emerging alternative conceptions.

Boyes and Stanisstreet (1992) conducted a study to reveal the conceptions of undergraduate students related to greenhouse effect in terms of consequences and causes of global warming in United Kingdom context. Two hundred eighteen first year undergraduate students whose ages between 18 and 20 participated in the study. The data were gathered through questionnaire which includes statements and closed response type questions related to greenhouse effect (e.g., possible causes, consequences of the greenhouse effect and actions for mitigating the greenhouse effect). The results indicated that participants possessed several misconceptions regarding greenhouse effect with respect to consequences and causes of global warming. As the consequences of the greenhouse effect, fewer participants indicated the earthquakes, heart attacks, poisoning of fish, unsafe tap water and food poisoning whereas slightly more than half participants considered the skin cancer. Majority of participants considered that skin cancer increases with exacerbation of global warming due to ozone layer depletion and they linked the global warming with holes found in the ozone layer. Less than fifteen percent of participants considered that global warming is triggered by acid rain, street litter, radioactive waste and rubbish in rivers. Related to the actions to mitigate the greenhouse effect, while cleaning beaches, global starvation, protecting wildlife, reducing nuclear weapons and healthy eating were stated by less participants, using lead-free petrol was stated by nearly half of the participants. Moreover, most participants expressed that the influence of vehicle usage on global warming could be decreased with using of lead-free petrol. Researchers concluded that people are conscious about environmental problems as well as environmental actions in general sense, but they did not establish relationship between the environmental problems and their solutions, effects and causes and this situation may lead to emerge misconceptions related to these issues.

Dove (1996) investigated the first- and second-year undergraduate students' (N=60) understanding and knowledge related to acid rain, greenhouse effect and ozone layer depletion. A questionnaire was used to gather data from respondents. The findings related to the greenhouse effect indicated that respondents possessed poor understanding because they had misconceptions that solar radiation lead to warm the Earth by passing along with holes in the ozone layer that cause greenhouse effect. Respondents believed that there are barriers of ozone layer or greenhouse gases around the Earth, and the vast majority of respondents could not understand the differences between long-wave outgoing radiation and incoming short-wave radiation. Carbon dioxide and then, carbon monoxide were stated mostly as greenhouse gases, but they did not mention about the other greenhouse gases (e.g., water vapor). But less respondents were aware of the significance of the greenhouse effect in life. Related to ozone layer depletion, it was emerged the prevalent misconception that students confused the concepts of ozone layer depletion and greenhouse effect, for example, many students considered greenhouse effect is raised with holes found in the ozone layer. In connection with this thought, most of the respondents considered that the rate of skin cancer increases with the rising of the greenhouse effect. Half of the respondents, however, believed a common misconception that "car emissions were also responsible for ozone layer depletion" (p.93). Students mostly comprehended the concept of ozone layer depletion because they emphasized the significance of ozone layer for life with saying that harmful radiations are filtered through ozone layer. Besides, they were aware of the role of CFC in ozone layer depletion by means of alerting related to aerosol cans and the effect of media. Lastly, related to acid rain, lots of respondents knew the role of burning coal in the formation of acid rain, but they had a lack of knowledge about which gases involved in the formation of acid rain (e.g., nitrogen oxide). Although the majority of students were aware that acid rain harmed the trees in Scandinavia, most students could not accurately explain the reason for this situation and some of them learned this information from televisions. Researcher attributed the respondents' poor understanding related to the greenhouse effect to being more complex concept in comparison with the ozone layer depletion.

Khalid (2001, 2003) conducted two series of studies to investigate pre-service teachers' understandings in regard of acid precipitation, greenhouse effect and ozone depletion in USA. For example, Khalid (2001) investigated misconceptions and knowledge of pre-service teachers in elementary education (N=113) with respect to acid precipitation, greenhouse effect and ozone depletion. The data were collected through a questionnaire including twenty-nine statements with a free response given by participants. Overall findings showed that participants held misconceptions with respect to these concepts. Qualitative and quantitative results also showed that even if the participants answer the questions correctly, they can give answers that contain misconceptions or incorrect knowledge. For example, related to the greenhouse effect, majority of the participants were aware that average temperature increases with increasing greenhouse effect. But some of them explained this idea with incorrect responses including common misconceptions related to confusion between ozone hole and greenhouse effect. Almost sixty five percent of the participants believed that greenhouse effect is mainly caused by human activities. It was found that their answers were media based and students had misconceptions such as the greenhouse effect is resulted from humans damaging ozone. Slightly more than half of the participants incorrectly believed that the number of people with skin cancer increases with the increase in the greenhouse effect. Related to the ozone, great majority of the participants were aware of the significance of ozone in life, but their explanations related to this idea contained misconceptions such as "It (ozone) maintains temperature, ensures life and growth" (p.109). The great majority of the participants incorrectly considered that car emissions are the one of the causes for destruction of ozone and their explanations contained misconceptions such as damaging of ozone could be originated from all pollution. Related to the acid rain, almost seventy percent of participants correctly stated that acid rain might be occurred through burning some kinds of coal, but their explanation included misconceptions. Researcher attributed the reasons of students' misconceptions to get deficient knowledge from media, abstract nature of the concepts, inefficacious classroom instruction and also using common terms (e.g., hole, ozone layer).

Studying with pre-service primary teachers (N=172), Papadimitriou (2004) explored their perceptions with respect to greenhouse effect, ozone layer depletion and climate change in Greece context. The data were collected via open-ended questionnaire. The findings indicated that pre-service primary teachers possessed lots of misunderstandings related to greenhouse effect, ozone layer depletion and climate change. All participants believed the climate change and they mostly attributed the change in climate to temperature rise (43.02%), restriction of four seasons to two (29.07%) and sudden change in weather (22.09%), which implied that they benefited from their daily life experience while responding that question. Participants confused the concepts of climate and weather due to not being conscious regarding uncertainty of climate change. About three quarters of the participants had a misconception that "ozone depletion contributes to climate change." (p.302), and more than half of the participants had a misconception that "climate change is connected to pollution" (p.302). Fewer participants associated the acid rain with the causes of climate change. Participants were found to be not possess knowledge related to actions for mitigating the climate change. About forty percent participants did not define the mechanism in greenhouse effect and also, about a quarter of the participants had a misconception that "pollutants (the supposed greenhouse gases) make a layer around the earth that traps the heat." (p.303). Fewer participants had a misconception that incoming solar radiation by way of ozone hole lead to global warming. Researcher concluded that the ozone layer depletion and pollution were associated with greenhouse effect by participants. Participants were found to be associate the pollutants with the ozone, which referred to a misconception. While approximately one third of the participants were aware of the main greenhouse gas which is carbon dioxide that led to greenhouse effect, majority of the participants were unaware of the other greenhouse gases (e.g., CFC). Researcher concluded that there are abstract concepts in science that challenges of students' learning (e.g., electromagnetic spectrum, absorption). Therefore, teachers can prepare a discussion environment with appropriate materials, eliminate students' misconceptions with questionnaire and ask questions to students to reveal their misconceptions instead of using didactic methods.

A recent study by Lane (2015b) is to explore the pre-service primary teachers' knowledge in terms of depth and accuracy related to key weather and climate processes included in the water cycle, causes of the wind, properties of air and air pressure. Four hundred thirty pre-service teachers from three different universities in Australia participated to the study. The data were gathered with two parts; in the first part, questionnaire including true/false items was implemented to pre-service teachers (N=430) and in the second part, detailed interviews were applied with pre-service teachers (N=29) who were selected based on findings of the first part. According to the findings, pre-service teachers possessed alternative conceptions with respect to key climate and weather process. Within all pre-service teachers, the idea was common that within the water cycle, water might be disappear and for example, one participant said that *"I think if it's damaged the water eventually does evaporate for good, it disappears."* (p.208). Nearly forty percentage of participants did not consider the air as a matter and also about twenty percentage of them considered that air had no mass. For example, one of the participants said that *"You can't weigh it [air] so it has no weight."* (p.208). Majority of participants considered that "coming closer to a source of heat [i.e. the sun] would make you hotter" (p.210) and therefore, they stated that in connection with their thoughts, the oceans will be very hot near the sun. Lane (2015b) concluded that for preparing students toward secondary geography and science studies, primary pre-service teachers did not possess detail knowledge related to weather and climate process.

Arslan, Cigdemoglu and Moseley (2012) tried to find out pre-service teachers' lack of knowledge and misconceptions with respect to ozone layer depletion, global warming, acid rain and greenhouse effect in USA context. Two hundred fifty-six pre-service teachers having different bachelors were involved in the study. The atmosphere-related environmental problems diagnostic test that created by researchers were applied to all participants in the beginning of undergraduate classes in the teacher education program. The findings indicated that pre-service teachers' understandings related to ozone layer depletion, global warming, acid rain and greenhouse effect were found as too weak and the least-known content was found as acid rain. It was revealed that pre-service teachers possessed six common misconceptions. Pre-service teachers' misconceptions are "Global warming is caused by ozone layer depletion", "Acid rain is a result of global warming", "Global warming will cause skin cancer", "Global warming can be reduced by setting limitations on chemical waste released into the rivers", "The greenhouse effect is a totally harmful phenomenon for mankind", "Using public transportation reduces ozone layer depletion" (p.1680). Findings showed that majority of misconceptions related to global warming in terms of consequences and mitigating its' impacts. Arslan et al. (2012) concluded that pre-service teachers incorrectly associate the consequences of global warming and actions to alleviate the global warming with other atmospheric environmental problems, because they do not correctly understand the nature of global warming. Researchers also attributed the pre-service teachers' too low understandings with respect to ozone layer depletion, global warming, acid rain and greenhouse effect to abstract and complex nature of these concepts.

In Turkey context, Ocal, Kisoglu, Alas and Gurbuz (2011) conducted a study to find out the ideas and misunderstandings of prospective elementary teachers related to the global warming as well as their opinions related to environmental education programs in Turkey. Five hundred sixty-four prospective teachers having different bachelors from three different universities participated in the study. The data were gathered through a closed-form questionnaire including two sections; the first section was related to demographic information and the second section contains true/false questions. The data were analyzed via qualitatively and quantitatively. The findings showed that participants possessed several misunderstandings with respect to global warming. The ozone layer depletion and global warming were confused by participants. For example, great majority of participants considered that “the hole in the ozone layer boosts global warming” (p.222) and “skin cancer increases due to global warming” (p.222). Majority of the participants were unaware that natural greenhouse effect kept the earth warm in order for life to continue in the earth and considered that “the natural greenhouse effect is the cause of global warming problem.” (p.222). More than half of the participants considered “the rise in global warming is a sign of an earthquake” (p.222). Slightly more than three quarters of the participants thought that “nuclear power stations increase global warming” (p.222) and more than eighty percent of participants considered “global warming causes acid rains” (p.222). Another finding showed that majority of participants get mostly information about global warming through television, internet etc. as opposed to during university education. Researchers attributed the causes of participants’ misunderstandings to several reasons including inadequacy of environmental education in teacher training programs of universities in Turkey (e.g., preferring traditional teaching methods, insufficient information in textbook and courses, time limitation in environmental courses, deficient activities related to environment) and sources of informal information (e.g., television, media, internet).

Considering the studies conducted with pre-service and in-service teachers reported above, it can be concluded that they have misconceptions as well as deficient knowledge with regard to the especially weather and climate related concepts (e.g., climate change, global warming, greenhouse effect). Following section, previous research conducted with students were reviewed and reported.

2.2.3 Research Conducted with Students

In this section, previous research on seasons, weather and climate understanding and knowledge conducted with students with respect to various topics such as seasons (e.g. Hsu, 2008; Sung, & Oh, 2018; Tsai, & Chang, 2005), weather (e.g. Cepni, 2014; Henriques, 2002), climate (e.g. Shepardson, Roychoudhury, Hirsch, Niyogi, & Top, 2014), climate change (e.g. Gowda, Fox, & Magelky, 1997; Porter, Weaver, & Raptis, 2012; Shepardson, Niyogi, Choi, & Charusombat; 2011), ozone layer depletion, global warming (e.g. Daniel, Stanisstreet, & Boyes, 2004; Rye, Rubba, & Wiesenmayer, 1997; Shepardson, Niyogi, Choi, & Charusombat, 2011), and greenhouse effect (e.g. Shepardson, Niyogi, Choi, & Charusombat, 2011) were reviewed and reported.

In recent study in Korea, Sung and Oh (2018) carried out a study to explore the content-specific challenges and competencies of 6th grade level students (N= 65) related to seasons by means of modelling. Two sixth grade level classrooms as Class 1 and Class 2 in elementary school participated in the study. One teacher having 16 years teaching experiences were assigned to these classes and three modelling pedagogies were implemented. In expressive modelling, students were requested to either construct a new model or revise the existing model in groups and make explanation on their models. In experimental modelling, they were requested to form their hypothesis related to their models followed by making comparison with experimental findings. In evaluative modelling, they were requested to evaluate the models and make discussion on weakness and strengthens of it. The data were gathered through audio-recorded interviews on students' reflection regarding modelling-based instruction, students' and teachers' artefacts and digitally recorded modelling-based lessons, and analyzed through qualitatively. The findings showed that students in both classes possessed competencies on expressing their opinions by constructing a physical model about the seasons during expressive and experimental modelling. In expressive modelling, however, Class 1 were not able to perceive the tilt of rotation axis of Earth as the reasons for seasons. Class 2 experienced challenges during establishing relationship between incoming solar energy and meridian altitude of Sun. Related to experimental modelling, both classes formed their hypothesis and tested their physical models with experimentation. However, whereas Class 1 experienced challenges while trying to find a cause of seasons through implementing disconfirming experiment, Class 2 had difficulty in measuring the meridian altitude of Sun on the globe. During the evaluative modelling, students made no changes to their initial models based on experimental results that their models explain the seasons well. Later, the teacher asked physical questions based on the deficiencies in the students' models, and thus, students made revision on their models by removing the deficiencies. Researcher stated that these students' difficulties were originated not only from students' challenges and competencies, but also from deficiency of teachers' pedagogical acts in the classroom. Sung and Oh (2018) concluded that with the help of their peers and teachers' proper acts, students are able to construct scientifically valid models related to seasons.

One of the early research in the field of development of students' understanding was carried out by Tsai and Chang (2005) to explore the changes of students' conceptual understanding regarding causes of seasons with applying the conflict map-based instruction through the long-term observation in Taiwan. Two groups of 9^{th} grade students (N=82) in high school were involved in the quasi-experimental study. While traditional teaching method was implemented in one classroom (N=42), the conflict map-based instruction was implemented in another classroom (N=40). In the first part of the conflict map-based instruction, students were desired to state the causes of seasons and make discussion in their groups followed by presenting their opinions. Then, teacher explained the discrepant events, and following, benefitted from the critical event targeting their alternative conceptions and allowed students to consider related to them. In the second part of this instruction, teacher performed several activities to show the link between earth and sun. Three audio-recorded interviews were applied to twenty-five participants in each group who were chosen randomly after completing intervention. The first interview was applied after one week, the second one after two months and the third one after 8 months. The phenomenographic method was used the analysis of data and three categories including no conception, alternative conception and scientific were used to classify students' responses. The first interview findings indicated that both groups' impact on students' view related to causes of seasons were found as similar. For example, while majority of both group's responses contained scientific conceptions, about sixteen percent of students in both groups had alternative conception. The second interview findings indicated that about forty percent of students in traditional group were able to remember scientific knowledge, but in the conflict map based group, this rate was about sixty five percent. However, seven students in conflict map based group and eleven students in traditional instruction group had alternative conception. The third interview findings indicated that more than half of the students were able to remember the same conceptions related to the causes of seasons in the conflict map based group, but in traditional group, this rate was about twenty two percent. But eight students in conflict map based group and thirteen students in traditional instruction group had alternative conception. Overall findings indicated that majority of students possessed a prevalent alternative conception that “Seasons are determined by earth’s distance to the sun.” (p.1094). Tsai and Chang (2005) concluded that the conflict map-based instruction may be influential for students to learn and also retain their scientific understanding with respect to causes of seasons through long-term study.

Through a technologically enhanced learning, Hsu (2008) conducted an experimental study to investigate the effects of students-centered and teacher-guided instruction on second year senior high school students’ (N=87) conceptual understanding regarding seasonal change in Taiwan context. Two different groups which are the teacher guided instruction (N= 44) and student-centered instruction (N=43) were created. Both classrooms’ instructions were based on technologically enhanced learning model but with applying different instructional approaches. Two stages were involved in technologically enhanced learning model. In Stage I, teacher showed the pictures related to the appearance of nature throughout the four seasons, and showed animations. In Stage II, the teacher used a computer simulation about the seasons followed by the students were requested to draw concept maps. The pre-concept maps were constructed by students before the Stage I, midconcept maps after Stage I and post-concept maps after Stage II. The analysis of students’ preconcept maps constructed before the seasons lesson indicated that fifty-nine students possessed alternative conceptions related to seasons. For example, thirty-one students possessed alternative conceptions derived from their daily experience regarding natural events such as “natural phenomena such as clouds, planetary wind systems, tides, ocean currents, monsoons, and the moon caused the seasons.” (p.329). Eleven students believed the alternative conception that “It is winter at the aphelion and summer at the perihelion in the northern hemisphere” (p.327). Four students believed the alternative conception that “The tilt of the earth’s axis causes the change in earth–sun distance and/or sunshine area” (p.327). Another result indicated that students’ postconcept maps scores outperformed their pre- and middle concept maps scores, but the performance of groups taught by teacher guided instruction were less than other group. Overall findings indicated that through the technologically enhanced learning environment including multimedia tools, majority of students’ conceptual understanding on causes of seasons improved because they gained detailed knowledge. Hsu (2008) concluded that as opposed to teacher-guided instruction, the student-centered approach was found as more influential with regards to change in students’ alternative conceptions.

In the scope of Henriques’s (2002) study, research found in literature with respect to children’s misconceptions on Earth science including climate, atmosphere and weather were reviewed. They reported that compared to Earth science, majority of misconceptions were found regarding physical sciences including atmosphere and gases, properties of water and water cycle, seasons and heating of the Earth, clouds and precipitation, global warming and greenhouse effect, phase changes of water as categories. Findings indicated that as students’ age get along, their conceptions became more sophisticated. For example, while younger children thought that matter has solid and concrete properties, they started to clarify the properties and structures of matter when their age increased. Another example is that younger students mention about properties of water (e.g., liquid aspect of water) and phase changes, melting and freezing and they do not mention about other phase changes (e.g., condensation) while talking about the water cycle. However, older students tend to think more complex and they express the changes of phase through models that they developed. Students possessed misconceptions related to the concepts of gases and atmosphere. For example, most of the students considered that “Hot air weighs less than cold air.” (p.212). Students also had misconceptions regarding the global warming, greenhouse effect and seasons. For instance, most of the students considered that “Seasons are caused by the Earth’s distance from the Sun.” (Philips, 1991, p.22). Researcher concluded that due to the fact that the concepts such as atom, gas, seasons are abstract concepts, students have difficulty in understanding these concepts and this situation lead to rise the possibility of misconceptions emerged in students. Henriques (2002) stated that students have to know somethings about the concepts of molecules and atoms for comprehending the matter and phase changes of matter. Henriques (2002) also suggested that if the teacher possess knowledge regarding the students' ideas related to the topic, teachers could design activities and experiments having purpose of force students to think.

Rye, Rubba and Wiesenmayer (1997) conducted a study with the aim of exploring the students’ alternative conceptions with respect to global warming in Pennsylvania context. Twenty-four middle school students including 6^{th}, 7^{th} and 8^{th} grade level were classified based on academic level as high (N=9), medium (N=9) and low (N=6) from four middle level classrooms were involved in the study. Each classroom was taught by four teachers related to different Science Technology Society (STS) global warming unit. Two weeks after this unit was taught; students were subject to open-ended interviews related to global warming. According to the findings, it was revealed that students' alternative conceptions did not correlate with their academic level and gender, and five alternative conceptions were identified. For instance, most of the participants considered the increased UV radiation or ozone depletion as the one of the causes of global warming and slightly more than half participants had a misconception that the primary cause of global warming is ozone layer depletion. Slightly more than half participants also possessed a misconception that “aerosol sprays contain CFCs and destroy the ozone layer” (p.536). A quarter of the participants had a misconception that “CFCs cause global warming exclusively through their role in destroying the ozone layer” (p.536) and some of the participants had a misconception that “carbon dioxide causes global warming exclusively by destroying the ozone layer” (p.536). These misconceptions were found to be significantly correlated to each other. Half of the participants had a misconception that ozone layer is devastated by carbon dioxide and researcher explained that the reason of why students think like that students considered the carbon dioxide and CFCs were similar to each other such as being a part of pollution, being greenhouse gas. Rye et al. (1997) concluded that students' understanding related to causation, resolution and nature of global warming might be confused and restricted by particular alternative conceptions of them. It was also concluded that since majority of teachers mentioned about ozone layer depletion in their teaching, which might lead to develop alternative conceptions in students.

Studying with high school students in Oklahoma (N=33) and Hawaii (N=66), Gowda, Fox and Magelky (1997) conducted a study to find out their understandings related to climate change. The data were collected by means of questionnaire having purpose of revealing their understandings and open-ended survey having purpose of getting more depth knowledge about where the participants made mistakes. The findings indicated that students' mistakes in both groups were not statistically different between each other and several prevalent misconceptions were revealed. For example, participants associated the ozone layer depletion and CFCs with climate change. Also, seasonal and weather changes, littering and chemical gases were expressed as causes of the climate change. Nearly more than a half participant specified the evidence for occurrence of the climate change, for example, participants erroneously stated the pollution, warmer temperatures and change in weather. The television was frequently said as source of evidence for climate change as opposed to the newspapers, books, magazines, personal experience and teachers. Participants considered that various environmental harmful actions (e.g., using aerosol spray cans) lead to climate change, which implied that they linked many environmental harms irrelevant to the climate change. Furthermore, the climate and weather concepts were confused by many participants. Researchers attributed the causes of the emerging students' misconceptions regarding climate change to several factors such as the restricted time for teaching the climate change in the classrooms, the possibility that the media can provide inaccurate information and students' trust toward media. Using their judgmental heuristics and making generalization using limited evidence are also sources of students' misconceptions related to climate change. In the study, the most trusted source of students was found as scientists and Gowda et al. (1997) suggested that scientists in tandem with educators could contribute to develop students' understanding and besides in particular eliminate the students' misconceptions that emerged in the study and previous studies in particular.

Daniel, Stanisstreet and Boyes (2004) conducted a study with the aim of exploring the secondary school students' (N=582) including Year 7, 9 and 11 misconceptions and ideas with respect to the way to mitigate global warming at best. The closed form questionnaire including statements about students' erroneous ideas and also scientific statements related to action for alleviating the global warming was used to collect data, and SPSS was used to analysis of data. The findings indicated that students possessed misconceptions related to the ways of mitigating global warming. For example, great majority of the participants held the idea of relationship between global warming and ozone layer depletion, which is the most prevalent misconception. The majority of the participants, especially more of the younger participants, held the major misconception that "less use of nuclear power to generate energy would reduce global warming" (p.218). More than half of the participants considered the mitigation strategies for global warming as decreasing the usage of pesticides and using unleaded petrol. Almost thirty three percent of the participants associated the global warming with local pollution including cigarette smoking, bonfires, street litter and also almost half of the participants considered a relation between global warming and dumping rubbish in rivers and marine pollution. However, the student group that supports these ideas least was the older students. The results uncovered that as students' age older (e.g., from Year 1 to 3), there were improvement of students' ideas and reduction of their misconceptions related to the way of alleviating global warming within majority of the part in the study. To illustrate, a smaller number of older students associated the pollution such as freshwater with global warming because their opinions developed as get older. However, some misconceptions were found in oldest students frequently. To illustrate, more than eighty percent of the oldest participants had a misconception that global warming is decreased with the supporting of ozone layer protection. Researchers concluded that strategies for mitigating the global warming can be confusing and sophisticated for students.

Shepardson, Niyogi, Choi and Charusombat conducted series of studies (2009, 2011) to explore the conceptions of students with respect to climate change, greenhouse effect and global warming in USA context. For instance, Shepardson et al. (2011) examined fifty-one secondary students' including high school (N=12) and junior high school students (N=39) from three different high schools conceptions in regard of the climate change, greenhouse effect and global warming. The data were collected through global warming and climate change assessment instrument including draw and explain item and open-response items and also, analyzed through content analysis. According to the findings, students possessed conceptions related to climate change, greenhouse effect and global warming. Almost one third of students considered the causes of climate change as air pollution and other atmospheric gases. Related to the effects of global warming, a little more than fifty percent students considered that ocean level increase due to increasing of precipitation or melting ice. Great majority of students considered that there would be negative effects on animals and plants, for example, the number of animals and plants may decrease. Whereas the vast majority of students stated that warming in the weather will occur, more than half of them stated that there will be changes in precipitation. Almost half of the students considered there is not major effect of global warming with respect to society and people. Whereas majority of students considered the rise the number of factories and vehicles as the causes of increasing carbon dioxide levels, slightly more than a third of students associated the rising the carbon dioxide levels with air pollution. Many students stated the using less energy and decreasing the car using as mitigation strategy of climate change and global warming, and some of them stated that the number of factories and general pollution should be decreased. Their responses related to prevention strategies showed that they failed to make connection between daily life and climate change and global warming. Majority of students had difficulty in comprehending greenhouse effect such as considering greenhouse gases as air pollution generally, not aware of the carbon dioxide as a greenhouse gas. Twenty four percent of them identified the greenhouse gases as a layer surrounding the atmosphere. Overall, researchers concluded that their conceptualization of climate change and global warming are not found as rich because they possessed simple and narrow conceptions of these.

Shepardson, Roychoudhury, Hirsch, Niyogi and Top (2014) conducted a study to investigate the process of 7th grade students' (N=42) conceptualization of climate system on the basis of system thinking. The data were gathered through climate system task including three prompts; the first one was related to impact of climate system components on climate, the second one was related to how the climate is affected by increasing of greenhouse gases and lastly, the third one was related to impact of global warming on climate on the basis of climate system. The data were analyzed through content analysis. As a result of the findings, twenty-two codes were created, and these codes were categorized according to the climate system components expressed by the students. The findings indicated that participants stated the "atmosphere" as the most cited component of climate system and "temperature change" which was code related to atmosphere most frequently cited code for all prompts. For prompt 1, students considered the main cause of climate change as atmospheric components (e.g., temperature change, water cycle) and less students associated the atmosphere with other components. For prompt 2, when asked the impact of greenhouse gases on climate, fewer students made association between atmosphere and other components, but their opinions related to systematic things were limited to the impact of rising of greenhouse gases on atmosphere. For prompt 3, when asked the impact of global warming on climate, students made more association among other components instead of greenhouse gases such as melting of ice-atmosphere. It was revealed that participants possessed rudimentary ideas with respect to global warming and greenhouse effect because they frequently referred to raising the temperature of the atmosphere as the impacts of greenhouse gases and global warming on the climate based on climate system. They also did not consider relation among other components and atmosphere. Overall, researcher concluded that there is a basic and unidirectional cause-effect relationship and linear association among climate system's components in students' conceptualization of climate system. Also, students did not address the feedback mechanism.

As well as investigating students' misconceptions and understandings, another line of the research is their development of understanding and knowledge through various interventions. In this sense, Porter, Weaver and Raptis (2012) conducted a study to explore the alteration of 4th grade students' (N=66) knowledge concerning fundamental concepts of climate change including "weather and climate", "carbon cycle and human impacts", "global warming and the greenhouse effect" during instruction for two weeks in Canada context. Researcher designed two instruction types which are teacher-based and presenter-based. While teacher-based instruction (N=31) applied by teacher having over 15 years' experience who was assigned to two classrooms, presenter-based instruction (N= 19) applied by certified teacher having over five years' experience and environmental educator in non-governmental organizations. Moreover, one classroom (N=16) was control group where there was no intervention. While quantitative data were collected by students via Survey on Climate Change applied as pre-post and follow-up, qualitative data were collected by teacher-based instructor via Post-Instruction Teacher Survey. The data were analyzed through paired-samples t-tests and ANOVA. The pre-instructional Survey on Climate Change results indicated that all students held similar prior knowledge related to fundamental concepts of climate change. But post and follow-up survey results indicated that the post-test scores in teacher-based instruction and presenter-based instruction showed improvement. But ANOVA results indicated the significant differences between groups in terms of instructions' types and presenter-based instruction was found to be less influential on students' knowledge related to climate change as compared to teacher-based instruction. The pair-samples t-tests results indicated that all students' performance related to climate change fundamental concepts, apart from control group, enhanced through pre-test to post-test, but this increase was not significant in terms of "greenhouse effect and global warming". Only the results based on "carbon cycle and human impacts" and "weather and climate" were found to be significant in teacher-based instruction. The Post-Instruction Teacher Survey results indicated that teacher-based instructor said that her background knowledge on "weather and climate" is better than other two concepts. She stated that the "greenhouse effect and global warming" was the most challenging concept and also added that the students had some difficulties related to these concepts. It was also indicated that teacher defined the lack of climate change topic in the curriculum, taking too much time to understand, the lack of her current knowledge and its' complexity as barriers for teaching climate change. The follow-up survey applied five weeks after the intervention revealed that teacher-based instruction provided retention of knowledge more than other groups. It was found that all groups including students and teacher were less comfortable related to greenhouse effect and global warming topics as opposed to other concepts. Researcher concluded that contextual and personal factors such as the low level of student participation due to the fact that their own teacher did not teach and the presenters did not communicate with the students before the intervention might lead to show lower level of performance in presenter-based instruction.

In Turkey context, Doğar and Başıbüyük's (2005) studied with fifth and seventh grade students, and found that the concepts of the climate and weather were often expressed by students as deficient. The majority of the students associated the weather with their daily lives (e.g., breathing) and so, expressed the weather as a source of life, and also about fifteen percent of seventh grade students confused the concept of weather with weather condition or climate. More than half of the students were not able to accurately express the weather condition, and under the influence of the media, the students defined the weather condition as a weather report. Whereas some of the secondary students defined the climate using definitions such as "Weather within the year", "Spring-summer-autumn-winter", "It is the geographical location" (Doğar, & Başıbüyük, 2005, p.355), some primary students defined the climate using definitions such as "Annual average temperature", "A factor that determines the season of a place", "It is the geographical location" (Doğar, &

Başıbüyük, 2005, p.355). Doğar and Başıbüyük (2005) attributed the reason why the students' knowledge about the climate and weather are not permanent to the rote learning, and in parallel, they suggest that concrete examples should be given and the constructivist approach should be applied in the teaching of these concepts.

Yılar (2007) investigated the knowledge of fifth grade students about some geography concepts and reached the conclusion that almost one third of the students described the climate scientifically. For example, one of the students said that "Climate is the average of weather events that occur in a place for a long time. When explaining the climate of a place, we say hot, cold, rainy etc." (Yılar, 2007, p.66). The researcher found that just more than half of the students did not describe the climate completely correct. For example, one of the students described the climate by saying that "Terrestrial climate, Black Sea climate, Mediterranean climate. Good climate is where people can live. In dry areas, people are dehydrated." (Yılar, 2007, p.67). In addition, approximately one-fifth of students were found to have misconceptions about the concept of climate because they confused the climate with various concepts such as weather, drought, seasons and temperature. Yılar (2007) attributed the students' lack of knowledge about the concept of climate to the lack of learning strategies and insufficient teaching methods and proposed to eliminate students' misconceptions by using effective teaching strategies such as conceptual change methods and concept maps.

Cepni (2014) conducted a study to investigate 6^{th} grade students' (N=242) who were from different schools perceptions related to weather events concept with applying phenomenological design. The data were obtained with form for collecting data via metaphor and students' drawing pictures/cartoons related to weather events, and analyzed through document analysis and content analysis. Findings showed that thirty-four metaphors created by students were categorized under five conceptual categories; "changing depending on conditions", "involving uncertainties", "continuous", "fearsome" and "having rules", and also, students addressed to various metaphors in these categories. According to the findings, the perceptions of most participants related to weather event were revealed as "continuities", "changing depending on conditions" and "involving certainties", and also, "our feelings", "air conditioner" and "teacher" were revealed as metaphors that mostly utilized by participants. For example, one student drew cartoon related to air conditioner metaphor in "changing depending on conditions" category and said that *"Weather event is like an air-conditioner. This is because; an air-conditioner sometimes cools and sometimes heats."* (p.349). Another example is that another student drew cartoon related to "human being" metaphor in "continuous" category and said that *"Weather event is like human beings. This is because; the facial expressions of human beings change."* (p.352). The findings indicated that students held misconceptions and lack of knowledge concerning weather events concept. For example, the concept of weather events was confused with climate and weather condition concepts by students. Another finding indicated that as compared to scientific definition of weather events, students' metaphors with respect to weather event were not completely consistent. Researcher concluded that the several factors such as teachers' competence, students' lack of knowledge, students' interest, curriculum might affect students' perceptions concerning weather events.

In this section, as reported above, previous research studied with students from different grade levels (e.g., 4th, 6th, 7th, 8th, 9th) were reviewed, and it was concluded that they had a lack of knowledge along with misconceptions about weather, climate and related concepts. Next section, summary of literature review was reported.

2.3 Summary of Literature Review

In the literature review section, at first, previous research conducted with in-service and pre-service teachers to find out their PCK and SMK on various topics from different areas which are Earth sciences, biology, chemistry, and physics were handled extensively. Considering the reported studies, some studies focused on uncovering teachers' existing PCK, while others focused on examining the development of their PCK. While some studies dealt with SMK-PCK relationship, others dealt with the impact of teachers' PCK or SMK on students' output. The qualitative methodology was generally preferred. As data sources, interviews, classroom observations and also Content Representation (CoRe) were frequently used. Magnusson et al.'s (1999) PCK model, one of the transformative models, was revealed to be the most preferred model. Briefly, previous research findings indicated that experienced teachers' PCK compared to less experienced teachers or pre-service teachers were found to be more developed. In addition, research on PCK for NOS has been another research field addressed by researchers. Some of the studies focused on teachers' context-embedded NOS understandings. Generally, the findings showed that experienced teachers, as well as in-service and pre-service teachers, possessed a lack of knowledge and misconceptions about NOS aspects. At the same time, they had difficulty in integrating NOS aspects into their teachings. In this direction, some studies aimed to develop teachers' NOS understandings as well as their PCK for NOS through various development programs.

Secondly, previous research on substantive knowledge conducted with in-service teachers, pre-service teachers, and students in the context of seasons, weather, climate and related concepts (e.g., climate change, greenhouse effect, global warming) were covered extensively. According to the findings, it was concluded that students, pre-service teachers and even in-service teachers have deficient knowledge and misconceptions about related concepts. Also, teachers' misconceptions were found to be similar to the students to some extent. In the light of these results, various development programs were carried out with the aim of developing their knowledge regarding related concepts.

CHAPTER 3

METHODOLOGY

In this study, the purpose is to investigate three in-service science teachers' subject matter knowledge and pedagogical content knowledge related to the seasons, weather, and climate addressing dual perspective. In methodology section, general design and rationale, the selection of participants, data collection tools, data analysis, trustworthiness, ethical issues, limitation and assumptions of this study were reported in detail.

3.1 General Design and Rationale of This Study

Denzin and Lincoln (2005) defined what the qualitative research and the role of the qualitative researcher is that;

> "Qualitative research is a situated activity that locates the observer in the world." (p.3) and "qualitative researchers study things in their natural settings, attempting to make sense of, or interpret, phenomena in terms of the meanings people bring to them." (p.3).

In this study, it was intended to explore the in-service science teachers' PCK regarding the seasons, weather and climate in depth. PCK is expressed as tacit knowledge (Kind, 2009; Mthethwa-Kunene, Onwu, & de Villiers, 2015) and complex construct (Nilsson, & Loughran, 2012). Thereby, qualitative research design was chosen because in general manner, rich in-depth information is obtained from very few cases and people through qualitative methods (Patton, 2002). Merriam (2009) stated that "Qualitative inquiry, which focuses on meaning in context, requires a data collection instrument that is sensitive to underlying meaning when gathering and interpreting data." (Merriam, 2009, p.2). Within the scope of qualitative studies, gathered data exist in the form of either pictures or words, not in the form of numbers (Bogdan, & Biklen, 2007; Fraenkel, Wallen, & Hyun, 2012). In accordance with these explanations, various data collection tools which are semi-structured interviews, classroom observations, observations reports, teacher documents as visual (e.g., classroom photos) and personal (e.g., written exams, activity sheets) were utilized to gather rich and detail data from in-service science teachers in this study. Furthermore, there are real settings that is direct data sources in qualitative research (Bogdan, & Biklen, 2007; Fraenkel, Wallen, & Hyun, 2012) and the key tool is defined as researcher (Bogdan, & Biklen, 2007; Fraenkel, Wallen, & Hyun, 2012; Yin, 2011) to analyze and gather data (Merriam, 2009). For this reason, the researcher's role is essential for collecting data properly from participants in this qualitative study. Lastly, the collected data were analyzed through inductive and deductive coding. The general design of this study was shown in Figure 3.1.

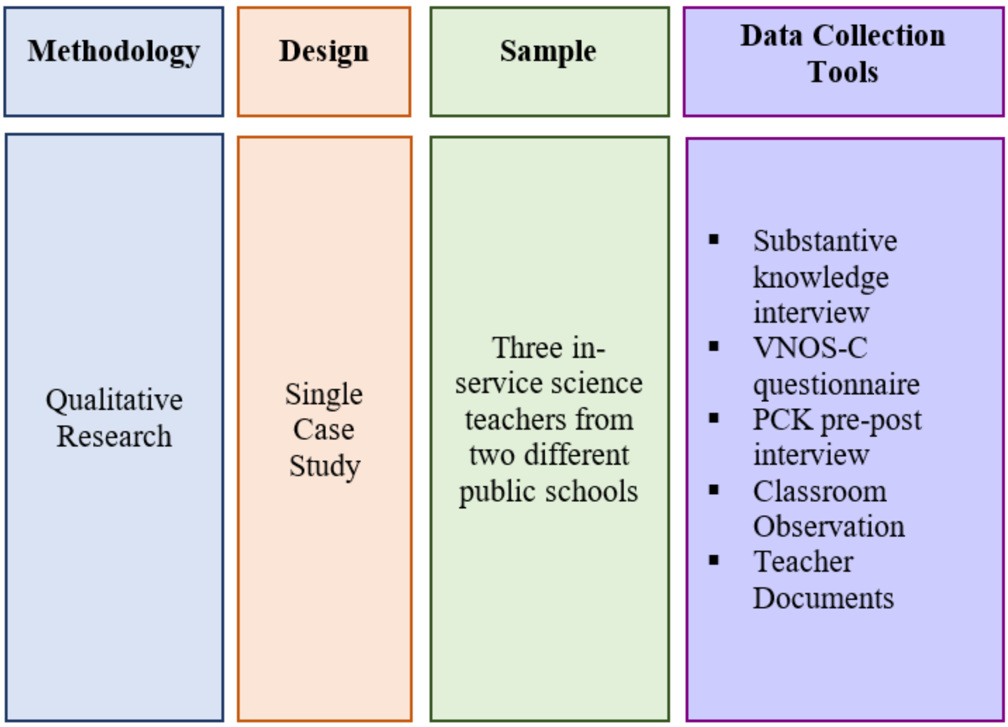


Figure 3.1 General Design of This Study

3.2 Case Study

Of all types of qualitative research, case study was selected for this study. For conducting qualitative research, the widespread way is case studies (Stake, 2005) and case study is one of the popular methods of qualitative research (Willis, 2007). Merriam (2009) defined the case study that "A *case study* is an in-depth description and analysis of a bounded system." (p.40). A program, an individual, a critical incident, a community, an event or a time period could be a case (Patton, 1987). Especially when an individual requires to grasp a specific circumstance or problem in detail and when individual could define cases having rich information, case study comes in beneficial (Patton, 1987).

This study was defined as a single case study because single case study can contain subcases or subunits, for example, students in a school, and it is aimed to comprehend a case deeply (Merriam, & Tisdell, 2016). In this study, single case consists of three experienced in-service science teachers who were selected to obtain in-depth and rich information about their PCK and SMK addressing dual perspective in the context of seasons, weather and climate.

3.3 The Selection of Participants

The purpose of this study is to obtain the in-depth information from three in-service science teachers' SMK and PCK, not generalize the findings to the whole populations. Probabilistic sampling is not required for a qualitative study because in qualitative studies, a statistical generalization is not aimed (Merriam, 2009). Correspondingly, it was decided to use nonprobability sampling to select the sample of this study. Among the types of nonprobability sampling, purposive sampling was preferred. In qualitative study, purposive sampling where the samples are selected in respect of intended form (Yin, 2011). To enlighten the research questions related to a study, it is highlighted the choosing of cases having rich information in purposeful sampling (Patton, 2002). Merriam (2009) stated that the fact that primarily deciding the criteria that are required to select the sites or people in the study is imperative to start the purposive sampling. In the scope of this study, therefore, two main criteria were determined by researcher in order to select the sample as compatible with the purpose of this study. These two criteria were specified as follows;

1. The location of the seasons, weather, and climate topic in the curriculum was the first criteria for selecting the sample. The aim of this study is to explore the three in-service science teachers' PCK related to the seasons, weather, and climate. The seasons, weather and climate topic were located as first unit of 8^{th} grade level in curriculum (MoNE, 2018). Accordingly, the in-service science teachers who teach students at 8^{th} grade level were chosen with the aim of getting rich and in-depth information with respect to their PCK regarding the seasons, weather and climate topic.
2. The selection of experienced teachers for this study was defined as the second criteria. In progress of time, PCK shows development (Abell, 2008; Cochran, DeRuiter, & King, 1993) through obtaining teaching experience while teaching lots of students found in lots of classroom environments (Cochran, DeRuiter, & King, 1993). The criteria for being experienced teachers is that their teaching experiences should be more than five years at least (Akerson, 2005). In line with these explanations, three in-service science teachers whose teaching experiences were 10, 11 and 25 years were chosen for this study to obtain rich information related to their PCK in the context of the seasons, weather, and climate topic.

In addition to this, convenient sampling which is one of the purposive samplings was preferred while selecting sample in this study. In convenient sampling, a sample is chosen according to respondents, location, time, convenience of sites or money (Merriam, 2009). Possibly the least preferred and most widely used sampling type is defined as convenient sampling (Patton, 1987; Patton, 2002). It is not too reliable to choose sample depend on just convenience sample and instead of information rich cases, information poor cases may be occurred (Merriam, 2009). However, in this study, the researcher has encountered some situations to use convenience sampling.

These situations can be expressed as the aforementioned criteria set by the researcher, having difficulty in finding willing participant teachers, researcher's time limitation and the schools where the study is conducted are close to each other. For example, since the researcher worked with three teachers and observed these teachers' teachings within the same unit, the distance between the schools where the study was conducted had to be close to each other. As a result, based on the criteria and sampling methods that were used, three in-service science teachers in two different public schools were selected as sample for this study. In the following section, the details of the participants of this study were explained.

3.3.1 Participants of This Study

Overall, three experienced in-service science teachers were attended in this study. The real names of the teachers were not used to provide teachers' confidentiality and safety. Thereby, the teachers were given different pseudonyms that were used throughout this study. Case 1 was named as "Burak", Case 2 was named as "Beyza", and Case 3 was named as "Esra". While teachers Burak and Beyza worked in the same public school, teacher Esra worked in different public school located in different district. All teachers' demographic information was shown in Table 3.1.

Table 3.1 *Participants of This Study*

Participant's Name	**Age**	**Teaching Experience**	**Years worked in current public school**	**Grades he/she taught currently**	**Graduation**	**Bachelor's degree**
Burak	33	10 years	7 years	7^{th} - 8^{th}	Faculty of Education	Science Education
Beyza	48	25 years	24 years	7^{th} - 8^{th}	Art and Science Faculty	Biology
Esra	36	11 years	5 years	8^{th}	Faculty of Education	Science Education

3.4 Data Collection Tools, Procedure and Process

To collect empirical materials, several methods are implemented by qualitative researchers (Denzin, & Lincoln, 2005). Written documents, open-ended and in-depth interviews and direct observation are three types of data collection tools where the qualitative findings are emerged (Patton, 2002). In harmony with Patton's (2002) ideas, in this study, the data were gathered through PCK pre-post interview, substantive knowledge interview, syntactic knowledge interview (Embedded-VNOS-C questionnaire), classroom observation and teacher documents (i.e., visual and personal). Table 3.2 showed all data collection tools used in this study and corresponding components of PCK and SMK, and dual perspective.

Table 3.2 *Data Collection Tools (Adapted from Tıraş (2019))*

Data Collection Tools	**Relevant PCK and SMK aspects, and Dual Perspective**	**Data Collected Time**
PCK Pre-interview	Orientation Toward Science Teaching Knowledge of Curriculum Knowledge of Students' Understanding Knowledge of Instructional Strategies Knowledge of Assessment Knowledge of Dual Perspective	At the beginning of the study
PCK Post-interview	Knowledge of Curriculum Knowledge of Instructional Strategies Knowledge of Assessment	At the end of the study
Substantive Knowledge Interview	Substantive Knowledge Knowledge of Dual Perspective	At the beginning of the study
Embedded VNOS-C Questionnaire	Syntactic Knowledge	At the beginning of the study
Classroom Observation	Substantive Knowledge Syntactic Knowledge Orientation Toward Science Teaching Knowledge of Curriculum Knowledge of Students' Understanding Knowledge of Instructional Strategies Knowledge of Assessment Knowledge of Dual Perspective	Throughout the study
Teacher Documents		Throughout the study
Worksheets	Knowledge of Curriculum	
Written Exam Questions	Knowledge of Assessment Knowledge of Dual Perspective	
Teachers' Drawings on the blackboard	Knowledge of Instructional Strategies Substantive Knowledge Knowledge of Dual Perspective	
Other textbooks published by different publishers	Knowledge of Curriculum Knowledge of Assessment Knowledge of Dual Perspective	

In addition to the data collection tools, Figure 3.2 shows how the data collection procedure and process were and in what order the data collection tools were used throughout this study.

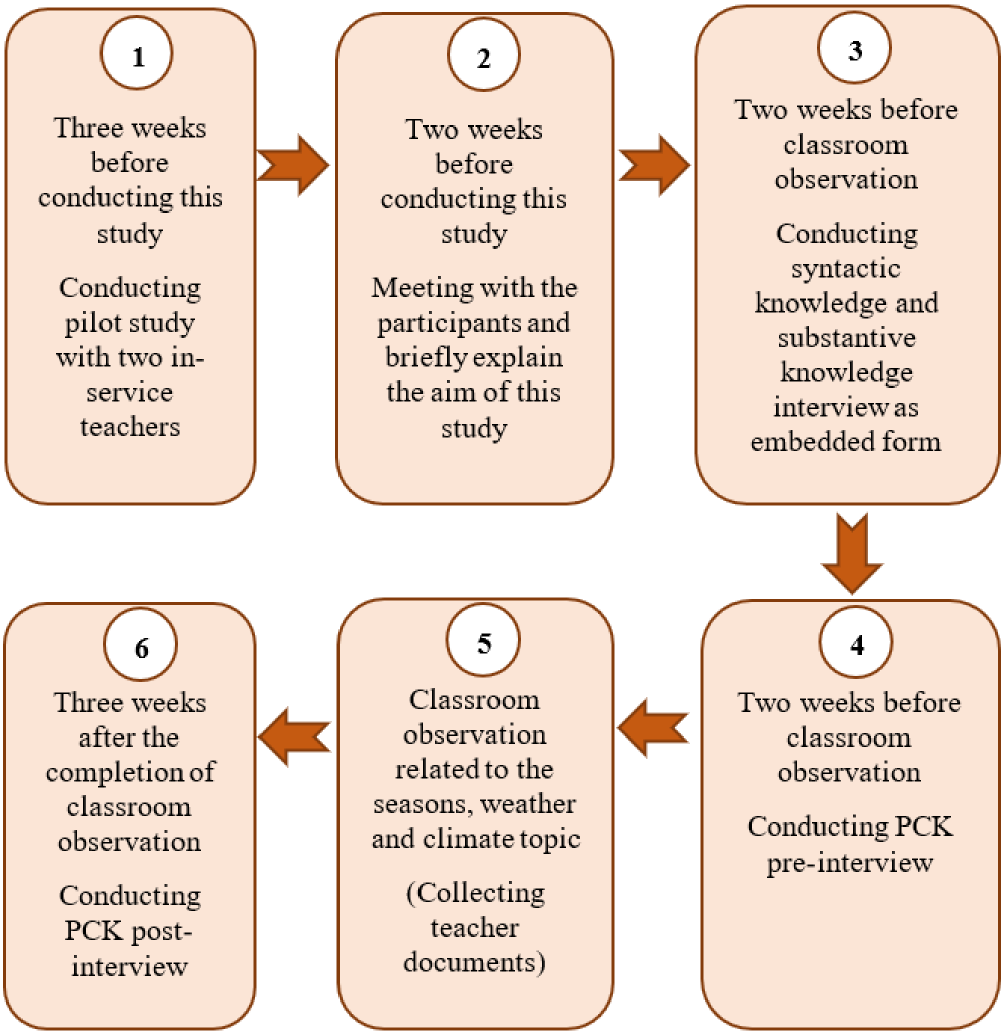


Figure 3.2 Data Collection Procedure and Process

In the following section, data collection tools were explained in detail separately.

3.4.1 Interviews

Interview is one of the most crucial sources to reach information related to case study (Yin, 1994) and getting specific type of information is expressed as the major aim in interview (Merriam, 2009). Evaluator is able to comprehend individual's point of view as well as go into another individual's world through interviews (Patton, 1987). By the time intense case studies with too less people are conducted, performing interview is a best method (Merriam, 2009). In the light of these explanations, several interviews were preferred to conduct in the scope of this study because it was aimed to obtain rich, in-depth information from participants and reveal the information in their mind. Semi-structured interviews, one of the types of interviews, were selected for this study. There is no specific order of the semi-structured interview questions and therefore, the interview progresses depending on the responses of the participants. Questions or comments pursuing anything previously asked are called probes (Merriam, 2009) and in the semi-structured interviews, based on the interviewee's responses, the impromptu questions named as probes are constituted (Fraenkel, Wallen, & Hyun, 2012). In other words, apart from the questions in the interview protocol, additional questions can be asked to the participants for getting in-depth information depend on participants' responses. For example, in this study, additional questions were asked to the participants to further elaborate their responses to the question, so that researcher had opportunity to learn the underlying reasons of the participant's responses.

Getting permission from the participants to record their voices is an essential point for providing the safety and confidentiality of the participants. Therefore, after giving permission, participants' responses were tape-recorded throughout the interview. Recording of the interview ensured that the researcher did not have anything to miss from the participants' responses during the interview and also, the loss of data was prevented. When each interview was completed, the audio recordings of the interviews were listened, and following, transcribed by the researcher to ready for data analysis.

3.4.1.1 PCK Pre-Interview

Before teachers' teaching practices, PCK pre-interview was applied to the teachers in order to reveal their PCK on the seasons, weather and climate topic. Loughran et al. (2004) constructed Content Representation (CoRe) and revealing knowledge of participant teachers regarding a specific science topic teaching is defined as the purpose for constructing CoRe (Nilsson, & Loughran, 2012). Then, Aydın (2012) made adaptation of CoRe into chemistry topic (i.e., electrochemical cells and nuclear reactions) and translation into Turkish. In this study, CoRe (See Appendix A and Appendix B) was adapted to the seasons, weather, and climate topic with giving permission from her (Appendix C) and then, used to apply to the teachers as interview. The questions in CoRe represent PCK components: knowledge of instructional strategies, knowledge of curriculum, knowledge of assessment, orientation toward science teaching and knowledge of students' understandings.

Each teacher's PCK pre-interview was applied about two weeks before the classroom practice regarding the seasons, weather and climate in the public schools where teachers currently worked, and interviews were tape-recorded with receiving permission. PCK pre-interview was conducted at the most appropriate time for each teacher. Each interview was lasted about one and half hour, and the researcher showed kind, sensitive and respectful behavior toward the teachers throughout the interviews.

3.4.1.2 PCK Post-Interview

The main target of the PCK post-interview is to solve the discrepancy between PCK pre-interview and classroom observation. The teachers' ideas in PCK pre-interview and their teaching practice were examined in detail and then, PCK post-interview questions were prepared based on inconsistent points between PCK pre-interview and classroom observation. PCK post-interview questions of each teacher are not same. The reason why these questions are prepared specifically for each participant is that the differences in the responses of the participants in the PCK pre-interview and their way of teaching the seasons, weather and climate topic (e.g., their teaching methods, activities used in lessons). Each teacher's PCK post-interview questions were shown separately in Appendix D for Burak, Appendix E for Beyza and Appendix F for Esra.

PCK post-interviews were applied to each participant about three weeks after completing their classroom practice related to the seasons, weather, and climate topic. All interviews were tape-recorded with receiving permission from participants. Participants had limited time to conduct PCK post-interviews and therefore, post-interviews were applied in the public schools where they currently worked, and at appropriate times determined by participants. Each post-interview lasted about 10-15 minutes. The researcher behaved to the participants in a polite and respectful way while asking the inconsistent points between PCK pre-interview and their teaching practices.

3.4.1.3 Syntactic Knowledge Interview: Embedded Views of Nature of Science Questionnaire

According to Abd-El-Khalick and BouJaoude (1997), the nature of science understanding alludes to syntactic knowledge. Similarly, in this study, the nature of science understanding represents the syntactic knowledge. Lederman, Abd-El-Khalick, Bell and Schwartz (2002) devised VNOS-C questionnaire and then, Doğan, Çakıroğlu, Çavuş, Bilican and Arslan (2011) translated and adapted VNOS-C questionnaire to Turkish version. As a conclusion, revised version of VNOS-C questionnaire (See Appendix G) was applied with the aim of revealing participants' understanding related to nature of science, and necessary permission was received to use VNOS-C questionnaire (Appendix H). In this questionnaire, there were thirteen open-ended questions corresponding to NOS tenets including tentative NOS, subjective NOS, socio cultural NOS, creative and imaginative NOS, inferential NOS, empirically based nature of scientific knowledge and the nature of theory and law. Furthermore, in addition to the questions in VNOS-C questionnaire, several questions were prepared by the researcher in the context of the weather and climate and asking these questions, the teachers' opinions about the NOS aspects were strived to be obtained. The examples of these context-specific questions were "*How do meteorologists predict weather events?", "Do you think the weather forecast made by meteorologist is accurate?", "How do climatologists collect data?".*

In this study, VNOS-C questionnaire was implemented embedded with substantive knowledge interview. Stated differently, the questions in VNOS-C questionnaire were placed next to related questions in substantive knowledge interview, enabling participants to explain their ideas about nature of science in an easy way. For example, after asking *"What is the greenhouse effect?"* in substantive knowledge interview, the related question in VNOS-C questionnaire *"Is greenhouse effect a scientific law or a scientific theory?"* was asked. VNOS-C questionnaire was applied to each participant about two weeks before their teaching of the seasons, weather, and climate topic. Interviews for each participant lasted almost forty-five minutes and all interviews were tape-recorded with getting permission from participants.

3.4.1.4 Substantive Knowledge Interview

Substantive knowledge interview was implemented to the participants with the purpose of getting information about their understandings on the seasons, weather, and climate. In substantive knowledge interview, the questions related to the seasons, weather, and climate were prepared by the researcher depending on science textbook approved by MoNE and related objectives stated in MoNE 2018. However, several questions were prepared beyond the curriculum knowledge because the fact that the knowledge that teacher needs to have been beyond the understanding of subject matter is prevalent admittance (Wheeldon, 2017). The questions in substantive knowledge interview covers the concepts included in the seasons, weather, and climate: climate change, global warming and greenhouse effect.

Overall, forty-eight open-ended questions (Appendix İ) were prepared by researcher to reveal participants' understanding with regard to the seasons, weather, and climate topic. Since the scope of seasons topic is narrow in the curriculum, few questions were prepared and asked in the interview. Within the scope of substantive knowledge interview, Word Association Test (WAT) and constructing concept maps were also used to reveal participants' substantive knowledge related to the weather and climate. In WAT, participants were desired to write twelve words regarding weather and climate concepts. Then, they were requested to construct their concept maps using these words. Five questions were asked to find out whether they perceive the climate as a system, address the components and the process within this system. Furthermore, another aim of this study is to explore teachers' understandings of dual perspective. For this reason, five questions in substantive knowledge interview were aimed to assess participants' understandings of dual perspective. The examples of the questions regarding dual perspective were "*Do you think that is there anything to do to mitigate and combat with the effects of climate change and global warming?", "According to you, what are the duties and responsibilities of individuals in preventing climate change?".*

Substantive knowledge interview was implemented to each participant about two weeks before their teaching practices regarding the seasons, weather, and climate topic. Interviews for each participant lasted almost one or one half an hour. Each interview was tape-recorded with getting permission from participants.

3.4.2 Classroom Observation

The firsthand and direct observation in the program is substantial source of qualitative evaluation data (Patton, 1987). For all qualitative inquiry, the critical and main method is described as observation and in natural social environments, observation is performed with the aim of exploring the complex interactions (Marshall, & Rossman, 1995). Patton (2002) also stated that "Observations take place in real-world settings" (p.39). The one example that is frequently used in educational field is classroom observational studies (Marshall, & Rossman, 1995). Considering these explanations, all participants' classroom practices were observed by researcher in real classroom settings until the seasons, weather, and climate topic was completed. The researcher is able to comprehend behaviors as well as the meanings related to that behaviors with doing observations (Marshall, & Rossman, 1995). The points that were not emerge during the interviews are recognized through observations performing usually together with interviews (Çaylak, 2017). That is, the researcher had the opportunity to check the consistency of the teachers' responses in the PCK pre-interview through classroom observation. For instance, researcher observed that although Esra said that she will perform model building activity to show the revolution of Earth around the sun in her PCK pre-interview, she did not perform this activity in her teaching practice. Then, the researcher asked this inconsistent point to the participant with the reasons in the PCK post-interview. Thus, PCK studies supported by observations are able to present rich and accurate information about teachers' PCK.

There are four types of position of observer in the classroom observation based on Merriam and Tisdell (2016) explanation: observer as participant, complete participant, complete observer and participant as observer. Among these types of observers' stances, researcher's stance is defined as complete observer within this study. In other words, the researcher did not interfere with any events or individuals during the classroom observation. The researcher sat in the back desks in the classroom - sometimes sitting in the front desks when there was no seat – and she observed the lessons carefully and quietly without disturbing anyone's attention toward the lesson.

Throughout this study, researcher observed each teacher's teaching of the seasons, weather, and climate topic in their classroom environment for 34 hours (1360 minutes) and the duration of each lesson is 40 minutes. All the classroom observations lasted almost two and a half weeks. Burak's (Case 1) teachings were observed for 12 hours (480 minutes), Beyza's (Case 2) teachings were observed for 10 hours (400 minutes), and Esra's (Case 3) teachings were observed for 12 hours

(480 minutes). The researcher tried to adjust her own program according to the teachers' schedule. In the social environment, taking notes in systematic way and recording of behaviors, artifacts and phenomenon are required for observation in the study selected to be explored (Marshall, & Rossman, 1995). That's why, researcher tried to take detailed notes of teachers' behaviors, the way of teaching of the seasons, weather, and climate, the students' behaviors, the teacher-student interactions and many other things during their classroom practices so far as she can. However, a checklist was not prepared for PCK by the researcher in attempt not to miss any events happened during classroom observation (Şen, 2014).

Since the permission for the recording of lessons were not obtained, teachers' teaching practices were not tape recorded and video recorded. For this reason, some data may have losses occurred in the classroom observation. However, the researcher carefully observed each class and gathered several materials used during the teaching of the unit after receiving permission from teachers and students, (i.e., taking photos of the teachers' a) drawings, b) writings on the blackboard, c) posters made by the students and class boards). In addition, after each teacher's teaching practice was over, the researcher wrote "memos" related to each classroom observation in order to recall the events occurred in the classroom and reduce the loss of classroom observation data.

3.4.3 Teacher Documents

Documents address to a great variety of physical, written, digital and visual materials that are related to the research (Merriam, 2009; Merriam, & Tisdell, 2016). According to Merriam (2009), there are several kinds of documents; visual documents, personal documents, public records, researcher-generated documents, popular culture documents and physical material/ artifacts.

In this study, visual documents, researcher-generated documents and personal documents were collected as data from participants and used for understanding teachers' PCK, SMK, and dual perspective in detail. Following part, these documents that were gathered in this study were explained in detail.

3.4.3.1 Personal Documents

Related to beliefs, perspectives and attitudes of individual's, the credible data sources are personal documents (Merriam, 2009). In this study, several personal documents were obtained from teachers. For example, Burak performed written exam including eight open-ended questions and the researcher noted these questions in their notebook to use this as teacher's personal data in her study. Another example is that various worksheets regarding the seasons, weather, and climate prepared by Esra were collected by the researcher with receiving her permission. Furthermore, Esra and Beyza used different textbooks published by different publishers to distribute tests questions to the students. The researcher collected these tests questions with receiving permissions from teachers.

3.4.3.2 Visual Documents

Visual documents contain web-based media, film, photography and video (Merriam, & Tisdell, 2016). In this study, various visual documents were obtained. For example, the researcher took photos of teachers' drawing figures (e.g., Earth's revolution around the sun), explanations written on the blackboard and posters prepared by the students within the classroom observation time after giving permission from teachers. Moreover, educational websites (i.e., EBA-Educational Information Network) and educational videos (i.e., seasons) used by teachers in their teaching practices were collected as data. Researcher received the link address of the videos from teacher with receiving permission and researcher examined the content of the videos in detail.

3.4.3.3 Researcher-Generated Documents

Researcher-generated documents refer to the documents which were prepared by participating teachers or by the researcher following the onset of the research (Merriam, 2009). For generating documents, getting more knowledge relevant to the phenomena, case or individual to be examined is defined as special aim (Merriam, 2009). In this study, researcher-generated documents were teachers' Word Association Test and their concept maps related to the weather and climate. In Word Association Test, teachers wrote twelve words related to the weather and climate and then, constructed concept maps related to the weather and climate using those words. Teachers' words written in Word Association Test and constructing concept maps prepared in Turkish were translated into English by the researcher without making any changes. The original versions of Burak, Beyza and Esra's Word Association Test and concept maps were presented respectively in Appendices section (see Appendix J, K and L).

3.5 Pilot Study

Conducting a pilot study is final stage of the collect data (Yin, 1994). Therefore, the researcher preferred to conduct a pilot study to understand whether there were any problems with the interview questions before conducting this study. PCK pre-interview, substantive knowledge interview, and VNOS-C questionnaire were applied to two in-service science teachers working in private school prior to conduct this study. Each interview was held at the time and place where the participants were available, and each interview lasted about two and a half hours for each participant. As a result of pilot study, researcher had an idea of what to pay attention to while interviewing, how to ask interview questions more understandable and in what order to apply the interviews to the participants. Overall, the pilot study provided an important experience for the researcher and therefore, enabled researcher to conduct more informative interviews with participants and obtain more comprehensive data.

After the pilot study, the researcher made some adjustments and changes in some questions and the order of the questions found in the substantive knowledge interview. In addition, all interview questions were checked by a science education expert, and she gave feedback on the improvement of the interview questions. After the conducting pilot study and receiving feedback from the expert, necessary adjustments were made in the interview questions and then, they were brought to final version for main implementation. As a result of the pilot study, the researcher decided to collect data regarding substantive knowledge interview and syntactic knowledge followed by PCK interviews (i.e., PCK pre-interview). In the following section, data analysis of this study was presented in detail.

3.6 Data Analysis

The process which covers organizing, structuring and making meaning into the mass of gathered data is defined as data analysis (Marshall, & Rossman, 1995). In this section, the data analysis of this study was explained under three main titles orderly. At first, subject matter knowledge analysis which includes substantive knowledge and syntactic knowledge analysis was presented. Secondly, PCK analysis was presented for all five components separately: orientation toward science teaching, knowledge of curriculum, knowledge of students' understanding, knowledge of instructional strategies and knowledge of assessment. Thirdly, dual perspective analysis was presented.

3.6.1 Subject Matter Knowledge Analysis

Throughout this section, analysis of substantive knowledge was presented at first and following, analysis of syntactic knowledge was presented in detail.

3.6.1.1 Substantive Knowledge Analysis

Participants' knowledge with respect to the seasons, weather, and climate corresponds the substantive knowledge for this study.

Substantive knowledge interview including forty-eight open-ended questions were applied to emerge participants' understanding of the seasons, weather, and climate. In the results section, responses of the participants were reported under three separate main categories: seasons, weather, and climate. The rubric including scientific explanations of the seasons, weather, climate and related concepts (i.e., greenhouse effect, climate change, global warming) was prepared based on related literature by researcher with the aim of assessing participants' responses to the questions. The rubric including scientific explanations of seasons, weather, climate and related concepts prepared by the researcher was presented in Appendix M. As a part of substantive knowledge, science teachers' system understanding in the context of climate was investigated (Appendix M), and evaluated by depending on the categorization used by Shepardson et al. (2014) (See Table 4.6 for Burak, Table 4.33 for Beyza and Table 4.60 for Esra in Substantive Knowledge section).

In substantive knowledge interview, word association test (WAT) and constructing concept maps were also used to reveal participants' content knowledge related to the weather and climate. WAT method was used by several researchers (e.g., Assaraf, & Orion, 2005; Assaraf, & Orion, 2010; Aydın, & Taşar, 2010; Bahar, Johnstone, & Sutcliffe, 1999; Daskolia, Flogaitis, & Papageorgiou, 2006). WAT is used with the aim of exploring cognitive structure (Aydın, & Taşar, 2010) and individual's conceptual understanding related to specific content (Daskolia, Flogaitis, & Papageorgiou, 2006). In this study, participants were requested to write twelve words which come to their mind related to the weather and climate separately in WAT. Participants words were categorized under two main titles as weather and climate.

In this study, it was tried to understand how teachers relate the concepts they wrote in the WAT, and therefore, participants were requested to construct a concept map with using those words they wrote in their WAT. The representation which is two-dimensional, node-link and hierarchical describing the major concepts and associations in the structure of knowledge is called concept map (Martin, Mintzes, & Clavijo, 2000). Concept map method was used several researchers (e.g., Abd-El-Khalick, & Boujaoude, 1997; Assaraf, & Orion, 2005; Hsu, 2008; Mthethwa-Kunene et al., 2015). In this study, concept maps drawn by participants were analyzed based on Kinchin, Hay and Adams's (2000) qualitative classification of concept maps including three structures which are spoke, chain and net. Kinchin et al.'s (2000) explanation for analysis of concept map was shown in Appendix N.

3.6.1.2 Syntactic Knowledge Analysis

Syntactic knowledge implies to NOS understanding based on Abd-El-Khalick and BouJaoude (1997) and similarly, nature of science knowledge represents the syntactic knowledge in this study.

With the help of applying VNOS-C questionnaire, participants' NOS understandings were revealed. The NOS aspects and descriptions rubric constituted by Lederman, Schwartz, Abd-El-Khalick and Bell (2001) includes the scientific explanation for "informed NOS view" for each aspect of NOS. This rubric was used to assess whether the participants had informed views related to NOS aspects. The NOS aspects and descriptions rubric was presented in Appendix O. In the following section, PCK analysis was presented.

3.6.2 PCK Analysis

In this study, Magnusson et al. (1999) model of PCK was used as a framework. For this reason, all teachers' PCK were analyzed based on the five components of PCK model; orientation toward science teaching, knowledge of curriculum, knowledge of students' understanding, knowledge of instructional strategies and knowledge of assessment. In this section, data analysis for each component were explained in detail separately. Table 3.3 presented all five components of PCK with their sub-components.

Table 3.3 *PCK components and their subcomponents (Adapted from Yılmaz Yendi (2019))*

PCK components	**Their Subcomponents**
Orientation toward Science Teaching	Peripheral Goals Central Goals
Knowledge of Curriculum	Knowledge of Goals and Objectives Knowledge of Materials
Knowledge of Students' Understanding	Knowledge of Areas of Students' Difficulties Knowledge of Requirements for Learning

Knowledge of Instructional Strategies	Knowledge of Subject-Specific Strategies
	Knowledge of Topic-Specific Strategies
	    Knowledge of Representations
	    Knowledge of Activities

Knowledge of Assessment	Knowledge of Methods of Assessment Knowledge of Dimensions of Science Learning to Assess

3.6.2.1 Orientation Toward Science Teaching

For teaching science, beliefs and knowledge of teachers related to the goals and purposes in specific grade level are described as orientation toward science teaching (Magnusson, Krajcik, & Borko, 1999). Regarding making decision about enacting, reflecting and planning for teaching, orientation toward science teaching has central role (Magnusson et al.,1999) and it is both affected by other components of PCK and affects these components (Friedrichsen, & Dana, 2005). What the teachers teach, the way of their teaching and performing assessment is directly affected by orientation (Demirdöğen, 2016). Nine different orientations were described by Magnusson et al. (1999): discovery, didactic, guided inquiry, process, activity-driven, project-based science, conceptual change, inquiry and academic rigor. Because beliefs have a complex nature and are not sufficient to attribute a single orientation to a teacher, researchers have opposed the view that it is beneficial to use these categories of nine orientations (Avraamidou, 2013). According to Friedrichsen and Dana (2005), orientation toward science teaching component in Magnusson et al. (1999) PCK model have deficiency in terms of empirical and theoretical. In light with these explanations, Friedrichsen and Dana (2005) developed a substantive-level theory of science teaching orientations and in this theory, teachers' beliefs about the purposes and goals of science teaching could constitute the science teaching orientation. Therefore, under the orientation toward science teaching title, teachers' beliefs about goals of science teaching were examined in this study.

PCK pre-interview and classroom observation were used as data source for gathering data regarding teachers' beliefs about goals of science teaching. In the PCK pre-interview, there were questions to reveal teachers' beliefs about goals of science teaching such as *"What does "science teaching" mean to you?"*, *"In your opinion, what are the goals of science teaching?"*. After performing PCK pre-interview, all teachers' teachings related to the seasons, weather, and climate topic were observed to reveal their knowledge of beliefs about goals of science teaching.

Friedrichsen and Dana (2005) defined the participants' science teaching orientations as complex. The results of Friedrichsen and Dana's (2005) study showed that by using peripheral and central components, the representation of science teaching orientations in the form of complex entities is better. Based on these explanations, as also in Şen's (2014) and Tıraş's (2019) studies, teachers' beliefs about goals of science teaching were specified by using the central and peripheral goals in this study.

- The goals which tended to manage the decision-making process in instruction and prevailing the ideas of teachers were described as central goals (Friedrichsen, & Dana, 2005).

- As compared to the central goals, peripheral goals hold less influence on teaching practice of teachers (Şen, 2014).

Furthermore, affective domain goals, subject matter goals and general schooling goals were contained as three main kinds of goals in participants' nature of science teaching orientations. (Friedrichsen, & Dana, 2005). For this reason, in this study, affective domain, subject matter and general schooling goals were used to decide teachers' beliefs about goals of science teaching. The explanations of these goals were as follows:

- Subject matter goals refer to convey the content knowledge (Friedrichsen, & Dana, 2005).
- General schooling goals refer to prepare students to general life skills (e.g., written communication skills, critical thinking skills), their lives in future and college (Friedrichsen, & Dana, 2005).
- Affective domain goals refer to develop self-confidence, curiosity and attitude toward science (Friedrichsen, & Dana, 2005).

3.6.2.2 Knowledge of Curriculum

Based on Magnusson et al. (1999), the knowledge of specific curricular programs and materials and the knowledge of mandated goals and objectives are two dimensions of knowledge of curriculum component in PCK.

First, in this study, the data related to teachers' knowledge of goals and objectives were gathered through PCK pre-interview and classroom observation. In the PCK pre-interview, there were questions to reveal teachers' knowledge of goals and objectives such as *"What are the objectives with respect to seasons, weather, and climate found in curriculum?"*, *"What do you intend the students to learn about the seasons, weather, and climate unit?"*. All teachers' teaching practices were examined to obtain data related to their knowledge regarding goals and objectives.

Second, the data related to teachers' knowledge of materials were gathered through PCK pre-interview, classroom observation and PCK post-interview. *"What are the sources that you use in the seasons, weather, and climate topic?"* and *"For what purpose do you use all resources?"* are the questions to assess the teachers' knowledge of materials. All teachers' teaching practices were examined to find out the materials (e.g., textbook, hands-on materials) teachers used in their teaching of the seasons, weather, and climate topic. Lastly, PCK post-interview was applied to teachers to resolve the discrepancy between PCK pre-interview and classroom observation. For assessing teachers' knowledge of curriculum, the codes related to knowledge of goals and objectives and knowledge of materials were constituted considering related literature. Table 3.4 presented the codes for knowledge of goals and objectives and knowledge of materials.

Table 3.4 *Codes for Knowledge of Goals and Objectives and Knowledge of Materials*

Codes for Knowledge of Goals and Objectives	**Sources**
Seasons objectives	Sneider, Bar, & Kavanagh (2011)
Weather and climate objectives	Teed, & Franco (2014)
Vertical Curriculum	Magnusson et al. (1999) Shulman (1986)
Horizontal Curriculum	Lewis, & Wood-Robinson (2000)
Sorting the objectives based on importance	Cohen, & Yarden (2009)
Limitations in science curriculum	Aydemir (2014)
Codes for Knowledge of Materials	**Sources**
Sources that teacher use	Cohen, & Yarden (2009)
Aim of using source	Lane (2009)

3.6.2.3 Knowledge of Students' Understanding of Science

Knowledge of students' understanding of science has two dimensions which are knowledge of areas of student difficulty and knowledge of requirements for learning (Magnusson et al., 1999). Teachers' knowledge regarding topics or concepts in science that students have difficulty in learning is defined as knowledge of areas of student difficulty (Magnusson et al., 1999). Teachers' beliefs and knowledge regarding prerequisite knowledge in order to learn specific scientific knowledge is defined as knowledge of requirements for learning (Magnusson et al., 1999).

In the light of these explanations, teachers' knowledge of students' understanding of science regarding the seasons, weather, and climate were analyzed in terms of knowledge of requirements for learning and knowledge of areas of student difficulty within the scope of this study. At first, teachers' knowledge of requirements for learning specific to the seasons, weather, and climate was examined with PCK pre-interview question such as *"What kind of prerequisite knowledge and skills do you think students need to learn the seasons, weather, and climate topic successfully?"*. Secondly, teachers' knowledge of areas of student difficulty specific to the seasons, weather, and climate was examined through several questions such as *"Can you tell me about which difficulties do students have while learning the seasons, weather, and climate topic?"*, *"Do your students have misconceptions about the seasons, weather, and climate?"*. Then, teachers' teaching practices regarding the seasons, weather, and climate were examined to obtain information about their knowledge of students' difficulty and misconceptions. Overall, science teachers' knowledge of students' understanding was investigated depending on PCK subcomponents and related literature on the seasons, weather and climate topic. For example, previous literature reported that to comprehend the concept of seasons, students should learn the connection between sun and Earth such as rotation of the Earth on its' axis, revolution of the Earth around the sun, the Earth's orbit shape (Salierno, Edelson, & Sherin, 2005; Sneider, Bar, & Kavanagh, 2011). Table 3.5 shows the examples of students' difficulties and their sources reported in the literature, and Table 3.6 shows the examples of students' misconceptions, sources of their misconceptions, the way of revealing and eliminating their misconceptions reported in the literature in the context of the seasons, weather, and climate.

Table 3.5 *Students' Difficulties related to the Seasons, Weather, and Climate*

Dimensions	Examples	Sources
Students' Difficulties	Understanding one of the reasons of the seasons which is the Earth's tilted axis	(Sung, & Oh, 2018)
	Confounding the terms which are Earth's daily (i.e., Earth's rotation on its' axis) and annual motions (i.e., revolution of the Earth around the sun)	(Salierno et al., 2005)
	Confounding the terms which are climate and weather	(Cepni, 2014; Doğar, & Başıbüyük, 2005; Gowda et al., 1997; Lambert, Lindgren, & Bleicher, 2012; Papadimitriou, 2004)
	Understanding the concept of climate	(Yılar, 2007)
	Comprehending the concept of climate change	(Ratinen, Viiri, & Lehesvuori, 2013)
	Comprehending the concepts of ozone layer depletion and greenhouse effect	(Österlind, 2005)
Sources of Students' Difficulties	Deficiency of teachers' pedagogical acts in the classroom	(Sung, & Oh, 2018)
	The abstract nature of some concepts in geography	(Cepni, 2014)
	Rote learning	(Doğar, & Başıbüyük, 2005)
	The deficiency of teaching methods	(Yılar, 2007)
	Contained abstract concepts and processes in climate change science like wavelength, IR rays, chemical reactions, electromagnetic spectrum	(Papadimitriou, 2004; Ratinen et al., 2013)

Table 3.6 *Students' Misconceptions related to the Seasons, Weather, and Climate*

Dimensions	Example
Misconceptions	▪ The formation of the seasons is based on the distance of the Earth to the sun. (Tsai, & Chang, 2005) ▪ Alteration in the Earth's axis tilt leads to form seasons. (Tsai, & Chang, 2005) ▪ One of the primary reasons forming the global warming is depletion of ozone layer. (Rye, Rubba, & Wiesenmayer, 1997) ▪ Generally, air pollution and greenhouse gases such as carbon dioxide bring about the global warming. (Shepardson, Niyogi, Choi, & Charusombat, 2011) ▪ Establishing link between the global warming and depletion of ozone layer. (Daniel, Stanisstreet, & Boyes, 2004)
Sources of Misconceptions	▪ Mentioning about ozone layer depletion in the teaching (Rye, Rubba, & Wiesenmayer, 1997) ▪ The restricted time for teaching the climate change in the classrooms (Gowda, Fox, & Magelky, 1997) ▪ The possibility that the media can provide inaccurate information and (Gowda, Fox, & Magelky, 1997) ▪ Students' trust toward media (Gowda, Fox, & Magelky, 1997) ▪ Making generalization using limited evidence (Gowda, Fox, & Magelky, 1997)
Revealing the Misconceptions	▪ Open-response items (Gowda, Fox, & Magelky, 1997; Shepardson, Niyogi, Choi, & Charusombat, 2011) ▪ Draw-and-explain item (Shepardson, Niyogi, Choi, & Charusombat, 2011) ▪ Open-ended interviews (Rye, Rubba, & Wiesenmayer, 1997) ▪ Closed-form questionnaire (Daniel, Stanisstreet, & Boyes, 2004) ▪ Using metaphors and drawing pictures/cartoons (Cepni, 2014)
Elimination of Misconceptions	▪ Conflict map-guided instruction including critical event, discrepant event, discussions (Tsai, & Chang, 2005) ▪ Technologically enhanced learning environment including multimedia tools (Hsu, 2008) ▪ Students' peers and teachers' proper acts (e.g., asking physical questions) (Sung, & Oh, 2018)

3.6.2.4 Knowledge of Instructional Strategies

Knowledge of instructional strategies that is one of the PCK components has two dimensions which are knowledge of topic-specific strategies and knowledge of subject-specific strategies (Magnusson et al., 1999).

- Subject-specific strategies are particular for science teaching (Magnusson et al., 1999). Knowledge of teachers for subject-specific strategies is relevant to the orientation toward science teaching because it contains general approach for teaching science (Magnusson et al., 1999).
- Topic-specific strategies are implemented in the scope of specific science topics (Magnusson et al., 1999). Knowledge of topic-specific strategies has two dimensions as activities and representations (Magnusson et al., 1999). Models, illustrations, analogies or examples could be included in representations (Magnusson et al., 1999). Investigations, problems, simulations, experiments or demonstrations are examples for activities (Magnusson et al., 1999).

In the light of these explanations, in this study, teachers' knowledge of instructional strategies regarding the seasons, weather, and climate were analyzed in terms of knowledge of subject-specific and topic-specific strategies including representations and activities.

First, in this study, teachers' knowledge of subject-specific strategies specific to the seasons, weather, and climate was examined through PCK pre-interview, PCK post-interview and classroom observation. In PCK pre-interview, there were questions to assess teachers' knowledge of subject-specific strategies regarding the seasons, weather, and climate. For instance, *"Which methods do you use to teach the seasons, weather, and climate topic?"*. Teachers' teaching practices related to the seasons, weather, and climate were examined to understand which subject-specific strategies the teacher used in terms of student-centered teaching strategies (e.g., conceptual change approach, 5E learning cycle) and teacher-centered teaching strategies (e.g., questioning, direct instruction). Lastly, PCK post-interview was applied to teachers to resolve the discrepancy between PCK pre-interview and classroom observation. Secondly, teachers' knowledge of topic-specific strategies was examined in terms of knowledge of representations and activities through PCK pre-interview, PCK post-interview and classroom observation. In PCK pre-interview, there were questions to assess teachers' knowledge of representations and activities specific to the seasons, weather, and climate such as *"Do you use illustrations, examples, models, drawings, and analogies to assist students' learning in the seasons, weather, and climate topics and concepts?", "Do you conduct activities in the class regarding the seasons, weather, and climate?", "What kind of activities do you perform?*". Moreover, teachers' teaching practices regarding the seasons, weather, and climate were examined to understand whether the teachers used the representations and implemented activities related to these topics. Lastly, for both teachers' knowledge of representations and activities, PCK post-interview was applied to teachers to resolve discrepancy between PCK pre-interview and classroom observation. Overall, science teachers' knowledge of instructional strategies was investigated depending on PCK subcomponents and related literature. Table 3.7 shows the several examples of representations and activities regarding the seasons, weather and climate topic found in the literature.

Table 3.7 *The Examples for Knowledge of Representation and Activities*

Dimensions	Examples	Sources
Knowledge of Representation	Videos	Teacher benefited from short-video sequences to assist her teaching related to the difficult topics like greenhouse effect, weather formation process (Clausen, 2017).
	Hands-on materials (e.g., globes, table lamps)	In teacher's teaching, students within groups benefited from several hands-on materials like table lamps, color pens, drawing paper and globes to show their models about seasons (Sung, & Oh, 2018).
	Analogy	The teacher used analogies between the student's daily life and air pressure to express the relationship between air pressure and air temperature (Clausen, 2017).
	Simulation	To demonstrate the factors that affect the seasons like Earth's tilted axis, longitude, eccentricity, and latitude, a computer simulation was used (Hsu, 2008).
	Animation	To enable students to visualize scientific concepts related to the seasons, animations showing the factors that cause the formation of the seasons were used (Hsu, 2008).
Knowledge of Activities	Simulation Activity	Teacher used simulation activity regarding tropical cyclone phenomenon and assigned role to the students as a risk management team (Lane, 2009).
	Experiment	Using hands-on materials, students were requested to implement experiments to enable them to identify the factors that cause the formation of the seasons (Sung, & Oh, 2018).
	Role-playing activities	With the purpose of expressing the links between the earth and the sun, the teacher preferred to apply role-playing activities and benefit from balls with different dimensions (Tsai, & Chang, 2005).
	Modeling practices	For explaining their thoughts regarding the seasons, students created a physical model using hands-on materials like table lamps, globe (Sung, & Oh, 2018).
	Hands-on activity	In their lessons on the hydrologic cycle, the teachers carried out hands-on learning activities that include the importance of safe behaviors throughout phenomena such as floods and extreme rain, and show the water power (Stewart, Knox, & Schneider, 2018).

3.6.2.5 Knowledge of Assessment

Knowledge of assessment that is one of the PCK components has two dimensions as knowledge of methods of assessment and knowledge of dimensions of science learning to assess (Magnusson et al., 1999). Firstly, knowledge of dimensions of science learning to assess is related to the assessment of crucial point for students' learning with respect to a specific topic (Magnusson et al., 1999). In science, students' understandings should not be assessed in that only factual knowledge (Tsai, & Chang, 2005). The crucial dimensions of science learning to assess were described as scientific investigation, conceptual understanding, nature of science, practical reasoning and interdisciplinary themes (Champagne, 1989, as cited in Magnusson et al., 1999). In this study, it was examined whether science teachers assessed students' understanding in terms of knowledge on the seasons, weather and climate topic, NOS understanding, science process skills and knowledge of dual perspective. Secondly, knowledge of methods of assessment is related to how teachers assess the crucial points for students' learning within a specific topic (Magnusson et al., 1999). The summative and formative assessments were defined as two kinds of assessments methods to assess students (Earle, 2014). The assessment that summarizes a student's success position is called as summative assessment (Sadler, 1989) and it is performed at the end of the lesson (Sadler, 1989; Şen, 2014). Particularly for speeding up and improving of learning, it is aimed to receive feedback for performance in formative assessment (Sadler, 1998). For advancing and revealing students' understanding, formative assessments are performed in three times as the beginning, end and middle of the course (Şen, 2014).

In the light of these explanations, teachers' knowledge of assessment regarding the seasons, weather, and climate were analyzed in terms of these two dimensions within the scope of this study. PCK pre-interview, classroom observation, teacher documents (e.g., written exams) and PCK post-interview were used to collect data related to teachers' knowledge of assessment. In PCK pre-interview, there were questions to assess teachers' knowledge of dimensions of science learning to assess such as *“What do you want to assess in depth when you assess your students’ knowledge in terms of seasons, weather, and climate?”*. In PCK pre-interview, there were also questions to assess teachers’ knowledge of methods of assessment such as *“Which assessment techniques do you use to assess their understanding in seasons, weather, and climate topic?”*. Then, teachers’ teachings related to the seasons, weather, and climate were examined to understand what the teacher wants to assess the students’ understanding, which methods they use to assess students in the classroom and when they assess students' learning. Lastly, PCK post-interview was applied to teachers to resolve the discrepancy between PCK pre-interview and classroom observation. Overall, science teachers' knowledge of assessment was investigated depending on PCK subcomponents and related literature. Table 3.8 shows several examples for summative and formative assessments from related literature.

Table 3.8 *The Examples for Summative and Formative Assessments*

Assessment Types	**Examples**	**Sources**
Formative Assessment	▪ Concept maps ▪ Questioning (open-ended, closed) ▪ Short-answer questions ▪ KWL grids ▪ True/false quiz ▪ Discussion ▪ Drama/ Role play ▪ Concept cartoon ▪ Self-assessment ▪ Game ▪ Observation of task ▪ Presentation ▪ Written laboratory reports ▪ Peer assessment ▪ Poster ▪ Journal entries	(Akerson, 2005; Clausen, 2017; Earle, 2014; Kaya, 2009; Lucero, Petrosino, & Delgado, 2017; Magnusson et al., 1999; Sadler, 1998; Şen, Öztekin, & Demirdöğen, 2018)
Summative Assessment	▪ Essay type questions (written questions) ▪ Multiple-choice exam ▪ Matching ▪ True/false ▪ Gap-filling	(Clausen, 2017; Lewis, & Wood-Robinson, 2000; Lucero, Petrosino, & Delgado, 2017; Şen, Öztekin, & Demirdöğen, 2018; Uşak, 2009)

3.6.3 Dual Perspective Analysis

The one of the research questions of this study is *"To what extent is teachers' instruction reflect dual perspective in seasons, weather, and climate topic?"*. Teaching involving students to be action competent citizens and learning about theories, models and concepts is called dual perspective (Clausen, 2017). The mixture of students' visions, knowledge/insight, action experience and commitment are described as students' action competence (Jensen, & Schnack, 1997). As in Clausen's study (2017), from dual perspective, all science teachers' teachings of the seasons, weather, and climate topic were assessed in terms of students' action competence including their knowledge, commitment, visions and action experiences.

To reveal teachers' understandings of dual perspective, PCK pre-interview, classroom observation and substantive knowledge interview were used as data sources. The teachers' responses regarding the dual perspective questions in the substantive knowledge interview were analyzed to understand whether they mentioned about the actions taken to prevent the climate change and global warming. Some examples of these questions were "*Do you think that is there anything to do to mitigate and combat with the effects of climate change and global warming?", "According to you, what are the duties and responsibilities of individuals in preventing climate change?"*. In addition, it was examined whether teachers mentioned about the dual perspective as a goal in the PCK pre-interview. Then, teachers' teaching practices related to the seasons, weather, and climate were observed to understand whether the teachers mentioned about the knowledge, commitment, vision and action experience aspects of action competence. In the following section, trustworthiness of this research was presented.

3.7 Trustworthiness of This Research

Lincoln and Guba (1985) defined the main subject with respect to trustworthiness as "How can an inquirer persuade his or her audiences (including self) that the findings of an inquiry are worth paying attention to, worth taking account of?" (p.290). To represent the qualitative paradigm's assumptions more correctly (Marshall, & Rossman, 1995), Lincoln and Guba (1985) offered four the terms that are credibility, transferability, dependability and confirmability as alternative criteria for trustworthiness of the qualitative research. Throughout this section, how credibility, dependability and transferability were provided for this study were explained in detailed manner. Table 3.9 presents the alternative criteria and strategies were used to provide trustworthiness of this research.

Table 3.9 *Alternative criteria and strategies used to provide trustworthiness of this research*

Alternative Criteria (Lincoln, &, Guba, 1985)	**Strategies used in this study**
Credibility	▪ Triangulation (sources triangulation, methods of triangulation) ▪ Adequate engagement ▪ Peer review ▪ Member check ▪ Reflexivity (researcher's position)
Dependability	▪ Triangulation (sources triangulation, methods of triangulation) ▪ Peer review ▪ Inter-rater agreement
Transferability	▪ Maximum variation ▪ Rich, thick description

3.7.1 Credibility (Internal Validity)

Internal validity is synonymous with credibility. How findings of research overlaps with reality are the subject of internal validity or credibility (Merriam, 2009). Merriam (2009) suggested several strategies to provide the credibility of the research such as triangulation, member checks, negative or discrepant case analysis, reflexivity (researcher's position), adequate engagement, peer review. Through this section, five strategies which are triangulation, adequate engagement, peer review, member check and reflexivity were explained respectively.

The first strategy is triangulation that is defined as probably most well-known strategy in order to ensure the internal validity of a research (Merriam, 2009). According to Patton (2002), analyst triangulation, methods of triangulation, theory/perspective triangulation and triangulation of sources are defined as four kinds of triangulation strategies. In this study, sources triangulation and methods of triangulation were used enabling the credibility. First, methods of triangulation were provided in this study because several methods of data collections strategies including pre-post interviews, classroom observation and teacher documents (e.g., visual, personal) were used to explore the participants' PCK, SMK, and knowledge of dual perspective. In this way, participants' data obtained from many data sources were compared in terms of consistency. For example, the interview data were compared and contrasted with classroom observation data and teacher documents and then, in the post-interview, inconsistent points were asked to the participants. Second, sources triangulation was provided for this study. For example, each teacher's several classroom practices were observed at different times and then, these observation notes of each teacher were compared and contrasted among themselves to get more credible data from the data sources. Another example is that teachers were subjected to several interviews as pre-post and teachers' transcripts of these interviews were also compared and crosschecked among themselves as well. However, investigator triangulation was not provided because the researcher did not have a friend knowledgeable about PCK to analyze the findings of this study. Also, since this study is based only on the Magnusson et al. (1999) model of PCK and different theoretical perspectives were not preferred for interpreting the data, theory/perspective triangulation was not used.

Secondly, adequate engagement was provided in this study. Prior to implementation of this study, the researcher met the teachers attended in this study and then, briefly explained the purpose of this study. Thanks to this meeting, researcher had opportunity to learn teachers' background knowledge, their demographic information (e.g., teaching experiences), and their school environment. The fact that the participants got to know the researcher and got information about this study facilitated to apply this research and gather data from participants.

Thirdly, member check which is second widespread strategy to provide credibility (Merriam, 2009) was provided through PCK post-interview in this study. Member check is defined as respondent validation and it is to ask for feedback from the interviewed people about the data that emerges (Merriam, 2009). In this study, teachers' PCK pre-interview and classroom observation were examined to understand whether there is any discrepancy between them and then, the inconsistent points were asked to the participants in the PCK post-interview. The participants remembered their answers in the PCK pre-interview and what they did in the classroom observation through PCK post-interview and thus, the accuracy of the researcher's data regarding PCK pre-interview and classroom observation were checked.

Fourthly, peer review was provided in this study. Researcher’s advisor who is expert in science education and PCK field examined the collected data of this study. She gave feedback related to English translation of the participants’ transcripts and thus, no loss of meaning and data was provided when translating data from Turkish to English. She also examined researcher’s data analysis and then, gave feedback on the points to be revised in the data analysis.

In the last one is that for qualitative research, the instrument is the researcher (Marshall, & Rossman, 1995; Patton, 2002) and researcher’s credibility that is influenced by their experience, status and training (Patton, 2002). Therefore, the researcher also tried to increase her credibility for this study prior to conduct this study. Firstly, the researcher carried out a case study that is one of the qualitative studies within the scope of “independent study” course she took the previous year in master program. By this way, the researcher had the opportunity to have information about how the qualitative research should be conducted and how the qualitative data should be analyzed. In this research, she collected data through interview from three participants, and thus, the researcher had opportunity to make practice regarding interviews. Secondly, researcher conducted several pilot studies prior to implementation of this study, which enabled her to learn information about which points to pay attention to while interviewing. Thirdly, researcher examined several articles conducted with qualitative methods and qualitative research books in order to get more detail information about nature of qualitative studies. Consequently, she broadened her horizon related to the nature of qualitative research and how to ensure the credibility of the data through taking lessons, conducting pilot studies and reading related resources.

3.7.2 Dependability (Reliability-Consistency)

Dependability is synonymous with reliability and consistency. According to Merriam (2009), "Reliability refers to the extent to which research findings can be replicated." (p.220). However, it is not possible to replicate the qualitative study because there are human factors in qualitative studies and the same findings cannot be obtained by repeating a qualitative study. In the field of social science, the issue of reliability is problematical due to dynamic nature of human behavior (Merriam, 2009). Therefore, in qualitative studies, the question of whether the gathered data is compatible with findings of the study is a more crucial (Merriam, 2009). Stated differently, the necessary point is that the researcher should pay attention to while doing qualitative study is that the collected data and the findings are consistent with each other, which refer to dependability.

In qualitative research, the researchers cannot provide the reliability of their research by one hundred percent but may implement some strategies to increase the reliability of their research. Merriam (2009) proposed several strategies for qualitative researcher to provide dependability and consistency and these strategies are investigator's position, triangulation, the audit trail and peer examination. In the scope of this study, triangulation and peer review were provided, and these were explained deeply in credibility section. In addition to these strategies, inter-rater agreement was provided to ensure the dependability of this research. An expert on PCK field and science education, at the same time researcher's advisor, examined the interview questions related to PCK and substantive knowledge and then, gave feedback on the places to be corrected in the interview questions. As a result, the inter-rater agreement on substantive knowledge interview was provided by 90 percent, and on PCK pre-interview was provided by 95 percent.

3.7.3 Transferability (External Validity)

The external validity refers to transferability. The application of the findings of research to another circumstance is the subject of external validity (Merriam, 2009). Two strategies were offered by Merriam (2009) for increasing the transferability of the study; maximum variation and rich, thick description and these strategies were explained in detail.

First, rich, thick description was provided in this study. Everything that might be necessary for the reader to know for comprehending the findings have to be included in the description (Lincoln, & Guba, 1985). In other words, the researchers should explain their studies (e.g., data collection tools) and the participants in detail that can be understood by readers to make transferability. In this study, researcher tried to explain the participants' background knowledge, demographic information (e.g., gender, teaching experience, age), the types of school where this study was conducted (e.g., public or private), school environments where participants worked currently and the schools' physical opportunities (e.g., having smart board) in a detailed manner as much as she can. Moreover, researcher deeply explained the data collection methods, all instruments and the data analysis of this study. Through thick and rich description of this study, readers can notice the similar points between this study and their studies and make inferences about their studies.

Second, maximum variation also was provided in this study. The readers' ability of application increases on a large scale through the sample with maximum variation (Merriam, & Tisdell, 2016). In this study, researcher worked with three different in-service science teachers from two different public-school contexts in different districts. Participant teachers' characteristics, background knowledge, teaching experiences, SMK and PCK were different from each other. Thereby, each teacher represents a different case, enhancing the variation of this study.

3.8 Ethical Considerations

According to Fraenkel, Wallen and Hyun (2012), researchers need to pay attention to three ethical issues while conducting study. These ethical issues were explained detailly in this section.

1. Primarily, researcher should protect participants toward dangers derived from the process of the research. Therefore, at first,
    a. ethical permission was received from METU Human Subjects Ethics Committee (Appendix P). This permission showed that there are no potential risks, dangers or factors that would disturb the participants in this study.
    b. another necessary permission required for conducting this study in two public schools was received from Ministry of National Education (Appendix Q).
2. The second ethical issue to be paid attention is that providing the confidentiality of data in study. In the light of this information, the real names of the participants were not indicated during this study. Instead, participants were given pseudonyms that were used within the scope of this study. The name of the two public schools where this study was carried out was known only by the researcher. The real names of these schools were kept confidential and were not indicated throughout the study. In addition, all findings of this study were not shared with anyone to provide the confidentiality of data except from the researcher's advisor.
3. The third ethical issue is defined as deception of subject. Prior to conducting this study, researcher arranged a meeting with the participants when they were available. In this meeting, she briefly explained the purpose of this research to the participants. Participants also were informed about the interviews and classroom observations to be applied within the scope of this study without giving much detail about the content. Furthermore, researcher especially specified that participants have the right to withdraw from this

study at any time. By this way, researcher prevented the deception in this study.

3.9 Limitations of the Study

This study has some limitations and these limitations were explained in detail throughout this section.

- The generalizability of this study is one of the limitations for this study. Transferability of this study was tried to be enhanced by providing maximum variation and rich, thick description. Readers or researchers studying in PCK field can find similar sides with their own studies and benefit from this study. But since this study was conducted only in the public schools, the data of this study cannot be generalized to private schools. In addition, the data of this study cannot be generalized to in-service teachers in other disciplines (e.g., mathematics teachers, social science teachers) because this study was conducted with only in-service science teachers. However, this study was conducted with in-service teachers who graduated from both the faculty of education and art and science faculty and therefore, the data of this study may be generalized for the in-service science teachers who graduated from these faculties.
- The presence of the researcher as an observer in the classroom may cause the teachers and students to limit their behaviors. Prior to conducting this study, researcher briefly explained the aim of this study to the participants was to learn their ideas and observe their lessons related to the seasons, weather, and climate topic. At the beginning of the classroom observation, each teacher told their students that the researcher would be guest for a while in their classrooms. Thus, it was tried to ensure that teachers and students to behave natural in the classroom.
- All teachers' teaching practices were not either video-recorded or tape-recorded because the public-school managements did not allow for recording

of the lesson due to the confidentiality and safety reasons. In order to reduce the data loss related to this study, the researcher tried to take observation notes during the lesson as much as she can and used several data sources to gather data from participants (e.g., interviews, teacher documents). However, she missed some points in the classroom observation due to the lack of any record regarding the lesson.

3.10 Assumptions of the Study

Several assumptions have been made by the researcher within the scope of this qualitative study. These assumptions were as follows:

1. Because the teachers are experienced, they have sufficient level of SMK and PCK about the seasons, weather, and climate topic.
2. Throughout the interviews, all teachers expressed their opinions clearly.
3. Doing classroom observation did not affect teachers' teachings.

CHAPTER 4

RESULTS

In this section, findings related to participants' subject matter knowledge (SMK) and pedagogical content knowledge (PCK) regarding the seasons, weather, and climate from the dual perspective were reported. In the first case, findings related to Burak's SMK, including substantive and syntactic, PCK and knowledge on dual perspective were represented (case 1). Then, Beyza's (case 2) and Esra's (case 3) findings were reported.

4.1 CASE 1: Burak's Subject Matter Knowledge and Pedagogical Content Knowledge Regarding the Seasons, Weather, and Climate: from the Dual Perspective

4.1.1 Burak's Background Knowledge and His Classroom Environment

Burak is a thirty-three years old male teacher. He was graduated from science education program of faculty of education in one of the universities in Turkey. Overall, he has ten years teaching experience and has been working for seven years in the public school where current study was conducted. In the year of data collection [2018], he was teaching science to 7th and 8th grade students. Classroom environment included smart board and three blackboards. The desks were arranged in rows. There were almost thirty students in his classroom. Although attended an in-service training program on occupational safety and health, he did not participate any in-service training related to the seasons, weather, and climate topic. Nevertheless, he indicated his interested in these topics.

4.1.2 Burak's Subject Matter Knowledge Regarding the Seasons, Weather, and Climate

Burak's SMK was reported under two subtitles which are substantive knowledge and syntactic knowledge. First, findings regarding Burak's substantive knowledge, which were collected through interview, classroom observation and teacher documents, were reported separately for seasons, weather, and climate respectively. Second, findings regarding Burak's syntactic knowledge, which were collected through interview and classroom observation, were reported.

4.1.2.1 Burak's Substantive Knowledge Regarding the Seasons, Weather, and Climate

4.1.2.1.1 Burak's Substantive Knowledge Regarding Seasons

Burak was asked several questions to reveal his knowledge regarding seasons concept:

> Researcher: How can you define seasons?
>
> Burak: Hmmm… We can say that they [seasons] are the time period that contains all of the weather events that are formed by the revolving of Earth around the Sun. The features of seasons are not constant yet changeable within the periods (eras) since the formation of the Earth.
>
> Researcher: Well, can you tell more about how seasons form?
>
> Burak: How are seasons formed? According to the science textbook, we can associate the formation of the seasons with two factors. The first and the most fundamental one [factor] is the revolution of Earth around the Sun. The second factor is the Earth's tilted axis. …. sunlight striking Earth at a different angle… Earth's revolution around the Sun and [Earth's] tilted axis are the main factors cause the seasons. But there may be other factors of course…

> perhaps, not directly, but indirectly affects seasons. Sunlight carries heat... deserts and poles, for example, desert absorbs [the sunlight] and poles reflect [the sunlight]. This absorption rate affects temperature and indirectly affects the seasons. In addition to Earth's revolution around the Sun and [Earth's] tilted axis, we can say that the absorption is an indirect factor [for the formation of seasons].

During the teaching of the seasons, consistent with interview, he mentioned about the causes of seasons as well as also, as a part of the science curriculum, the formation of day and night by saying that;

> The Earth rotates on its' axis. As a result of this movement, the day and night form. The Earth completes this movement in 24 hours. A 24-hour period is called 1 day. The Earth also orbits the Sun. As a result of this rotational movement, the seasons form. Another factor affecting the formation of the seasons is the Earth's tilted axis. The [Earth's] tilted axis allows the sun's rays strike Earth at different angles. The Earth rotates with an angle of 23° 27′ on its' rotational axis.
>
> [Classroom Observation]

Burak also drew figure related to the formation of seasons on the blackboard (See Figure 4.1). In the figure, he showed the solstices dates as December 21 (winter solstice), June 21 (summer solstice) and equinoxes dates [March 21 (spring equinox), and September 23 (autumnal equinox)] as well as the longest day- shortest night (i.e., June 21) and shortest day-longest night (December 21). Further, he specified the seasons that experienced on solstices and equinoxes dates in each Hemisphere on the figure and identified the Tropic of Capricorn and Tropic of Cancer (Burak's Original drawing was depicted in Appendix R).

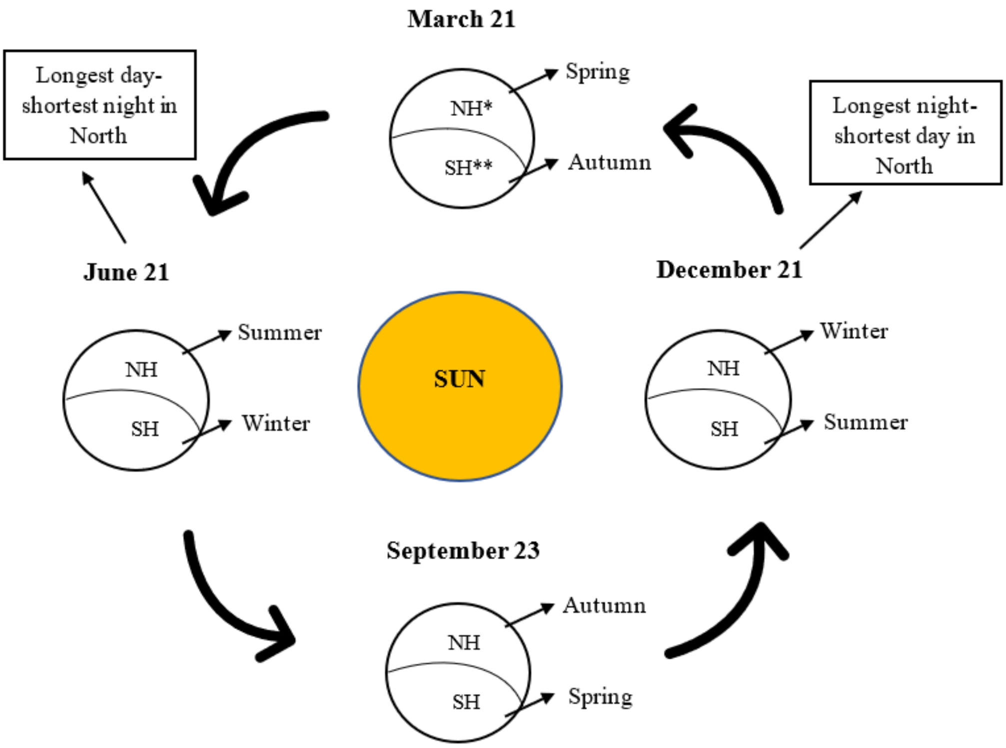


Figure 4.1 Burak's Drawing a Model Regarding the Formation of Seasons

[NH*: Northern Hemisphere, SH**: Southern Hemisphere]

After drawing figure 4.1, he touched on the concept of the Tropic of Cancer and Tropic of Capricorn as a part of the science curriculum saying that;

> Burak: There are two special latitudes on the Earth. One of them is the Tropic of Cancer located in the Northern Hemisphere, while the other is the Tropic of Capricorn located in the Southern Hemisphere. On June 21, summer begins in the Northern Hemisphere because the sun's rays strike as perpendicular to the Tropic of Cancer. On December 21, summer begins in the Southern Hemisphere because the sun's rays strike as perpendicular to the Tropic of Capricorn.

[Classroom Observation]

Overall, Burak correctly indicated the causes of the formation of seasons by expressing two main factors which are Earth's revolution around the Sun and Earth's tilted axis. Depending on the curriculum, he expressed the Earth's tilted axis as 23° 27′. Besides that, he correctly mentioned about the absorption event affecting indirectly the formation of the seasons and explained that the temperatures will be different because while deserts absorb the sunlight, poles reflect the sunlight. The classroom observation data also confirmed his awareness of the causes of the seasons and the topic such as solstices, equinoxes, the Tropic of Capricorn, the Tropic of Cancer, equator. Burak's knowledge regarding the seasons was shown in Table 4.1.

Table 4.1 *Burak's Knowledge Regarding the Seasons*

The Concepts	**Response**
The Seasons	He associated the causes of the seasons with three factors: a) The first and the most fundamental one [factor] is the revolution of Earth around the Sun. b) The second factor is the Earth's tilted axis. …..sunlight striking Earth at a different angle… c) Absorption rate affects temperature and indirectly affects the seasons.

In the following section, Burak's substantive knowledge regarding weather was presented.

4.1.2.1.2 Burak's Substantive Knowledge Regarding Weather

First question asked to clarify his knowledge on weather and weather events. Both the interview and classroom observation data showed that Burak possessed a good understanding of these concepts.

Burak: Weather events occur in a particular place. Weather events deal with short-term event. Weather events show variation.

[Interview]

He correctly expressed the weather events saying that they cover short-term events, and they can change. During his teaching, he added that ‘Weather events occur in a particular area. Weather events are predictable’.

Researcher: Well, what comes to your mind when saying weather events? Could you explain?

Burak: When we say weather events, the two things come to my mind. The first one is the types of precipitation. The second one is the types of wind. …the types of precipitation are rain, snow, rime, dew, hail… and… tsunami, breeze, kinds of breeze, storm… tornado, hurricane are the wind types … These are all weather events.

Researcher: What about when I say weather?

Burak: Weather forecast comes first to my mind… When saying weather forecast, [then] meteorology comes to my mind; because meteorology examines the weather events. We know it [meteorology] from the news. Next, wind comes to my mind. …storm… We can call this [storm] as a type of wind. Then, rime, dew… These [rime, dew] are types of precipitation. Due to the effects of weather events on nature, nature comes to my mind. Then, flood, a negative natural phenomenon... sometimes rainfall exceeded the expected level which affect the nature adversely.…. In rainy areas, flood is one of the most important weather events. If the soil structure is appropriate, this kind of natural disaster [flood] can occur. …weather events depend on the climate [and therefore], I write the climate... rain, snow…

His list of weather-related words included weather forecast, meteorology, climate, rain, snow, wind, storm, rime, dew, nature, and flood. He also added ‘breeze’ to his list of weather-related words. Overall, he associated weather with meteorology, climate, but mostly with weather events.

R: Can you construct a concept map by using the concepts you mentioned above? Please explain your map briefly.

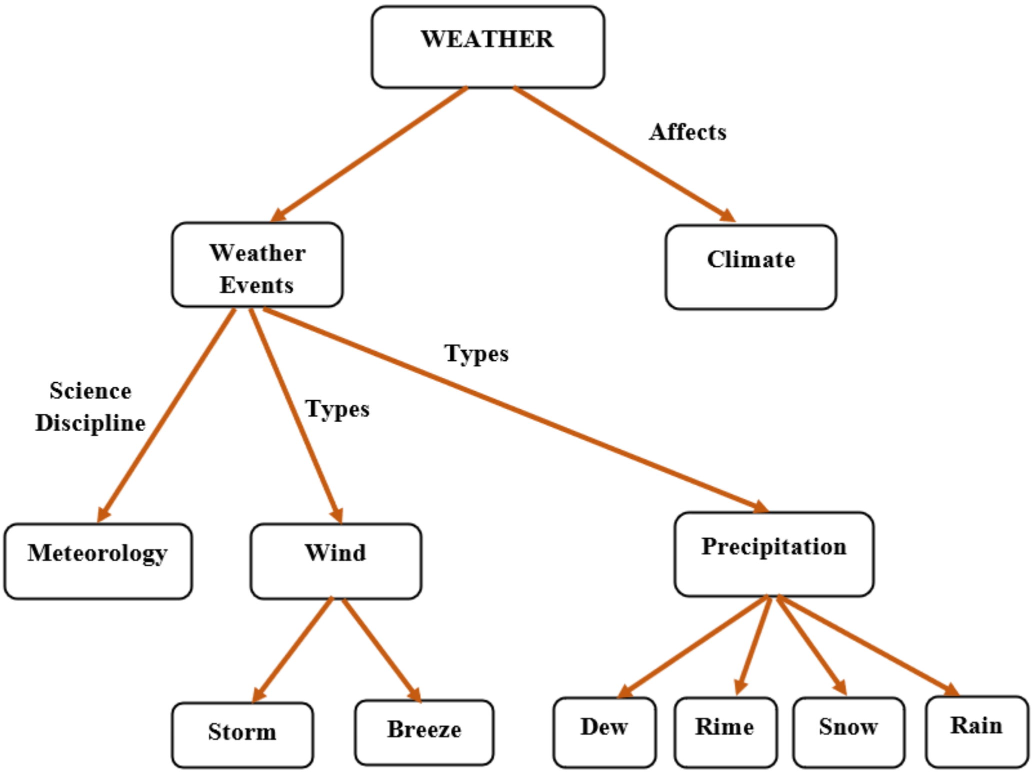


Figure 4.2 Burak's Concept Map Regarding Weather

As seen from Figure 4.2, Burak's concept map regarding the concept of weather consists of two ***chain-like structures*** (Kinchin, Hay, & Adams, 2000): one for weather and other was for weather events. He identified the interaction between the concepts of weather and climate only with the idea that 'weather affects climate'. Then, although he connected the weather and weather events with an arrow, he did not use any link over the arrow that indicates how they are connected with each other. He extended the concept of the weather events with the example of the types of wind (e.g., breeze and storm) and precipitation (e.g., rain, snow, rime, dew), and also linked it to the meteorology concept as a science discipline.

To elaborate his understanding on weather events, Burak was asked about the nature of weather events. He believed that global warming, greenhouse effect and pollution (especially air pollution) are the factors that change the weather events.

> Burak: Are weather events vary?... Yes… The climate has already changed….it changes since the formation of the Earth. Accordingly, the weather events vary. How?... For example, Ankara has a terrestrial climate and [thus] should be cold in winter. In last winter, [however] it did not snow regularly. Normally, it should be. [Likewise,] it did not rain [in Ankara] as well in last winter or the middle of summer. Normally in the middle of summer heavy rainfalls occurred [in Ankara]. It [rain] starts suddenly and affects roads and people. Therefore, they [weather events] show variation of course…
>
> Researcher: What causes these changes in weather events?
>
> Burak: …. of course. The greenhouse effect and global warming come to our mind … In fact, we can associate the reasons [in the change of weather events] with the causes of global warming. One of the main factors is pollution, of course… Air pollution comes to our mind at first... Now, as air pollution increases and the amount of greenhouse gases in the air such as carbon dioxide, sulfur dioxide, nitrogen dioxide increases, the greenhouse effect forms on the Earth. As everyone knows, [greenhouse effect] causes the warming of the glaciers [melts the glaciers] and changes the climates…

However, contrary to the interview, in the classroom observation, he addressed the pressure, temperature and humidity (water vapor) as the factors causing the weather events to change. While teaching of the unit, for example, he drew attention to the water vapor by saying that *"Water vapor is very important gas found in the air."*.

His teaching partly confirms his interview (Table 4.2). As a result of interview findings, he was knowledgeable about weather and weather events, or whether it is static or dynamic. But he harbored some doubt about the cause of variation in weather events. He tended to attribute it to greenhouse effect, pollution, and global warming. On the other hand, in his teaching, he correctly addressed the humidity, temperature and pressure as the factors lead to change in weather events. But he did not mention about other factors (e.g., precipitation, wind).

Table 4.2 *Weather Events that Burak Mentioned in Interview and Classroom Observation*

The Concepts	Interview	Classroom Observation
Weather	Weather events occur in a particular place. Weather events deal with short-term event. Weather events show variation.	Weather events occur in a particular area. Weather events are predictable.
Types of Weather Events		
Rain	As the water vapor rises to above [in the sky], it [water vapor] will cool of course… Types of precipitation form depending on cooling [of water vapor]. If it [water vapor] condenses above [in the sky], we say that rain forms.	Rain forms by condensation of water close to the sky.
Snow	If it [water vapor] freezes above [in the sky], we say that snow or hail occurs.	If the water vapor freezes above [in the sky] and descends in the form of crystals, snow occurs.
Hail	If it [water vapor] freezes above [in the sky], we say that snow or hail occurs.	If it [water vapor] suddenly freezes and falls as a marble, hail occurs.
Dew	If it [water vapor] condenses near the surface, dew occurs.	If it [water vapor] condenses near the surface, the dew occurs. It [dew] occurs mostly in the spring. When the dew occurs, water droplets are existed on the leaves and on the lawns... the surface is not wet. You can see that the top of the grass is wet in spring.
Fog	Not mentioned.	It [fog] is a heterogeneous mixture. It [fog] carries water vapor in it. When the air warms up and moves to the above [to the sky], the fog dissipates.

Table 4.2 *(cont'd)*

The Concepts	Interview	Classroom Observation
Typhoon	Not mentioned.	It [typhoon] occurs when the ocean water is 27-28 °C.
Rime	If it [water vapor] freezes close to the surface, rime occurs.	The rime occurs in Ankara* in winter. You can see that the top of the cars seems white.
Wind	The wind occurs as a result of the pressure difference. You know that there are low pressure and high pressure. The wind is air current that blowing from high pressure area to low pressure area… the wind is a horizontal air current.	The wind forms as a result of pressure difference. The wind does not occur without pressure difference. The wind is always [blowing] from the high-pressure area to the low-pressure area. It [wind] is horizontal directional air movement.
Hurricane	In the horizontal directional air current, the names of the winds change according to the severity. If the [wind's] speed is more than 118-120 kilometers, we say that it is a hurricane. This [hurricane] is dangerous.	The hurricane continues with certain periods.
Tornado	For the formation of the tornado, as far as I know, the ocean or the sea must be at a certain temperature. I remember that 27°C... The tornado does not occur under all conditions and all environments… This [tornado] is a weather event and a type of wind.	It [tornado] occurs as a result of sudden displacement of warm air and cold air.
Tsunami	Tsunami is a type of wave in oceanic regions caused by earthquake, movement in the Earth's crust and energy discharge. They [tsunami] are big waves.	Tsunami occurs in the ocean as a result of earthquake and sliding in the Earth's crust.

[*: is a capital city located in Central Anatolia Region of Turkey]

In the following section, Burak's substantive knowledge regarding the climate was presented.

4.1.2.1.3 Burak's Substantive Knowledge Regarding Climate

Burak's substantive knowledge, obtained from interview and classroom observation, regarding the climate was summarized under three subtitles: knowledge on climate, climate system and climate change, global warming, and greenhouse effect, respectively.

At first, Burak was asked his opinions regarding the definition of the climate and stated that;

> Burak: Climate is the long-term average of weather events. In other words, we can say that climate is an average value of weather events within 25-30 years in brief…

[Interview]

> Burak: Climate is the long-term average of weather events such as pressure, temperature, humidity, wind. For example, we sweat in the summer, and we get cold in the winter in Yozgat's* climate. There are Mediterranean and Black Sea climate [in Turkey]. The climate affects the wide area.

[Classroom Observation]

***:** *is a city located in Central Anatolia Region of Turkey*

Both in the interview and classroom observation, he correctly defined the climate as long-term average of weather events like pressure, temperature, humidity, wind. He also enriched his teaching by giving examples from daily life (e.g., sweating in the summer) and mentioning about several types of the climate such as Mediterranean climate, Black Sea climate.

Burak, as an answer of next interview question, associated the climate with weather events, climatology, climatologist, Sun, seasons, Equatorial climate, and Terrestrial climate. Then, he constructed a concept map by using these words. Burak's concept map regarding the climate was shown in Figure 4.3.

> R: Can you construct a concept map by using the concepts you mentioned above? Please explain your map briefly.

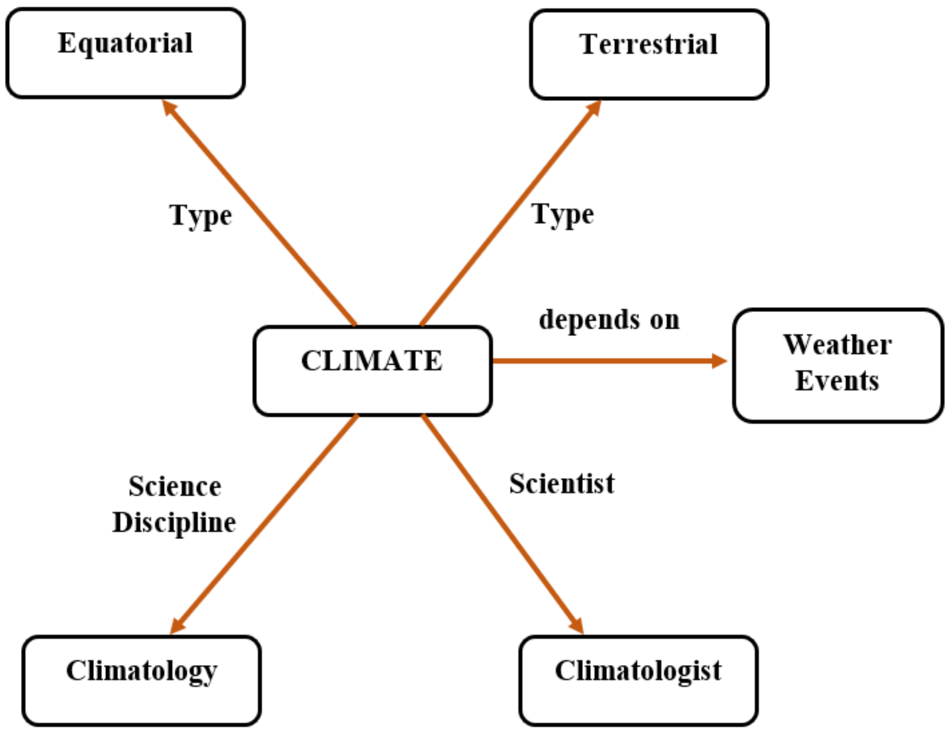


Figure 4.3 Burak's Concept Map Regarding the Climate

He created ***a spoke structure*** (Kinchin, Hay, & Adams, 2000) by putting climate at the center. Other concepts were radiated from the central concept, which is climate. Stated differently, his map has a radial structure and all concepts related to the climate were directly connected only with the climate. There was no connection among other concepts.

Since Burak frequently associated climate with weather or vice versa, he was asked to combine both concepts in a single concept map. As shown in Figure 4.4, his map included 2 separated *chain-like structure*; one for climate, other was for weather. However, his map was limited to only one connection between climate and weather, ‘climate depends on weather’.

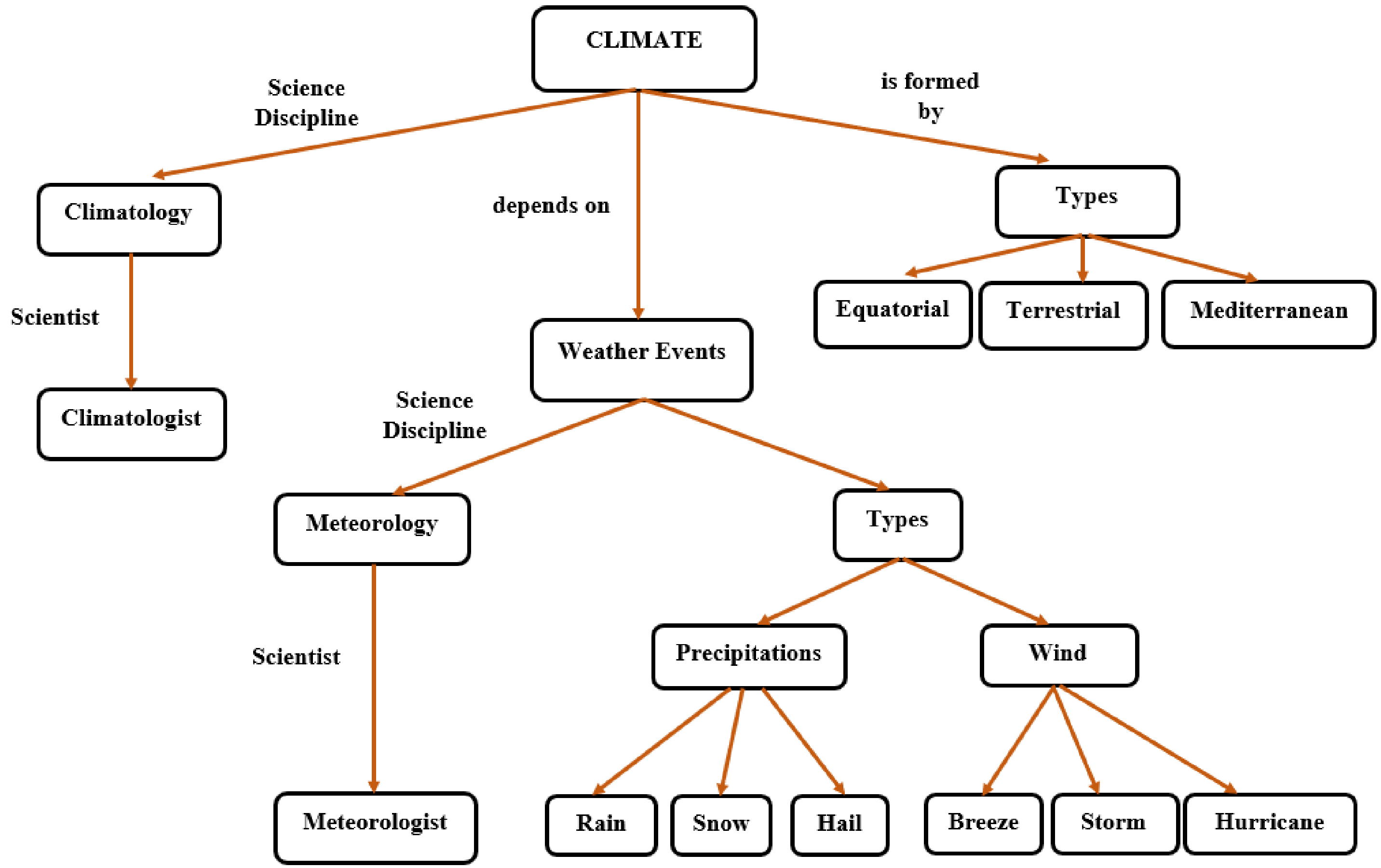


Figure 4.4 Burak's Concept Map Regarding the Relationship Between Weather and Climate

Researcher: Well, can you elaborate more on the link between climate and weather events, if any?

Burak: I think that climate is a concept that involves weather events. In other words, climate is a long-term effect of weather events…. It [climate] depends on the weather events. While teaching the climate, I say that the winter is snowy, or cold… or the summer is sunny, or rainy… These are the weather events, the weather condition… Therefore, the climate depends on weather events.

Contrary to interview, he addressed the differences between the weather events and climate in class saying that;

[The differences between] weather events and climate... This is important. Weather events deal with short-term event and they [weather events] are predictable. Meteorology is the science discipline examining weather events. People [scientists] studying on the weather events are called meteorologists. The climate deals with long-term event. The science discipline examining the climate is called climatology. A scientist studying on the climate is called climatologist.

[Classroom Observation]

Moreover, during his teaching, he drew a table on the blackboard comparing and contrasting weather events and climate (See Table 4.3).

Table 4.3 *Burak's Table about the Difference Between Climate and Weather Events*

Weather Events	**Climate**
It is short-term.	It is long-term.
Weather events are predictable.	Climate shows less variation.
It occurs in a particular place.	It occurs in a wide area.
Meteorologist deals with the weather events.	Climatologist deals with the climate.
Meteorology deals with the weather events.	Climatology deals with the climate.

Throughout the interview, Burak was asked the several questions regarding seasons, weather/weather events and climate concepts. However, the unit is consisted of all these concepts together, it is important to clarify participants' understanding of possible relationship among the seasons, climate, and weather events. Therefore, as a last question, he was asked to make connection among the seasons, climate, and weather events. He said that the seasons, weather events and climate concepts are related to each other hierarchically. He considered the climate as the main concept among those three concepts, follow by seasons and weather events in brief. The sample related excerpts from the interview were as follows;

> Burak: Of course, there is… Now, let's me sort them... climate at the top of level. Climate is the biggest element... Then, seasons… Lastly, the weather events… For example, the angle of incoming sunlight and the Earth's tilted axis cause seasons and also, on weather events. They are not the only factors that affect weather events. The climate is more complicated and more integrated one among the other two concepts [seasons and weather events]. I think all three concepts are related with each other.

His teaching partly confirms his interview. Burak was knowledgeable with respect to the concept of climate. While he touched on the relationship between climate and weather events in the interview, he correctly addressed the differences between climate and weather events in his teaching and also showed their differences by means of drawing a table. He tended to consider a hierarchical relationship among the concepts of seasons, climate and weather, adding that the concept of climate is the main concept. Burak's knowledge of climate based on interview and classroom observation data were presented in Table 4.4.

Table 4.4 *Burak's Knowledge of Climate*

The Concepts	Burak's Responses
Climate	Climate is the long-term average of weather events such as pressure, temperature, humidity, wind. Climate is an average value of weather events within 25-30 years in brief.
The Differences Between Weather and Climate	**Weather;** Weather events deal with short-term event and weather events are predictable. It occurs in a particular place. Meteorology is the science discipline examining weather events. Scientists studying on the weather events are called meteorologists. **Climate;** The climate deals with long-term event. It occurs in a wide area. Climate shows less variation. The science discipline examining the climate is called climatology. A scientist studying on the climate is called climatologist.

Specifically, in this part, whether Burak perceived climate as a complex system or not.

> Researcher: Up to now, we talk about climate. Do you think that climate is a system? Why/why not?
>
> Burak: It [climate] may be a system. This system [climate system] has certain elements…. affecting it [climate system]. There is sun... there are people who study on this system... Then, there is a science discipline which study on this system. If we think in this way, we can think that the climate is quite complicated. The elements that form the climate are weather events at first… Besides that, terraform... Then, altitude… These affect the climate of a region…

Researcher: Well, what kinds of processes occur in climate system?

Burak: There's energy coming from the sun and that comes with an angle [i.e., different angle]. Seasons form because of [Earth's] tilted axis. Then, the location of the region, and the terraform... also, the rate of light absorption and reflection of heat... They all affect the climate… While the glaciers reflect it [sunlight], the desert absorbs more [sunlight], which affect the temperature, which in turn influence climate. The process within the climate system… For example, climate determines people's lifestyle, including their choice of clothing, the building material used for houses (e.g., wooden, adobe). Climate can affect agriculture and industry… It [climate] affects living species... animal species, plant species. For example, plant species that [need humidity] grow in the Black Sea region… same plant may not grow in the Central Anatolia region or vice versa … Or plants that grow in the Aegean region and the Mediterranean region may not grow in another region.

Researcher: Well, assume that, one of the components of the climate system has changed. What happened? How these change influence climate system? Can you give an example?

Burak: Of course, it [climate system] is affected, but the variable factor is important. Is this variable factor small or large [in magnitude]? We should pay attention to this… Assume that, we build a dam. Dam can affect the climate of the region... You imagine that a region with a terrestrial climate… Constructing a large dam can increase the humidity of that region… Immigration of animals, growth of plants or fishery in the region may be also affected [adversely]. As a result, a different food chain can emerge. You imagine that such a dam was built in a naturally formed pond. Agriculture, natural areas, plant, and animal species in that region will be affected negatively from this situation [by the dam construction].

Burak's knowledge of the climate system was shown in Table 4.5. Hence, he seems to be knowledgeable about the complex nature of climate. He perceived climate as a complex system, which included many components like people studying on this system, science discipline which study this system, weather events, sun, terraforms, and altitude.

Regarding the processes in the climate system, he stated the energy coming from the Sun, the formation of seasons, and the effect of different absorption and reflection rates of sunlight by different biomes (i.e., glaciers and deserts) on temperature. Then, he mentioned the impact of the human activity (i.e., construction of a large dam) on the natural areas, humidity, other living things, and humans' life. Based on the findings, he seems to be aware that a change in any component of the climate system affects this system.

Table 4.5 *Burak's Knowledge of Climate System*

Component	**Description**
Sun	Energy coming from the sun Absorption and reflection
Living things (animal, plant)	Immigration of animals Growth of plants, food chain
Human	People studying on this system Adverse effect on climate (Constructing a large dam) Influenced adversely (Fishery)
Weather	Weather events (i.e., humidity)
Terraform	A dam was built in a naturally formed pond.
Altitude	-

Overall, data obtained from Burak can be summarized as a whole depending on categorization by Shepardson et al. (2014), and also, the interactions he established among the components of climate system were presented based on Shepardson et al. (2014) (See Table 4.6).

Table 4.6 *The Categorization of Burak's Knowledge of Climate System depending on Shepardson et al. (2014)*

Component	**Description**
Human	Negative impact on climate (indirect - Constructing a large dam) People studying on this system Influenced adversely (Fishery)
Atmosphere	Weather events Humidity
Glacial	Glaciers
Sun	Energy coming from the sun Absorption and reflection
Life (plants and animals)	Immigration of animals Growth of plants Food chain
Land	Terraform A dam was built in a naturally formed pond. Desert
The Interactions among the components of climate system based on Shepardson et al. (2014)	
Glacial (glaciers) → Sun (reflecting sunlight) → Atmosphere (affecting temperature) Land (desert) → Sun (absorbing sunlight) → Atmosphere (affecting temperature) Human (constructing a large dam) → Atmosphere (increasing the humidity) → Life (adversely affecting immigration of animals, growth of plants) Human (constructing a large dam) → Atmosphere (increasing the humidity) → Human (adversely affecting fishery) Human (constructing a dam in a naturally formed pond) → Human (adversely affecting agriculture) Human (constructing a dam in a naturally formed pond) → Life (adversely affecting plant, and animal species) Human (constructing a dam in a naturally formed pond) → Land (adversely affecting natural areas)	

Since Burak highlighted the environmental issues like climate change, global warming, and greenhouse effect, it was decided to unveil his ideas more on these issues by asking follow-up questions. His responses briefly were reported in the next part.

4.1.2.1.3.1 Burak's Substantive Knowledge Regarding Climate Change, Global Warming and Greenhouse Effect

When asked to explain the climate change, he stated that;

> Hmmm… It [climate change] is a disruption of the balance of nature. Nowadays, it is said that nature has become imbalance as a result of global warming. Scientists say that the poles are melting constantly and that it is snowing in the desert. This [snowing in the desert or melting of the poles] is not an event that will happen under normal conditions. Climate change affects species… it [climate change] affects everything…
>
> Researcher: Well, you think that climates have changed.
>
> Burak: Hmmm… I partially think that the climate changes... Yes... At least, we see [observe] that [climate changes]. For example, nowadays, the air temperature is above the normal level. The available data and the things [news] we hear and examine [regarding the climate] make us think that climate changes. [For example], weather condition... Meteorologists mentioned about unseasonal weather; temperature either above or below the seasonal range. This change [in climate] is not short-term, but long-term. This shows us that some things have changed...

After expressing his idea about the climate change, he gave examples from daily life, such as snowfall in the desert, melting of glaciers at the poles. He, based his thinking, on the events he witnessed in daily life, for instance, the air temperature is above normal level.

> Researcher: Well, what causes the climate to change?

Burak: Global warming…The causes of global warming are also cause of climate change. You know that air pollution is the main factor of global warming… The increase in the greenhouse gases due to air pollution form the greenhouse effect…. consequently, the natural disaster, which we call global warming, occurs. Of course, there are more causes… environmental factors... I believe that human can do many things. I mean, they [humans] can either fix or can break things. Assume that, you have a factory… you can install a filter [to factory] ... or if you have a car, you can do regular car maintenance or not… It depends on you [human being] … For example, you can damage the trees, or you may not… This is your choice… There are people whose behaviors harm the environment [e.g., damaging the trees] … such behaviors cause environmental problem. The damage done by someone does sometimes influence all of us all at the end… We heard on the news. For example, making [cook] a barbecue on a picnic, sometimes may cause forest fire and resulting gas releasing from the fire pollute the environment... [as a result] you destroyed not only the air, but also trees which clean the forest... you're destroying the forest... What you're destroying is nature. In other words, you destroy the system and the environment. I think human beings are at the center of these events…

After mentioning about the greenhouse effect and greenhouse gases, Burak was asked more questions on those issues.

Burak: The greenhouse effect is that greenhouse gases keep the heat around the Earth. The greenhouse is surrounded by a transparent nylon, and with the entering of the [sun]light, it [greenhouse] maintains the heat and makes it [any place] warm. It's the same logic [with greenhouse effect]. The greenhouse effect is that heating of the region due to the inability of the sunlight to go out completely [from the atmosphere] … We say the carbon dioxide, nitrogen dioxide, nitrous oxide, sulfur dioxide as gases causing the greenhouse effect.

Researcher: What are the factors that increase greenhouse gases?

Burak: Of course, there are many factors… For example, the gas releasing from the car's exhaust… or chimney, stove, natural gas… combi boilers used in houses which release carbon dioxide and other gases. …... gases are also released from industrial chimneys. But are these only things that pollute the nature? No… We use deodorants, refrigerators, air conditioners... fossil fuels, car… these are all affect [the amount of greenhouse gases].

Researcher: Is greenhouse gases normally exist in nature?

Burak: There is no problem in existing of them [greenhouse gases] in nature. But the problem arises from existing of greenhouse gases in nature or are they [greenhouse gases] more than expected? There is a considerable number of vehicles right now, not just in industry... [Reducing] exhaust gases of vehicles… or switching to natural gas, which is cleaner than the other fuels used in homes. We try to take such precautions [in attempt to reduce greenhouse gases]. But there is a significant amount of carbon dioxide emissions. There are also some attempts studies [by the governments] to reduce carbon dioxide emissions in the world. These gases [greenhouse gases] exist in the nature. But they [greenhouse gases] are more than normal level… Carbon dioxide is an essential gas in nature… Why? Because a plant that does photosynthesis uses it [carbon dioxide]. However, when the carbon dioxide gas increases to an excessive level, the problem arises in nature... When it [carbon dioxide] reaches a high level [with using of] fossil fuels and exhaust gases, problems arise.

Researcher: What would happen without greenhouse gases?

Burak: Hmmm… After a while, life would be probably end.

In short, he emphasized that the factors that cause the global warming also the causes of the climate change, that the air pollution increases the greenhouse gases and that greenhouse effect causes the global warming, thereby the causes the climate change.

According to him, human activities cause the global warming and climate change. He broadened his ideas through giving examples related to the human activities, such as, omitting the regular cars maintenance, not installing the filters in factories, damaging the trees, causing fire forests. He expressed the greenhouse effect as warming the Earth by keeping the sunlight in the atmosphere by greenhouse gases. He appeared to aware that it is natural for greenhouse gases to be found in nature (e.g., plants use the carbon dioxide to make photosynthesis) and followed by it can be a problem that greenhouse gases are more than that should be found in nature. He attributed the increasing the amount of greenhouse gases to many factors such as the gases releasing from the car's exhaust and industrial chimneys, the use of natural gas, fossil fuels and combi boilers. However, he seems to have a lack of knowledge and misconceptions regarding the climate change, global warming and greenhouse effect. For example, he incorrectly expressed nitrogen dioxide and sulfur dioxide as greenhouse gases. While explaining the process of greenhouse effect, he used the concept of sunlight instead of sun's incoming short-wave radiation and earth's outgoing long-wave heat radiation. He wrongly associated the greenhouse gases increase with pollution, which cause the greenhouse effect, global warming and thus climate change. Thus, he has a misconception related to the view that he associated the global warming, greenhouse effect and climate change with pollution.

In the following question, Burak was asked his opinions regarding the consequences of climate change and its' impact on our daily life.

> In my opinion, the consequences of climate change will be negative of course… After all, there is a system [in climate change]. There is a dynamic system [in climate change]. If it [system] breaks down, it may not be a big problem in the short term. But in the long-term, the system will break down. What can be the consequences [of the climate change]? We see.... currently, for example, it doesn't rain when there should be rain… or the air is getting dirty. The soil is becoming infertile …unproductive and dirty. We're not the only living things in the world. There are other living things as… there are animals… there are plants. Plants are very important for us biologically in

terms of both the source of oxygen and food. [Accordingly], it’s benefit will decrease for both of us and others within this system [in climate change]. …. When we think about a food chain, the destruction of forests and the damage to animals mean indirectly damaging human beings. Imagine that the forests and then, the species living in the forest were affected adversely by the climate change... What about if the marine ecosystem was disrupted? … marine species [affected negatively] …or desert ecosystem…... As a result, we are at the top of the food chain and it [climate change] will indirectly affect us [human beings]. The factors that harm the environment, forests, also disrupt the nature’s balance… Then, environmental disasters will be occurred or living things… animal species and plant species…are endangered. I mean, these are all consequences [of the climate change] … In the long-term, it [climate change] will affect [our daily lives] of course. Even now, climate change is affecting [our daily lives]. [For instance] diseases emerge due to air pollution. Now, we are in Autumn and I'm sick, my throat is very bad now…... the doctor told me something interesting that virus, called Beta, normally, infect people in winter frequently. But currently, it is also common in summer. [Thus], it [climate change] has an impact on human health.

Researcher: Do you want to say more about the effects of global warming on environment and living things?

Burak: Hmmm… We hear in newspaper or news on tv about the condition of polar bears, the position of glaciers, or it is said that there occurs a sudden rainfall or precipitation in some agricultural areas, or the absence of snow when it needs to snow… forest fires… Forest is a home for living things. When we destroy it [forest], we indirectly destroy it [habitat of living things]. Global warming affects living things negatively of course... Now, the most important factor is the melting of the poles. The temperature in that area is rising... The pieces of the glaciers are breaking. Biodiversity is affected. Biodiversity, the food chain of polar bears is affected… For example, you imagine a machine… If one of the gears [in machine] is broken, the machine will stop, or warning signal starts to light up. If it [machine] does not stop, then smoke comes out of the machine and warning signal starts to light up. This situation is also happening in the nature … Food chain is a system; if people hunt the animals, they [people] break the chain. One of the biggest factors that disturbs this [food chain] is the global warming now…

Briefly, he believed that climate change and global warming affect both environment and living things. It should be noted that he touched upon the consequences of climate change and global warming with a systems-thinking approach and expanded his idea with examples about a change in the system affecting the whole system. For example, he defined the food chain as a system, and therefore, stated that humans are affected indirectly from deforestation, and damaging of animals and plant species caused by climate change and global warming. He addressed the deforestation (e.g., fire in forest) that leads to restrict the habitat of living things, and the impact of extreme weather events in agricultural area (e.g., sudden rains). Also, as consequences of global warming, he said that as temperature increases, the poles are melting and therefore, biodiversity is affected (e.g., food chain of polar bear). As consequences of the climate change, he added the damaging of various ecosystems (e.g., sea ecosystem, desert ecosystem), and human health (e.g., Beta virus seen in summer rather than winter). However, he did not mention about the impact of climate change and global warming on the chemistry of ocean water.

As a last question, Burak was asked about a possible relationship between greenhouse gases and the matter cycles.

Researcher: Do you think that whether the changes (e.g., decreases or increases) in amount of greenhouse gases affect the matter cycles?

Burak: Of course, it [changing the amount of greenhouse gases] will affect [the matter cycles]. Carbon cycle… You know that the carbon cycle and the oxygen cycle are two opposing cycles. While photosynthesis is main factor in one of the cycles [carbon cycle], the respiration is main factor in other cycle [oxygen cycle]. The photosynthesis is the most basic way to reduce

> carbon dioxide. Who does photosynthesis? Of course, we can give many examples, but we say that the plants are the most effective living things [making photosynthesis]. Also, some bacteria, ...amoeba make photosynthesis. But main factor [for reducing carbon dioxide] is plants… forests... so without increasing the forest population, it is meaningless to teach [to the students] how to protect … People are damaging the environment, such events [behaviors], sooner or later affect you [humanity]. If you do not do anything to reduce the amount of carbon dioxide, the balance [between these cycles] changes automatically. Who will be affected when the balance changes…?... Of course, there are people at the top of this [matter] cycle in nature and people or other living things will be affected [adversely]...

He considered that the changes in the amount of greenhouse gases affect the matter cycles in nature and he gave the examples of the oxygen and carbon cycles. While he associated the carbon cycle with photosynthesis, he associated the oxygen cycle with respiration. For example, he stated that when no action is taken to reduce the amount of carbon dioxide (e.g., inability to increase in forest population), it will disturb the balance between the two opposite cycles, which in turn influence humans and other living things.

Up to this section, the interview findings were presented. Next section the findings were reported obtained from classroom observation.

4.1.2.1.3.1.1 Burak's Substantive Knowledge Regarding Climate Change, Global Warming and Greenhouse Effect: Classroom Observation Findings

His responses to interview questions partly supported by classroom observation for example, while teaching of the weather and climate topic, he mentioned about consequences of the global warming, and he said that;

Burak: Unexpected weather conditions occur as a result of global warming if the storm hit the Aegean. As a result of global warming, climate change occurs…. The glaciers are melting… the sea level rises… The air temperature changes…. ecosystem is affected [adversely]…in turn, biodiversity is affected [decrease] … some regions receive too much snow… it's snowing in the Nevada desert…Yet some regions like Ankara do not receive snow [compared to past] … some plant and animal species are disappearing… the ecosystem is destroying. [At this point] you should take precaution to reverse the process [prevent the process of damaging].

[Classroom Observation]

In his teaching, similar to his interview, he attributed one of the causes of climate change to the global warming. He addressed the decreasing in biodiversity, damaging in ecosystem, melting of glaciers and so rising the sea level, and changes in precipitation patterns (e.g., snowing in desert) as consequences of global warming. He also reminded that precautions should be taken to prevent the effects of global warming (Burak's ideas regarding the precautions taken toward environmental problems will be mentioned more under dual perspective section).

In classroom observation, he taught concepts related to global warming as parallels to interview (e.g., greenhouse gases, greenhouse effect). He drew a figure on the blackboard, emphasizing that the greenhouse effect causes global warming (See Figure 4.5). As compatible with the interview, for example, he correctly identified carbon dioxide and nitrous oxide as greenhouse gases causing the greenhouse effect. He stated that not doing regular maintenance of cars, using fossil fuels, not installing filters in factory chimneys and damaging trees lead to release greenhouse gases to the atmosphere. His responses also indicated his awareness that the presence of greenhouse gases in nature is natural, and the problem occurs when it reaches extreme levels. The related excerpts from the classroom observation were as follows;

Burak: …People don't do regular maintenance of their car [people neglect basic maintenance on their car] ... In winter time, they [people] are using coal and natural gas in homes. [People] don't use filters in their factory's chimneys. [Factories] release carbon dioxide, nitrous oxide, nitrogen dioxide to the atmosphere…. They [people] are doing something worse…they [people] cut down trees which are the only living things removing carbon dioxide. [Trees] photosynthesize.... What about people? They [people] breathe. We [humans] have to release carbon dioxide into nature because the plant does photosynthesis. The problem is about releasing too much [carbon dioxide into nature].

[Classroom Observation]

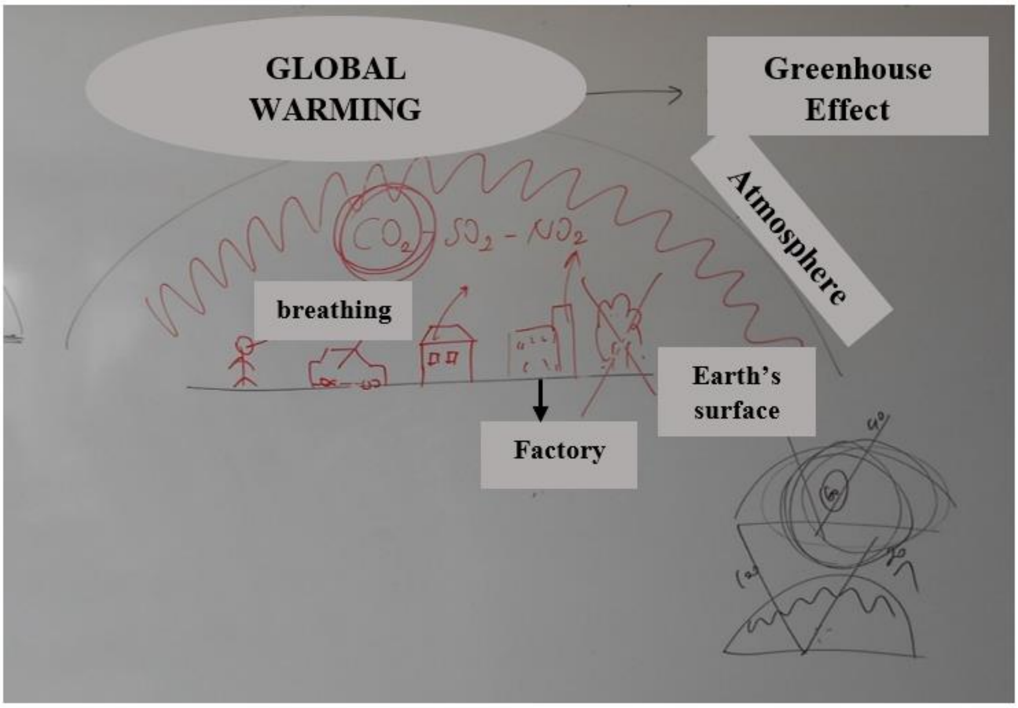


Figure 4.5 Burak's Drawing Regarding the Global Warming and Greenhouse Effect on the Blackboard

While drawing Figure 4.5, he defined the process of greenhouse effect by saying that;

"A layer is formed around the Earth due to greenhouse gases [CO_2, NO_2, SO_2]. Sixty percent of the sun's rays pass through the atmosphere and forty percent of them reflect back from the atmosphere."

As he mentioned in the interview, his definition of greenhouse effect includes the concept of sun’s rays instead of incoming short-wave radiation passing through the atmosphere and outgoing long wave heat radiation bouncing back from the atmosphere. Apart from carbon dioxide, he has incorrect idea that he stated sulfur dioxide and nitrogen dioxide as greenhouse gases. Also, his idea pointed to a misconception by saying that greenhouse gases, which he associated it with pollution in previous questions, forming a layer surrounding the Earth trapping sun rays (e.g., Papadimitriou, 2004). Similar to his idea of a layer consisting of greenhouse gases in his misconception, he explained the greenhouse effect with *analogy* and exemplified that a greenhouse surrounded by transparent nylon is heated by the entering of sun's rays.

> Burak: What is the greenhouse?... assume that, somebody is planting plants, such as vegetable, in a particular place. Usually, he/she covers up [with transparent nylon] his/her plants in winter. [This setup is known as greenhouse] and it is quite common in Antalya*, not in Erzurum** because it [Erzurum] is a very cold [city]. The sun's rays come down there and heat it. Those (e.g., plant, vegetable) will grow at a certain temperature [in greenhouse].

[Classroom Observation]

*: *is a city in Mediterranean Region*;

**: *is a city in Eastern Anatolia Region located of Turkey*

Consequently, above findings indicated that despite he considered cause-effect relationship among climate change, global warming and greenhouse effect, he had difficulty in explaining these concepts. For example, although he expressed the function of the greenhouse gases correctly, he incorrectly associated the greenhouse gases with pollution. Since he associated with greenhouse gases, he had a misconception about associating climate change, global warming and greenhouse effect with pollution. While teaching the unit, it was detected that he had a lack of knowledge and misconception about the process of greenhouse effect. On the other hand, he mentioned about many consequences of the climate change and global warming such as deforestation, damaging the biodiversity of living things. Burak's knowledge of climate change, global warming and greenhouse effect based on the interview and classroom observation data were shown in Table 4.7.

Table 4.7 *Burak's Knowledge of Climate Change, Global Warming and Greenhouse Effect*

The Concepts	Burak's Responses
The Causes of Climate Change	Global warming Air pollution Increasing of the greenhouse gases due to air pollution Not taking the cars to timely maintenance Not installing the filters in factories Damaging the trees Destruction of the forest
The Consequences of Climate Change	Pollution (e.g., Soil pollution, Air pollution) Destruction of forests Extinction of animal and plant species Occurring the environmental disasters Occurring the extreme weather events Melting of glaciers Inefficiency of soil Disruption of ecosystems (e.g., Marine ecosystem, Desert ecosystem) Impact on human health
The Causes of Global Warming	Air pollution Increasing of the greenhouse gases due to air pollution Greenhouse effect Not taking the cars to timely maintenance Not installing the filters in factories Damaging the trees Destruction of the forest

Table 4.7 *(cont'd)*

The Consequences of Global Warming	Biodiversity of living things are decreasing.
	Melting of the poles
	  The pieces of the glaciers are breaking
	  Sea level is rising
	  The food chain of polar bear is affected
	Increasing of the air temperature
	Deforestation
	Extinction of living things
	Damaging the ecosystem
	Changes in precipitation patterns
	Sudden precipitation in some agricultural areas

Greenhouse Effect	The greenhouse effect is that greenhouse gases keep the heat around the Earth due to the inability of the sunlight to go out completely from the atmosphere.
Greenhouse Gases	Carbon dioxide (CO_2) Nitrogen dioxide (NO_2) Sulphur dioxide (SO_2) Nitrous oxide (N_2O)
The Function of Greenhouse Gases	Greenhouse gases keep the heat around the Earth. There is no problem in existing of greenhouse gases in nature. When carbon dioxide reaches a high level with using of fossil fuels and exhaust gases, problems arise. Without greenhouse gases, after a while, life would be probably end.

4.1.2.1.4 General Summary for Burak's Substantive Knowledge Regarding the Seasons, Weather, and Climate

Under this heading, general summary for Burak's substantive knowledge regarding the seasons, weather, and climate was presented.

Regarding the concepts included in seasons, Burak was able to identify the Earth's tilted axis and Earth's revolution around the Sun as the causes of the seasons both in the interview and classroom observation. He also explained the weather concept correctly and mentioned about many weather events both in the interview and classroom observation such as tsunami, rime, wind, rain, snow. He addressed humidity, temperature and pressure as factors that lead to change in weather events. He was aware of the concept of the meteorology and meteorologist as well. He tried to relate the weather with the climate. He correctly defined the climate as long-term average of weather events like humidity, temperature, pressure and was able to express the differences between the weather and climate. He was aware of the climatology and climatologist concepts. He tended to perceive the climate as a complex system by mentioning about most of the components of the climate system and some interactions among the components. Regarding the causes of the climate change, he only focused on anthropogenic causes, neglect the natural causes of the climate change (e.g., volcanic activity) (Lambert, Lindgren, & Bleicher, 2012). He also holds a misconception as to the relationship between climate change, and pollution (Table 4.8). He labelled the disruption of ecosystems (e.g., marine ecosystem), destruction of forests, extinction of animal and plant species, melting of glaciers as consequences of the climate change. Similar to climate change, he also associated global warming with pollution, by saying that ‘pollution causes the global warming’ (Table 4.8). Several consequences of the global warming such as increasing air temperature, loss of biodiversity, melting of poles were mentioned both in interview and classroom observation. As far as greenhouse effect was considered, data showed that he was knowledgeable about the factors increase the amount of the greenhouse gases such as use of the combi boilers, stove, deodorants, fossil fuels, the gas releasing from the car's exhaust, and damaging trees. He was also aware of the function of the greenhouse gases by saying that keeping the heat around the Earth. However, he had lack of knowledge regarding greenhouse gases found in the nature, and incorrectly associated the greenhouse gases causing the greenhouse effect with pollution. Also, in his teaching, it was revealed that he holds misconceptions as to the process of greenhouse effect (See Table 4.8).

Table 4.8 *Burak's Misconceptions*

Burak's Misconceptions	Supporting References
Relating the climate change and global warming with air pollution.	(Papadimitriou, 2004)
Saying that greenhouse gases, which he associated it with pollution in previous questions, forming a layer surrounding the Earth trapping sun rays.	(Papadimitriou, 2004)
Relating the greenhouse effect with pollution	(Papadimitriou, 2004)

Overall, it was concluded that he seemed to be more knowledgeable about the basic concepts of seasons, weather, climate and climate system compared to climate change, global warming, and greenhouse effect (See Table 4.9).

Table 4.9 *Summary of Burak's Substantive Knowledge*

Concepts	Burak's Substantive Knowledge
Seasons	Knowledgeable
Weather	Knowledgeable
Climate	Knowledgeable
Climate System	Knowledgeable
Climate Change	Lack of knowledge
Global Warming	Lack of knowledge
Greenhouse Effect	Lack of knowledge

4.1.2.2 Burak's Syntactic Knowledge

In this section, Burak's syntactic knowledge regarding the aspects of nature of science both separately and in the context of weather and climate was reported by using VNOS-C questionnaire (Lederman et al., 2002).

Firstly, Burak was asked his opinions regarding the science and what distinguishes science from other disciplines.

> Burak: Hmmm… I can say that science is an investigation conducted to reach the truth, to formulate hypotheses, conduct research, to evaluate and…to reach a conclusion. But I always told that science is changeable and developing. Nowadays, accessing to information is not a very difficult task by the help of today's technology… In fact, technology is also a science …needs of human beings and nature all contribute to the development of science significantly… Of course, curiosity is the leading contributor… curiosity is the one of the most critical words that comes to mind when we said science... instinct sometimes contributes…… But these are not enough of course... what we are doing is to make research and to reach conclusion. The result may be true or false. After that, the decision is made and it becomes law... and hypothesis is refuted etc….
>
> Researcher: What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines (e.g., philosophy)?
>
> Burak: In fact… There are also points in which science and other disciplines are intermingled as well as differentiates. Hmmm… Let me give an example from philosophy. My high school philosophy teacher asked us a question by putting a chair on the table, and then asked "Is there a chair here?". I never forget that... From scientific perspective, does the chair exist? You see [chair] through your eyes. Is chair’s location certain? Yes, it [chair’s location] is certain. But philosophically, you discuss whether the chair really exist or not”. At this point, there are differences [between science and other disciplines]. But as I said, if you want to advance, you need to investigate…inquire... to learn [in science and other disciplines]. I think, the main thing in science is to investigate…

When asked what the science is, Burak addressed the empirical and tentative NOS and defined the science as a discipline including investigation, formulating hypothesis, evaluating information and reaching the truth (i.e., empirical NOS) and also, he stated that science can change and develop (i.e., tentative NOS). He emphasized that the technology, curiosity and needs of humans contribute to the development of science. His response revealed a misconception that technology is a science. Above questions gave some clues about Burak's knowledge regarding empirical NOS. His understanding of empirical nature of science was elaborated in following questions.

> Researcher: Does the development of scientific knowledge require experiments? Why/ Why not?
>
> Burak: It [experiment] is necessary [for the development of scientific knowledge]. Let's think in this way... The simplest example is the law of gravity or the buoyancy of liquids or Newton laws etc.... Because physics is abstract, it [gravity] may not be understood [by people]. But demonstrating by experiment make it [gravity] concrete... Therefore, I think it [experiment] contributes scientific knowledge in a positive way.
>
> Researcher: Do you think that is there a sequence of steps (that scientists follow) in their research?
>
> Burak: There are scientific methods to follow. They [scientists] will formulate their hypothesis. They [scientists] will investigate ... … They [scientists] will reach the conclusion as a result of the experiment. Then, they [scientists] will evaluate the results. They [scientists] will decide whether the results are in line with his/her will want…. For example, a physicist, a Turkish teacher, a literature teacher or an astronomer can use different kinds of methods and techniques... But as I said, all of them [scientists] follow such methods in general.

Since, in previous questions, he defined meteorology as a *science discipline that examines weather events* and meteorologists as *scientists who study on weather events,* and mentioned climatology as a *science discipline examines the climate* and climatologist as *scientists who study on climate*, he was asked how meteorologists or climatologist collect data in their studies.

> Researcher: What about meteorologists or climatologist? How do meteorologists predict weather events, for example?
>
> Burak: There's a science discipline called meteorology that monitors weather events. Meteorologists make measurements [regarding weather events]. I don't say too much things because I haven't seen [measuring tools]. As far as I know, the measuring tools are sent to the certain height in sky to collect data. Temperatures and variations at the certain height are measured at different points… such as the direction of the wind, pressure… Depending on the data, meteorologists make predictions… make evaluation and reach conclusion... Meteorologists use their prediction and observations [related to weather events] to produce results.

As a follow-up question, he was asked to whether those prediction accurate.

> Researcher: Do you think the weather forecast made by meteorologist is accurate?
>
> Burak: Hmm… Of course, there is a factor of fallibility because meteorologist's devices are manmade…humans made them…thus errors are unavoidable…in meteorologist's measurements… But there is a high degree of accuracy [in weather forecast]. But now, we know that meteorology is doing well... even provides us with hourly weather forecast in a day. For example, meteorology says that the wind speed will increase. Meteorology says that it's going to rain and it's raining sooner or later… But in general terms, I think that meteorology makes more accurate predictions as we see in the meteorology's weather forecast in the news. Meteorology says that "It is expected to snow on around 6 o'clock in Istanbul*." and predictions of meteorology become true.
>
> [***:** *is a city located in Marmara region in Turkey*]

In the same way, Burak's teaching provided important clues regarding his understanding of certainty in science saying that:

> Meteorologist says that "It's going to rain… It's going to snow.". Meteorologist warns that it is going to snow in Istanbul at 6 o'clock in the morning. [But] weather events are short-term and based on prediction. It is not certain.
>
> [Classroom Observation]

Next question gives his ideas regarding how climatologists collect data, analyze data and reach a conclusion.

> Researcher: How do climatologists collect data? What kind of devices do climatologists use to investigate the climate?
>
> Burak: Weather events are the most basic element of it [climatology] of course… They [climatologists] get benefit from meteorology, weather events... Hmm… Actually, I'm not sure what kinds of devices they [climatologists] use. But probably they [climatologists] use the same devices similar to ones used in meteorology... balloons for example…the tool used to measure wind. They [climatologists] use all of them. Meteorology makes daily and short-term prediction. Climatology [makes prediction] in the longer term. For example, in this summer [2018], it did not snow much in Ankara*. The fact that there is not much snow in Ankara* does not indicate the climate of Ankara…. Climatologists, in general, investigate them [data related to weather] over a long period of time, and then, they [climatologists] produce data by taking their average. Climatologists examine data accumulated in periods of 20-30 years, not in periods of 3-5 years.
>
> [*: *a capital city located in Central Anatolia region in Turkey*]

Since Burak mentioned performing experiment and making observation to obtain scientific knowledge and also making prediction depending on the available data, it was seen that he was aware of the empirical NOS. Although he said that teachers from different disciplines (e.g., literature teacher) use different kinds of methods, his responses implied that he possesses a common misconception that scientists follow general scientific method including sequence of steps such as formulating hypothesis, investigating, performing experiment. Similarly, when asked how meteorologists predict weather events and climatologists collect data on climate, his responses, such as making measurements with devices, making observations, evaluating the data and reaching conclusions, indicated that he had the idea of general scientific method. For example, in the context of weather and climate, he mentioned about the tool used for weather forecasting, stated that meteorologists make prediction about the weather events based on available data and that meteorologists reach the results by means of observations and predictions. Similarly, he stated that climatologists use the measurement tools used by meteorologists with the aim of collecting data regarding weather such as balloons and wind measurement tools. He stated that climatologists examine the long-term data from the past (e.g., 20, 30-year data), make prediction in the long-term and then, produce a result with the average of the data. It means that climatologists make inferences related to climate based on the past data. Responses of Burak also revealed his understandings of inferential nature of science, besides empirical nature.

Next question examines his knowledge on theory and law.

> Researcher: Is there a difference between a scientific theory and a scientific law?
>
> Burak: What was taught us regarding [the differences between] theory and law at the university?... If it [scientific knowledge] is accepted by the scientific community and whole world, it is called law. If not, or it [scientific knowledge] is still under investigation, it is called theory. Big bang for example… It [Big bang] is a theory, but gravity is a law. As I said, the main difference between them is that while one of them [laws] is proven and fully accepted, the research is still going on in other one [theory]. Now, Big bang is a theory… You cannot say "it [Big bang] has happened definitely…for

> 100% sure.”. But there are factors [evidences] that support the Big bang theory. You can't say “It [Big bang] has not happened” … This is the theory …… But as I said, when we drop the pen, pen tends to fall to the ground because of Newton's gravity. Nobody can object to it. It [Newton's gravity] is accepted by the world. One of the most fundamental differences between theory and law is that scientists continue their research on theory… In the theory, the final step has not been completed yet. … there is one more step for theory to become law… That's what I have learned… That's what my teachers taught me…

As clearly seen, he holds a misconception that there is a hierarchical order between theory and laws. This conception also reflected in the follow-up questions. For example, he tried to explain whether the greenhouse effect is a theory or not depending on his naïve view:

> Researcher: Okay, what can you say about greenhouse effect? Is greenhouse effect a scientific law or a scientific theory?
>
> Burak: Well... Frankly, I don't have any knowledge [about whether the greenhouse effect is a theory or law]. But it seems a little more reasonable to me that it [greenhouse effect] is a theory. Of course, it [greenhouse effect] is accepted by the entire world now. From this side, it [greenhouse effect] could be the law. More importantly, is there a greenhouse effect?... There is [greenhouse effect]. Does it [greenhouse effect] has any effect?... yes… Is this effect positive?... No... since it [greenhouse effect] is widely accepted, it could be the law… yes… Because I have never heard anyone who refuses the greenhouse effect and global warming neither in the sources I read nor elsewhere. At this point, I think it [greenhouse effect] is closer to be law. But it [greenhouse effect] can be a theory as well. I don't know much [information] about this…

Similar to greenhouse effect, he also remained undecided in the following question asking about certainty in global warming whether global warming is a theory or law.

He added that global warming can be a law in case people agree on it. Following excerpts give further idea about his understanding of theory and law as well as certainty in science. In one of the previous questions, Burak mentioned about certainty, stating that there is no certainty about whether the Big Bang occurred or not, but there is evidence that the Big Bang could be a theory. Also, he stated that generally meteorologists reach the correct information regarding weather forecast and that the weather forecast made by meteorology is not certain and there may be fallibility in the weather forecasts caused by meteorologists' errors or fallibility of meteorologists' device.

> Researcher: Do scientists certain about global warming?
>
> Burak: They [scientists] tell us that global warming exists… If they [scientists] were sure, it [global warming] would be a law. Therefore, I couldn't decide whether it [global warming] is a law or theory. Now, there is a difference [between theory and law] … In my opinion, it [global warming] is not already become a law. If everyone agrees, then it [global warming] becomes law. But I think that the majority [of people] believe in global warming. At least, this [existence of global warming] was said in news, newsletters, or magazines…

He defined the law as a proven and superior knowledge compared to theory, and that the theory is a knowledge that needs to be studied on it. Overall, his responses indicated that he appears to fail to notice that laws and theories are defined as different types of knowledge and one cannot turn into another, or one cannot improve over the other one (Lederman, 1999). Therefore, it can be concluded that he possessed incomplete understanding regarding the functions of the theory and law.

> Researcher: In the questions above we talked about theory and law. Do scientific theories (e.g., a theory about climate change) change over time? Why/Why not?

Burak: Sure, it [scientific theory] can change… I think that everything can change in science. We still teach that there are three states of matter, but research is going on about the possibility that matter may have also different states. But this knowledge has not reflected in the curriculum yet…. It [scientific theory] can change. For example, climate... Does climate changes? Yes. Climates have changed since the formation of the Earth. Of course, it [scientific theory] can change over time. Isn't science like that?... It always makes sense to me that there is a change in progress [in science] ... but some other things [knowledge] in science do not change like the law of gravity …

Researcher: What are the factors that make changes in scientific theories?

Burak: Science can change… theories… Why?... For example, technology… [Theories can change] with advancing technology... For example, we gave the example of Big bang. Research [on Big bang theory] is still continuing. In the past, some of Muslim scientists made research on it [Big bang theory] as well. In the past, [research have conducted] with observatories, and then with Galileo… The technology in the past that examines the sky is not the same as the current technology. I think it's not surprising that their [scientists'] perspective toward scientific knowledge do not remain the same as technology progresses. Scientists can see [now] what [they] could not see [in the past]. For example, the things that have not been seen or detected in the past can be detected now. This leads to change [in scientific theories]. As a result, research in science does not end... but keep going there is continuity [in science] … Humans need to continue to investigate… Learning has no end... same logic…. There is no end to learning in science. I think the biggest factor [for changes in scientific theories] is the advancement of technology.

Researcher: What about the scientific laws? Do they change?

Burak: The change of laws… It [scientific law] can change…. Does it [scientific law] change? But for me, it [changing of scientific law] is hard. Why?... If it [scientific knowledge] has already become a law, the factors or

> all the cases should have been investigated… For example, [in] the scientific communities, scientists discussed there were different perspectives toward scientific knowledge…. I believe it [law] was accepted in this way. It [changing of law] is quite hard, but we cannot say for sure that ‘’Law does not change”. …. I do not know… Does someone say “There is no gravity?” … But there is [gravity]. Was it [law of gravity] accepted?... It [law of gravity] was accepted…. Does everyone believe [law of gravity]?... They [people] believe [law of gravity] ... For example, the buoyancy of water... Archimedes… Does it [the buoyancy of water] exist? yes... ... But laws can be developed. This development happens with time, and with different ways of scientific thinking… which lead to change [in law].

Although he stated that scientific knowledge can change in previous questions, he stated that laws hardly change because it has been already evaluated in terms of every aspect by scientists. By contrast, he thought the theory (i.e., Big Bang theory) as a knowledge that is incomplete and needs to be developed. For example, Burak considered that theories can change due to technological development, and he extended his idea with giving example, such as Big Bang theory. Improvement in technology led scientists to make more detailed observation. Overall, his responses implied that he perceived the law as proven scientific knowledge and the theory as incomplete scientific knowledge. But last question revealed his tendency to accept that laws can be developed through the time, and with different ways of scientific thinking [subjectivity] in turn lead to change in law. He seems to have confusing idea about the nature of scientific laws. His understanding of subjectivity was also clarified by the following question:

> Researcher: Scientists disagree about the causes of global warming. Some researchers say that the continuous use of fossil fuels by humans causes our planet to warm up, while other scientists say that natural forces that have been determining weather conditions for millions of years have caused it [global warming]. From this example, how can scientists reach the different results using the same data? Can you explain?

> Burak: …[Scientists'] perspective… For example, there is a wall here... when you look at these walls [pointing the wall] ... you see that it is painted with white color at the top [of the wall] ... I see the pink color at the bottom [of the wall]. Science is also like that… That is, the differences make science progress and develop. For example, atomic models… [they developed] ... Some scientists said that the atom is indivisible. After then, some scientists said that the atom would be divided. After scientists said "[atom is] divided", scientists found that there is something inside [the atom]. Other scientists added that there is something outside [of the atom]. Then, scientists reached the latest atomic model. Didn't [scientists] look at the same thing? This is perspective…influence of technology. I said that everybody has a different perspective.

Burak's responses gave some information about his understanding regarding both subjective and tentative NOS. First, he addressed the tentative NOS by saying that science can develop and advance with differences. He attributed the reasons why scientists reach the different results using the same data to having different perspectives due to the impact of technology by giving examples about making different interpretations related to atomic models. However, he did not address the impacts of inferences, creativity, social and cultural factors on scientists to reach different conclusion through same data.

> Researcher: Scientists conduct scientific experiments let's say on renewable energy sources or climate change. Do scientists use their own imagination and creativity in their research?
> Burak: Imagination... Of course, imagination has a great importance in science. You need to imagine... You need to think…. You need to inquiry if you want to reach the conclusion in science... You need to do these things…
> Researcher: You said that imagination is very important. At what stages of their research do scientists use their imagination and creativity?
> Burak: People imagine... You can't do anything without imagination. You will imagine for innovation. It would be meaningless to imagine something

has already discovered such as this eraser [pointing the eraser] .... I'm talking about imagination for innovation. [Scientist] should think that "For innovation, I should imagine ". I think that [scientist] can improve existing thing or find new thing. [Scientist] should be constantly in work for innovation or things that beneficial for humanity. Innovation is important, of course, the fruitful one.

This question enlightened Burak's understanding regarding creative and imaginative NOS. He stated that imagination has a crucial role in science and scientists use their imagination to produce something new. However, he did not say anything about the phases that scientists use their imagination and creativity.

> Researcher: Some argue that science is influenced by the values of the society in which it is created such as religion, social, cultural values, philosophical assumptions and intellectual norms. For some, science is universal and independent from concepts such as social, cultural values, philosophical assumptions, and intellectual norms. What do you think about that? Do you think science is independent or influenced by the values of society?
>
> Burak: Frankly, I am not sure.... But, of course, science depends on research, inquiry and so on... at least, social values and religious belief could affect the scientist alone. Scientists always need to do research… But while doing this [research], they [scientists] need to think more broadly, not only within the framework of certain things.
>
> Researcher: Can you give an example that supports your opinion?
>
> Burak: In science, scientist needs to do something concrete [e.g., making experiment] ….to prove for example... Social values and philosophical values are very broad [concept]. For example, he/she [scientist] is going to investigate the DNA. This [investigating DNA] does not contradict with social values. But evolution... It [evolution] is still debating. In such a case, the scientist may conflict with the social norms.

Burak's responses gave some information regarding his understanding about empirical and socio-cultural NOS. His responses indicated that he was undecided regarding socio cultural NOS. For example, on the one hand, he stated that scientists should think generally while doing research by giving example related to the research on DNA. On the other hand, he also stated that scientists are affected from values of society by stating that research on evolution conflicts with social norms. He added that scientific knowledge needs to be proven with concrete things such as making experiment in science.

In the following section, summary of Burak's syntactic knowledge was reported.

4.1.2.2.1 Summary of Burak's Syntactic Knowledge

Overall, Burak's responses related to syntactic knowledge were evaluated based on the interview and classroom observation data together (See Table 4.10). According to the findings, it was found that he had deficiencies related to some NOS aspects. For example, although he believed that scientific knowledge including scientific theory could change with progression in technology, curiosity and having different perspectives, he had difficulty in transforming this view for the law because he was in dilemma whether the law changes. So, his view about tentative NOS was appeared to be influenced by his view about the theory and law. Also, he did not state other reasons of change in scientific knowledge (e.g., reinterpretations of existing scientific knowledge, emerging new evidence). His perception of the law as proven knowledge compared to the theory revealed a common misconception with respect to hierarchical relationship between theory and law. His hesitation whether the greenhouse effect is a law or theory reflected his incomplete understanding. He also was not certain whether science is independent or influenced from the social and cultural values. He had difficulty in explaining creative and imaginative NOS because he did not address the phases of scientific investigation in which scientists use their creativity and imagination. His understanding about empirical NOS showed inconsistency because, although he was aware of the experiment, observation and also making prediction based on available data, he had a common misconception that scientists follow general scientific method containing stepwise procedure. On the other hand, he was able to explain the subjectivity by stating that scientists have different perspectives with the development of technology. He was able to express inferential NOS in the embedded NOS questions. In his teaching of weather and climate, he briefly addressed empirical NOS by highlighting that weather events are depending on prediction, and also addressed that there is no certainty in science.

Table 4.10 *Burak's Responses Related to Syntactic Knowledge*

NOS Aspect	**Example from Burak's Responses**
Tentative NOS	➢ Science is changeable and developing. Nowadays, accessing to information is not a very difficult task by the help of today's technology… In fact, technology is also a science …needs of human beings and nature all contribute to the development of science significantly… ➢ Scientific theory can change… Theories can change with advancing technology... I think it's not surprising that scientists' perspective toward scientific knowledge do not remain the same as technology progresses. ➢ Changing of scientific law is hard. But laws can be developed. This development happens with time, and with different ways of scientific thinking… which lead to change in law.
Empirical NOS	➢ Science is an investigation conducted to reach the truth, to formulate hypotheses, conduct research, to evaluate and…to reach a conclusion. ➢ Experiment is necessary for the development of scientific knowledge. ➢ Meteorologists make measurements regarding weather events. As far as I know, the measuring tools are sent to the certain height in sky to collect data. Temperatures and variations at the certain height are measured at different points… such as the direction of the wind, pressure… Depending on the data, meteorologists make predictions… Meteorologists use their prediction and observations related to weather events to produce results. ➢ Climatology makes prediction in the longer term.

Table 4.10 *(cont'd)*

Subjective NOS	➢ Some scientists said that the atom is indivisible. After then, some scientists said that the atom would be divided. Didn't scientists look at the same thing? This is perspective…influence of technology. I said that everybody has a different perspective. ➢ The technology in the past that examines the sky is not the same as the current technology. I think it's not surprising that scientists' perspective toward scientific knowledge do not remain the same as technology progresses. ➢ But laws can be developed. This development happens with time, and with different ways of scientific thinking… which lead to change in law.
Inferential NOS	➢ Climatologists examine data accumulated in periods of 20-30 years, not in periods of 3-5 years. Climatologists, in general, investigate data related to weather over a long period of time, and then, climatologists produce data by taking their average.
Theory and Law	➢ If scientific knowledge is accepted by the scientific community and whole world, it is called law. If not, or scientific knowledge is still under investigation, it is called theory. In the theory, the final step has not been completed yet. … there is one more step for theory to become law… ➢ Frankly, I don't have any knowledge about whether the greenhouse effect is a theory or law. But it seems a little more reasonable to me that greenhouse effect is a theory. Of course, greenhouse effect is accepted by the entire world now. From this side, greenhouse effect could be the law. ➢ If scientists were sure, global warming would be a law. Therefore, I couldn't decide whether global warming is a law or theory.
Creative and Imaginative NOS	➢ Imagination has a great importance in science. ➢ Scientist can improve existing thing or find new thing. ➢ Scientist should be constantly in work for innovation or things that beneficial for humanity.
Socio cultural NOS	➢ Scientists always need to do research… But while doing research, scientist needs to think more broadly, not only within the framework of certain things. ➢ For example, scientist is going to investigate the DNA. Investigating DNA does not contradict with social values. But evolution... Evolution is still debating. In such a case, the scientist may conflict with the social norms.

4.1.3 Burak's Pedagogical Content Knowledge Regarding the Seasons, Weather and Climate

Burak's PCK was examined in terms of five components of Magnusson et al. (1999) Model of PCK. PCK pre-interviews, PCK post-interviews, classroom observation and teachers' documents were used to examine teachers' PCK.

Burak's responses to the PCK pre-interview questions regarding the seasons, weather and climate topic were summarized in Table 4.11.

Table 4.11 *Burak's PCK Summary on Seasons, Weather and Climate Topic (Adapted from Tıraş (2019))*

Pedagogical Questions (CoRe)	**Burak's PCK Summary**
What you intend the students to learn regarding this idea	The basic points students need to learn in this unit [seasons, weather, and climate] are the formation of the seasons, the factors affecting the formation of the seasons which are the revolution of the Earth [around the Sun] and [Earth's] tilted axis, seasonal changes in life, weather, climate. We expect that the children learn scientific definitions of these concepts and apply in their life.
The importance for the students to know this	These [seasons, weather, and climate topic] are related to life… We are familiar with them from daily life. For instance, they [students] will know how the weather condition is…When does it rain?... When does it snow?... They [students] should need to understand how they need to take precautions in case of the snowing and raining…
Difficulty connected with teaching of this idea	[For me], [teaching this topic] is not difficult because my communication with students is strong.

Table 4.11 *(cont'd)*

Knowledge regarding student thinking which influences teaching regarding this idea	I think that the students do not have any difficulty in understanding [the seasons, weather, and climate topic]. It [misconception] can be about [Earth's] tilted axis. Sometimes students may not understand how the Earth stand as obliqued due to "abstract thinking." Students have learned the Earth and its' structure, layers and atmosphere, planets, Sun and moon in previous grade level [before Grade 8]. They have learned how Earth, planets, Sun, and moon rotate… its' [Earth's] revolution around the Sun. They have learned sunlight, energy, landforms.
Other factor that influences your teaching regarding this idea	We teach our topic and curriculum within the framework of the program given by the MoNE. We apply [the activities] according to the feedbacks provided by students. It [performing drama activity] makes the classroom environment more comfortable. Also, children enjoy it.
Teaching procedures (and particular reasons to use of these to engage with this idea)	We use the textbook approved by MoNE to know our limitations [regarding the seasons, weather, and climate topic]. We use direct instruction. We use demonstration… simulation, smart board. We use EBA. Let's say the topic is the Earth's revolution around the Sun…We show the visuals related to it... the formation of the day and night, the formation of the seasons… In addition, we show videos from the smart board … We do analogy. We use drama… investigation, discussion… [In drama activity], for example, one student animates the Earth; another student animates the Sun. Then, they [students] revolve around each other. Then, we asked [students] to prepare posters… We construct a concept map activity, Then, fill in the blank activity. Because they [teaching methods] facilitate long term retention. I believe those teaching methods make [the seasons, weather, and climate topic] more concrete, make learning easier.

Table 4.11 *(cont'd)*

Ways of ascertaining student understanding or confusion regarding this idea	[I want to assess] whether the objectives [related to the seasons, weather, and climate topic] were learned or not [by the students] … whether we gained students to the ability to interpret.... I like to use different methods in measurement-assessment tools because I want the student not only memorize but also interpret. We ask all kinds of questions about fill in the blank, true/false, test, classic… open-ended, multiple choice… [I assess students' learning] at different times… I frequently use the question-answer method. I administered two written exams within a semester (i.e., general evaluation). One is in the middle of the semester, the other one towards the end of the semester… I do the unit evaluations at the end of each unit.

4.1.3.1 Burak's Orientation Towards Science

Burak's orientation towards science, his belief about goals of science teaching were investigated through pre-interview, classroom observations and analyzed under two categories which are peripheral goals and central goals.

4.1.3.1.1 Burak's Beliefs about Goals of Science Teaching

In this part, Burak's responses regarding beliefs about goals of science teaching in the pre-interview were reported. The interviews data were supported by classroom observation as well (See Table 4.12 and Table 4.13).

> Researcher: According to you, why do we teach science in middle school?
>
> Burak: Science is life... So, we [as a teacher] are actually teaching life in science…we teach living things. We teach what the plant is… why plant is important… what is in the air… what they [students] breathe in the air… what they [students] eat… what it [food] gives to them? Carbon hydrate or protein… If it's protein, we teach them why they [students] need protein… Science is everywhere in our lives. For example, in physic…Children play

football and they [children] learn how to hit the ball and why the ball bounce back. For example, in chemistry… We teach whether the ingredients of the substance are dangerous, or eatable or inedible [for health] … Why are acidic beverages dangerous?... As a result, science is related to life. Therefore, science is indispensable [part of life].

Researcher: What does "science teaching" mean to you?

Burak: For me, science is not just a course… It is more than that... In general sense, we are teaching many things majority of which related to students' daily life experiences. We are teaching about life itself in fact…. in science. For example, how to ferment milk… who makes fermentation, bacteria… We teach that not every fungus found in nature should be eaten. We teach living things in science. I mean we are actually teaching life.

Researcher: In your opinion, what are the goals of science teaching?

Burak: As a science teacher, first of all, my aim is to raise students who love their homeland, and nation as well as do useful things for their country [Turkey]. My goals are for students to be respectful individuals, have high values and like science [as a school subject]. Honestly speaking, these are my priority... To achieve this aim, they [students] first must love themselves and we try for that. He/she must first love himself/herself in order to love science. Undoubtedly, we may also have inadequacies. But like in every profession, [teaching] profession can also be developed. Every year, we try to improve ourselves… We [as teachers] have a long way [in teaching profession].

Researcher: Well, how do you determine these goals?

Burak: Hmmm… These goals were taught to us in school [in university]. In addition, we have personal goals which is influenced by the place where we live...but it is the only one of these factors. Assume that you are living in a village [rural area] … and you are a teacher in that village. Now, the child living in a village should recognize the plant, the animal [compared to those living in the urban area] … [student who lives in a rural area] needs to know what to do with the soil or aware of what happens when he/she pollutes the soil…

[PCK Pre-Interview]

Table 4.12 *Burak's Beliefs about Goals of Science Teaching*

Questions	Burak's Response	Central Goals	Peripheral Goals
According to you, why do we teach science in middle school?	We [as a teacher] are actually teaching life in science…	Schooling goal	-
	We teach living things. We teach what the plant is… why the plant is important…	Subject matter goal	-
What does "science teaching" mean to you?	Science is not just a course… It is more than that... In general sense, we are teaching many things majority of which related to students' daily life experiences. We are actually *teaching life*. For example, how to ferment milk… who makes *fermentation*, *bacteria*… We teach that not every *fungus* found in nature should be eaten.	Schooling goal	-
	We teach *living things* in science.	Subject matter goal	-
In your opinion, what are the goals of science teaching?	As a science teacher, first of all, my aim is to raise students who *love their homeland, and nation* as well as *do useful things* for their country [Turkey]. My goals are for students to *be respectful individuals, have high values* and *like science as a school subject*. Honestly speaking, these are my priority... To achieve this aim, students first must *love themselves*.	Affective goal	-
As a science teacher, what is the meaning of teaching the seasons, weather, and climate topic for you?	We teach *the environment and environmental problems*.	Schooling goal	-
	We teach *the Sun, the Earth and the effect of sunlight*… We can relate the Sun and the Earth with the seasons.	Subject matter goal	-

Table 4.12 *(cont'd)*

Questions	Burak's Response	Central Goals	Peripheral Goals
Why do you teach the seasons, weather, and climate topic as a science teacher?	Frankly, we are teaching because *seasons, weather, and climate topic presented in the science curriculum…* Seasons, weather and climate topic is mandeded…I have *a unit plan* and I should strictly follow that plan. There are *predetermined objectives…*	Subject matter goal	-
What do you expect students to have knowledge and skills by teaching science?	Students *learn the basic knowledge* in the curriculum.	Subject matter goal	-
	Also, for example, the students are at the puberty. Students will grow. In science class, students will learn why they should drink milk. In science course, I expect from students to *learn the effects of environmental problems…*	-	Schooling goal
	In science course, I expect from students to learn why students should behave pro-environmetally and protect the environment, plants, trees, animals and living things …	-	Affective goal

His response to above questions revealed that he mostly put emphasis on subject matter goal and schooling goal. He said that he teaches science in middle school because he teaches life in science, which clearly indicated the association between the science and students' daily life (i.e., schooling goal as central goal). Also, he stated that he teaches the living things such as plants (i.e., subject matter goal as central goal). He emphasized the meaning of science teaching as teaching the knowledge that students can use in their daily life, such as fermentation of milk (i.e., schooling goal as central goal), and the teaching the living things such as fungi, bacteria (i.e., subject matter goal as central goal). His primary goal of science teaching as a teacher is to raise individuals having high moral values or doing beneficial things for the country they live and to educate individuals who love themselves and science (i.e., affective goal as central goal). Lastly, he stated that he determined the goals for teaching science depending on his university education, his own personal goals as well as the place where he lived.

In the following question, Burak was asked about what knowledge and skills he expects from students through teaching science.

> Burak: Hmmm… Students learn the basic knowledge in the curriculum. Also, for example, the students are at the puberty. Students will grow. In science class, students will learn why they should drink milk or what is inside of the vegetables and fruits… or why they should eat [vegetables]. We mention about nutrition because nutrition is one of the most important things for children. [In science course], I expect from students to learn the effects of environmental problems or what will happen if they pollute the environment? or why they [students] should behave pro-environmentally and protect the environment, plants, trees, animals and living things … We teach all of them in science.
>
> [PCK Pre-Interview]

Briefly, he expects from students to learn the basic knowledge in the curriculum, which makes his central goal as subject matter goal. Then, he stated that he expects from students to learn the knowledge related to daily life (i.e., schooling goal as peripheral goal) such as learning why students need to drink milk, eat vegetables and learn environmental problems through science teaching. Besides, he expects from students to protect the environment and living things (e.g., animals, plants, trees) (i.e., affective goal as a peripheral goal), which indicates his tendency toward raising his students as action competent citizens (i.e., dual perspective).

In the following question, Burak was asked about the role of the teacher and the student in science teaching.

> Researcher: How can you define the role of teacher in science teaching?
>
> Burak: I believe that the role of the teacher in all teaching is crucially important. Hmmm… Teacher is a character. For example, you watch a series or movies if you like the character. I believe that the teacher is very important. Our students are a value and they are our future… I value students. Therefore, I always prefer to behave students friendly and by giving a value …. [If the students like their teachers], the students do most things willingly because they do not want to lose [their teachers'] sincerity and respect…. As I said, everything is happening with sincerity…. [For me] the teachers and their characters are very important… [For example], parents' attitude towards their child determines that child's attitude at home. To conclude, all of the students are value… all of them are precious for us. We try to know the value of our students.
>
> Researcher: What about the role of the student in science teaching?
>
> Burak: The student's role is important because in science lesson, experiments can be performed. [Students'] active participation [to the lesson] is important… the students' questions are important… You can transmit knowledge directly, but students ask many questions such as "Why we did it?... How it happened? ...". Of course, we want the active participation of the student [to the lesson]. [However,] if students do not ask questions, we cannot create an active lesson… and we really don't want such a teaching environment. At least for myself, I always encourage students to be active in

the lesson… the students will ask, speak… Students speak where they feel themselves comfortable. [Therefore,] students should be comfortable [in the learning environment]. People feel themselves comfortable in a friendly atmosphere … This is the most critical point for the student. The student should be comfortable in my lesson and therefore, [the learning environment] should be friendly … the teacher should be friendly.

[PCK Pre-Interview]

He underlined the importance of both creating a friendly and comfortable learning environment, valuing the students and ensuring students' active participation.

In the following question, Burak was asked what he does maximize student learning in the classroom. From Burak's perspective, a comfortable and enjoyable environment is needed for students to maximize their learning in the classroom. He thought that students' learning levels can reach the advance level if they found learning environment comfortable and happy. He claimed the importance of *"teaching love and respect"* to grow students properly as well.

Researcher: How do you do to maximize student learning in your classroom?

Burak: Hmmm… My first priority is this; [creating a] comfortable and friendly atmosphere, having a smile on our face… this is the most important thing for me. I try to make as enjoyable lesson as possible; because the students can move their learning to next [higher] level where they feel comfortable and happy. Students listen their lesson when they are in a peaceful and comfortable environment. After all, they [students] are children and they are valuable… they are our future. We have to teach with love [by heart] and respect to pointing students in the right direction. It is easier to overcome difficulties in an environment which includes love and respect… [We can overcome many difficulties] with comfortable and friendly atmosphere… with the right methods and techniques, with smiling face, understanding and tolerance…

Researcher: How do you know when your students understand?

> Burak: I can understand what students have learned from their eyes. [That is], I notice students who don't understand [the lesson] from their glances… I've never been wrong until now. The student who understands the lesson glance more assertively… We understand this through our experience over time. Of course, we have long ways [in teaching profession to improve ourselves]. But, if I create a comfortable environment with the students and behave naturally, it will be easier for me to understand the students. [Thus], I more easily understand their reactions because I know the student...
>
> [PCK Pre-Interview]

He claimed that he understands whether the students understood the topic from students' body language, which he gained through his experience develop over time. To him, teachers should create a comfortable and natural learning environment to both recognize students and understand their reactions.

Burak, then was asked how he decides what to teach or not teach in the school setting. He argued that MoNE determine what he teach and does not teach in the school environment, and accordingly he teaches the topic based on the goals and targets presented in MoNE program. In addition, he was found to attach importance to the concept of dual perspective by stating that he teaches social values and right behaviors on behalf of the society with the responsibility of being a teacher (e.g., respecting people, keeping the environment clean).

> Researcher: Well, in the school setting, how do you decide what to teach and what not to teach?
>
> Burak: We have target and goals which are offered by Ministry of National Education [MoNE]. Thus, we teach our topic and curriculum within the framework of the program given by the MoNE. We teach social values such as respecting and loving people, loving nature, loving elders and children, being [a responsible] an individual and being helpful... After all, if you are a teacher, you have to teach the right things for society. … For instance, we teach not to throw rubbish on the ground, to keep the environment clean, to

help an elderly person getting across the street, or to give our seat to elder persons if we are on a bus or on subway....

Researcher: So, how do you decide when to move on to a new topic in your classroom?

Burak: When learning takes place, we can move on to the new topic. However, if not, we can extend the time allocated for the topic until it is understood by students. … due to the spiral nature of the science, students should learn the concept successfully in the previous grade. Otherwise, the students will have difficulty. Everyone's learning capacity is not the same… there are individual differences. They [students] can ask questions easily if don't understand the topic…

[PCK Pre-Interview]

Lastly, Burak was asked how students learn science best. According to his view, students learn the science best through doing research, experiment, discussing and questioning in general. But he added that the best way of learning science show variation based on the topics. For example, he stated that while he uses visuals, smart board and performs poster activity in teaching of the seasons, he performs experiments in teaching of acid and base topics in chemistry. In addition, he mentioned that the fact that students do not smile and not react is an indicator that they have difficulty in understanding the topic. The related excerpts from the interview were as follows;

Burak: Hmmm… It [way of learning science best] may vary according to the topic. We don't have much chance to make experiment in the seasons. [Instead], for example, we use more visuals... we use the smart board… we use technology… we want them [students] to investigate… For example, I have students prepare posters. [On the other hand], we can do experiments regarding acid, base, pH measurements in chemistry… we can do experiments in physics… Of course, the techniques and methods can change depend on the topic… [We are] not use single method and technique. However, I usually believe that when I teach, I need to smile. If I smile, my student smiles mean he/she understands [the topic]. If he/she does not smile, I understand that he/she has difficulty in understanding the topic… for me, this is a great alerter. For instance, if he/she doesn't react to something and if he/she does not smile, then I know that there's something goes wrong… for me, that's a method.

Researcher: In general, how do you think your students learn best when you think about science?

Burak: Hmmmm… [Students learn the science best] by researching, questioning, experimenting, discussing and listening to lessons.

[PCK Pre-Interview]

As well as collecting information regarding Burak's beliefs about goals of science teaching via pre-interviews, researcher besides gathered data via classroom observation in order to further understand his beliefs about goals of science teaching. Briefly, his pre-interview data showed that he underlined the subject matter goals and schooling goals as central goals, and affective goals were seemed to be peripheral goals. Burak's beliefs about goals of teaching in the context of seasons, weather, and climate was unveiled.

Researcher: As a science teacher, what is the meaning of teaching the seasons, weather, and climate topic for you?

Burak: These topics [seasons, weather, and climate] are taught in geography in high school. We teach the environment and environmental problems. Therefore, we teach the Sun, the Earth and the effect of sunlight… We can relate the Sun and the Earth with the seasons. For that reason, this topic [seasons, weather, and climate] is common in geography and science curriculum. [Therefore,] this topic is important of course...

Researcher: Why do you teach the seasons, weather, and climate topic as a science teacher?

Burak: Hmmm… Frankly, we are teaching because seasons, weather, and climate topic presented in the science curriculum… It [seasons, weather, and

> climate topic] is mandated…I have a unit plan and I should strictly follow that plan. There are predetermined objectives… We teach the science according to the objectives determined by the Ministry of National Education within the scope of the annual plan. If seasons unit is presented in our textbook, we should teach it [seasons unit]. Our aim is to teach [objectives/concepts] correctly and understandably way…
>
> [PCK Pre-Interview]

When asked the meaning of teaching of the seasons, weather, and climate topic for him, he emphasized that he teaches the concepts in seasons, weather, and climate topic such as the Sun, the Earth, seasons (i.e., subject matter goal as a central goal). Then, he associated this topic with daily life by giving example such as teaching environmental problems (i.e., schooling goal as a central goal). From this response, it can be stated that he attaches importance to the concept of *"dual perspective"* and so, has a tendency to grow his students as action competent citizens. Furthermore, he pointed out that seasons, weather, and climate topic is an interdisciplinary topic because of located in both geography and science curriculum. When asked why he teaches the seasons, weather, and climate topic, he explained that he teaches this topic due to existed both in teachers' annual plans and in the curriculum, which implied the subject matter goal as central goal.

While teaching the seasons, weather, and climate topic, in line with his belief stated above, he frequently focused on the subject matter knowledge and aimed to transmit the related curriculum objectives to the students. Therefore, it can be concluded that his subject matter goal was observed as central goal during his teaching. A related excerpt is shown below;

> Burak: Wind is a weather event. Snowy, sunny, rainy are related to weather forecast. The main cause of precipitation is humidity… We should know that. Water vapor means humidity. Humidity means water vapor. We will divide the rain as rainfall close to the sky and rainfall close to the Earth's surface. Some rainfall is close to the sky while some are close to the Earth's surface... actually, we know them. What is the rainfall that close to the sky?

S_1: Rain.

S_2: Snow.

S_3: Hail.

Burak: What is the rainfall that close to the Earth's surface?

S_4: Dew.

S_5: Rime.

S_6: Fog.

[Classroom Observation]

Additionally, he stated that;

"Wind was asked as a question in High school entrance exam (i.e., LGS). The question about this concept will be asked in the exam.".

By drawing the figure of the Earth on the blackboard, he said that;

"You should need to think of the Earth in three dimensions. You should think the shape of the Earth as geoid. The shape of the Earth will be asked in the exam.".

As clearly seen, in contrast to his reported PCK, his enacted PCK showed that his schooling goal regarding the preparing students to High school entrance exam was central goal. He, also, encouraged students to use the science textbook approved by MoNE claiming that the questions in the nation-wide exam were asked within the scope of the curriculum. Hence, it can be concluded that he primarily aims to draw students' attention to high school entrance exam.

In contrast to his reported PCK, his enacted PCK indicated that the relationship between the seasons, weather, and climate topic and daily life was observed as a peripheral goal in his teaching (i.e., schooling goals). For example, he gave brief information about meteorology, and its' importance on daily life. A related excerpt is shown below;

> Burak: Meteorology is a science discipline that examines weather events and informs you about weather events. [Meteorology says that] “It's going to rain, or it's going to snow”. [For example, at last evening] meteorologist warns [us] that in Istanbul, it is going to snow today at 6 a.m. Didn't you watch the weather forecast?
>
> S_1: I watched.
>
> Burak: [Meteorologists] make minute-by-minute predictions. Meteorology is really good at making predictions. [For example], we have a match on Tuesday… I look at the weather forecast [from mobile phone] … choose the province… then the country… [and search for] “Is there rain between 19-20 p.m.?... [If so] when will the rain stop? ...” Meteorologist says all of that information. Why is it [weather forecast] important? For example, there was flood in the country [Turkey] in summer... or assume that you get stuck in traffic [in a snowy day]. A driver without snow tires causes this traffic jam [on the roads] because he didn’t check the weather forecast. [Thus] weather forecast is important… it [weather forecast] is related to our lives.
>
> [Classroom Observation]

Researcher also observed the indication of affective goal as peripheral goal in the classroom observation. He attempted to raise awareness about the environmental problems by briefly touching upon the environmental problems and precautions taken to prevent them, such as behaving pro-environmentally, using natural gas instead of coal, not throwing garbage to the classroom (detail information will be mentioned under Burak’s dual perspective section). Overall, this affective goal revealed his effort to integrate *the concept of dual perspective* into the lesson and the importance he gave to raising his students as action competent citizens.

Table 4.13 indicates Burak’s beliefs about goals of science teaching based on classroom observation during the seasons, weather, and climate topic.

Table 4.13 *Burak's Beliefs About Goals of Science Teaching Based on Classroom Observation*

Beliefs About Goals of Science Teaching	**Central Goals**	**Peripheral Goals**	**Example**
To convey the objectives	Subject matter goal	-	Teaching the weather events such as rain, snow
To prepare students to high school entrance exam	Schooling goal	-	Emphasizing that the concept of wind can be asked as a question in the high school entrance exam
To establish a relationship between seasons, weather and climate topic and daily life	-	Schooling goal	Giving information about meteorology and its' importance on daily life
To raise the students' awareness towards the environmental problems	-	Affective goal	Emphasizing the behaving pro-environmentally

All in all, his pre-interview responses revealed that his subject matter goals and schooling goals were central goals. In the classroom observation, his subject matter goals were found as same. Contrary to his pre-interview responses, it was observed that his schooling goals as central goals were revealed as different (i.e., equipping students toward high school entrance exam). His schooling goal (i.e., establishing relationship between the daily life and the seasons, weather, and climate topic) and affective goal were observed as peripheral goals because these goals were less emphasized in his teaching.

Following part, next component of PCK which is knowledge of curriculum is presented.

4.1.3.2 Burak's Knowledge of Curriculum

Burak's knowledge of curriculum, with collected data through pre-interview, teacher documents and classroom observation, was reported under two sub-titles as knowledge of goals and objectives and knowledge of materials in this section. At first, Burak's knowledge of goals and objectives about the seasons, weather, and climate topic was summarized.

4.1.3.2.1 Burak's Knowledge of Goals and Objectives about the Seasons, Weather, and Climate

All data sources revealed that experienced science teacher was found as knowledgeable about goals and objectives about the seasons, weather, and climate. For example, he correctly expressed all objectives determined by the MoNE, identified the vertical and horizontal connections, in addition to preceding and following topics. He correctly stated that any misconception was not mentioned regarding the seasons, weather, and climate topic in the curriculum. However, he went beyond the curriculum by giving some advance knowledge such as the formation of typhoon and tsunami.

In the following question, Burak was asked questions about the place of seasons, weather, and climate topic in the curriculum, its relation to other topics, units or classes in the curriculum. (i.e., vertical and horizontal curriculum).

> Researcher: Do you know the place of the seasons, weather, and climate in curriculum?
> Burak: Eighth grade level… First unit.
> Researcher: You stated that it is the first unit. What are the topics taught after this unit [seasons, weather, and climate]?
> Burak: We are starting to DNA [topic] in second unit.
> Researcher: Is there any science topic taught in earlier grades related to the seasons, weather, and climate?

Burak: Hmmm… Of course, it [seasons, weather, and climate topic] is associated [with topic taught in earlier grades]. For example, in previous grades [before Grade 8], we teach the Earth and its' structure, layers and atmosphere… Then, we teach the moon, the Sun, the planets, the Earth's rotation around itself, and its' [Earth's] revolution around the Sun…. Now, when we come to the 8^{th} grade level, we teach what happen when Earth rotates around itself… what happen when it [Earth] revolves around the Sun… and the tilt of [Earth's] rotation axis….

[PCK Pre-Interview]

Similarly, during teaching, he mentioned about the Earth's movements as well as the formation of day and night taught in 4^{th} grade level. Related dialogues occurred between the teacher and students were as follows;

Burak: We started to the lesson with two kinds of Earth's movements. What happens when the Earth rotates on its' axis?

S_1: Day and night occur.

S_2: Daily temperature differences occur.

Burak: Well, what happens when the Earth revolves around the Sun?

S_3: The seasons occur.

Burak: Is there any other factor affecting the formation of seasons?

S_4: The coming of the sun's rays with different angles to the Earth due to Earth's tilted axis.

[Classroom Observation]

During teaching, he mentioned about the Earth's shape taught in 3^{rd} grade level asking the question *"At first, let's start with the shape of the Earth. What is the shape of the Earth?"*, and then, one of the students responded as *"Geoid"*. He also drew the figures of the Sun and the Earth depending on their real size on the blackboard in order to show their size differences between them (See Figure 4.6). After drawing the figures on the blackboard, he stated that;

Burak: We are sorting by their size; the largest one is Sun… then, moon… then, Earth.

[Classroom Observation]

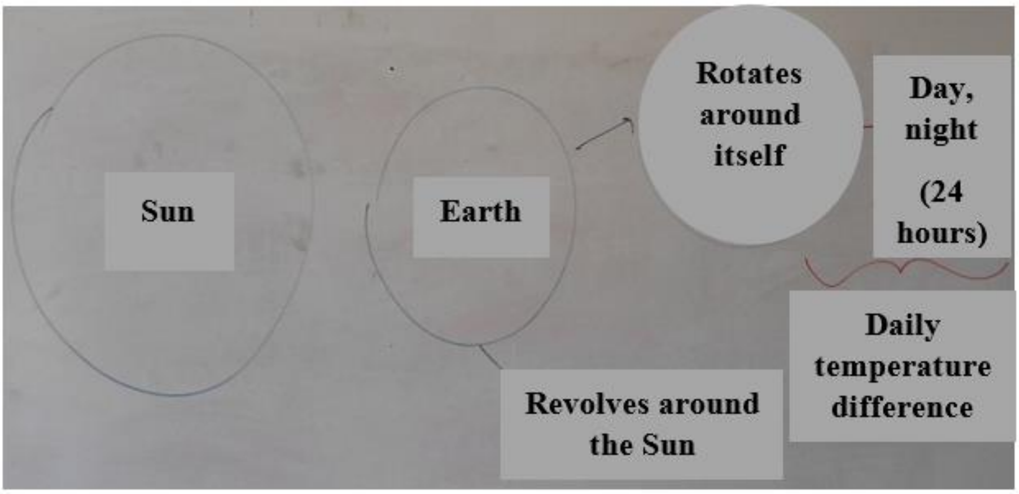


Figure 4.6 Burak's Drawing about the Earth and the Sun

Moreover, he touched on the concept of rain has been taught since primary school (i.e., 5th grade level), and following touched on the concept of *lunar eclipse* taught at 6th grade level. Lastly, he touched on the *mixtures topic* at 7th grade level and for example, in his teaching, the dialogues between teacher and students were occurred as follows;

Burak: Is air a compound? We have learned that in mixtures topic at the 7th grade level.
S_1: No.
Burak: Air is a homogeneous mixture. What's in it? Nitrogen, oxygen, other gases.
S_1: Water vapor.

[Classroom Observation]

In the next question, his knowledge on horizontal relations of seasons, weather and climate topic in the curriculum was asked.

> Researcher: Is there any science topic taught in 8^{th} grade level related with seasons, weather, and climate?
>
> Burak: It [seasons, weather, and climate topic] can be related to the environmental topics in the 8^{th} grade curriculum.

[PCK Pre-Interview]

He associated the environmental topics located in 8^{th} grade level with the seasons, weather and climate topic. Similarly, during teaching, he mentioned about the global warming and the greenhouse effect in *Matter cycles and Environmental problems topic* in 6^{th} unit of same grade level (i.e., 8^{th}). His emphasis on these environmental problems and the precautions to be taken to prevent these problems points to his attempt to raise his students as action competent citizens, which indicates his tendency to integrate the dual perspective into his teaching. For example, he stated that;

> Burak: As a result of global warming, climate change occurs…. The glaciers are melting… the sea level rises… The air temperature changes….

[Classroom Observation]

Overall data revealed his awareness about place of the topic, the horizontal, and vertical relations. After correctly determined the place of the topic in the curriculum, he mentioned the Earth (e.g., its' structure, layers, and atmosphere), the moon, the Sun, the Earth's rotation around itself, the Earth's revolution around the Sun and the planets prior to Grade 8 as vertical relation. Similarly, in his teaching, he addressed *the Earth's shape* in 3^{rd} grade level, *the movements of the Earth* and *the formation of day and night* in 4^{th} grade level and then, the relationship among the size of the Earth, Sun and moon in *The Sun, Earth, and Moon* unit in 5^{th} grade level. Also, he addressed *the lunar eclipse* in 6^{th} grade level and *mixtures* in 7^{th} grade level. As horizontal relations, briefly, he correctly stated that seasons, weather, and climate topic is related to environmental problem topic in the 8^{th} grade level. As he stated, while teaching the unit, he addressed to the concepts of the global warming and greenhouse effect that located in sixth unit named as *Matter cycles and Environmental problems* in 8th grade level (See more in substantive knowledge section). It can be concluded that his reported PCK and enacted PCK seem to be consistent in general (Table 4.14).

Table 4.14 *Summary of Burak's Knowledge of Vertical and Horizontal Relations of Seasons, Weather and Climate Topic in the Curriculum*

Burak	**Vertical Relations**	PCK Pre-Interview	The Earth's structure and layers (3rd grade) The Movements of the Earth (4th grade) The Sun, Earth, and Moon (5th grade) The planets (6th grade)
		Classroom Observation	The Earth's shape (3rd grade) The Movements of the Earth (4th grade) The Sun, Earth, and Moon (5th grade) The concept of rain (5th grade) Lunar Eclipse (6th grade) The Mixtures (7th grade)
	Horizontal Relations	PCK Pre-Interview	Environmental topics (8th grade)
		Classroom Observation	Matter cycles and Environmental problems (8th grade)

Researcher: What are the objectives with respect to seasons, weather, and climate found in curriculum?

Burak: [The objectives are] the formation of the seasons, the causes [of the seasons], climate, the factors affecting the climate, weather events, the factors affecting the weather events, how weather events occur... the scientists and science disciplines dealing with the climate and weather events, what scientists do… We can briefly mention about them…

[PCK Pre-Interview]

Among three objectives, Burak identified two of them in the interview. The objective, he didn't mention was about *"the difference between climate and weather* *events" (MoNE, 2018, p. 47).* In his lesson, *however*, he explained the differences between weather events and climate by drawing a table (See Table 4.3). Therefore, it was concluded that he was aware of all objectives of the seasons, weather, and climate. Burak's understanding of objectives regarding the seasons, weather, and climate was depicted in the Table 4.15. This table also indicated consistency and inconsistency between his reported PCK and enacted PCK.

Table 4.15 *Burak's Understanding of Objectives Regarding the Seasons, Weather, and Climate*

Objectives Stated in the Science Curriculum (MoNE 2018, p.47)	**Interviews**	**Does Burak's response meet the curriculum objectives? (Classroom Observations)**
"8.1.1.1. Make predictions about the formation of seasons."	Mentioned	Mentioned
"8.1.2.1. Explain the difference between climate and weather events."	Not mentioned	Mentioned
"8.1.2.2. State that climate science (climatology) is a branch of science and that experts working in this field are called climate scientist (climatologist)."	Mentioned	Mentioned

Researcher: Well, could you sort the objectives based on their importance?

Burak: Of course, all the objectives are important. [However], it is important to know the order in which you should teach the concepts. For example, it is not logical to teach the concept of "climatologist" without teaching the climate… First, you should teach the climate…. what is climate?... what is affected by the climate?... Then, you should teach the concept of "climatologist".

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

Burak: No. I think the [seasons, weather, and climate] topic taught already is quite sufficient for the middle school children.

[PCK Pre-Interview]

From Burak's perspective, all objectives are important and therefore, he did not range the objectives related to the topics in any order like from most important one to less important one. However, he emphasized that the seasons, weather, and climate topic should be taught in logical order such as teaching the concept of climate followed by the concept of climatologist. He stated that there are not any other important points about the seasons, weather, and climate topic other than the existing objectives in the science curriculum and added that the current objectives are adequate for the students.

In the following question, Burak was asked whether there are limitations regarding the seasons, weather, and climate topic in the science curriculum.

Researcher: Is there any limitations implied in curriculum regarding the seasons, weather and climate?

Burak: Hmmm…We teach the Earth's rotation around its' axis and the Earth's revolution around the Sun. For example, other planets also rotate… or there may be lots of factors affecting the climate… I think that all of these details do not need to be taught during the lesson. Meteorology and climatology are science disciplines, but I think that they [meteorology and climatology] do not need to be taught in detail during the lesson.

[PCK Pre-Interview]

His degree of knowledge prescribed in the curriculum was examined through his classroom observation data. It was revealed that he mentioned some advance knowledge related to weather events by going beyond the curriculum. As an example, these advance knowledges that he mentioned are as follows:

It [typhoon] occurs when the ocean water are 27-28 degrees.

Tsunami occurs as a result of earthquake and sliding in the Earth's crust in the ocean.

(taught in Grade 10 Geography curriculum).

In the following question, Burak was asked whether there is misconception about the seasons, weather, and climate topic in the science curriculum. He correctly stated that there is no misconception stated in curriculum regarding the seasons, weather, and climate. However, in his teaching, he mentioned about misconception about the seasons. For example, when he asked the factors that affect the formation of seasons, one of the students responded as the rotation of Earth around own axis. Then, he tried to eliminate this misconception by stating that "Earth's rotation [around itself] causes the formation of day and night, and daily temperature differences occur.". Another student stated that distance of the Earth to the Sun has an impact on the seasons. Then, he tried to eliminate this misconception by stating that there is no relation between distance of the Earth to the Sun and the formation of seasons (See more detail in Burak's knowledge of students' difficulties section).

Researcher: In your view, why do seasons, weather, and climate topic place in curriculum?

Burak: These [seasons, weather, and climate topic] are related to life… We are familiar with them from daily life. For example, you are in outside and [therefore], you need to know whether the weather is rainy, snowy, sunny. [For example], why the weather is cold?... why we live the winter?... They [students] should need to know. We teach them in science course because this topic [seasons, weather, and climate] was included in both geography and science curriculum. Also, now, this is the first time we will teach this unit [seasons, weather, and climate] as a first topic with the change of the curriculum [in MoNE 2018] because this topic was presented in last units in previous curriculum [i.e., MoNE 2013] … [For me], [teaching this topic] is not difficult because my communication with students is strong.

Researcher: So, what do you intend the students to learn about the seasons, weather, and climate unit?

Burak: The basic points students need to learn in this unit [seasons, weather, and climate] are the formation of the seasons, the factors affecting the formation of the seasons which are the revolution of the Earth [around the Sun] and [Earth's] tilted axis… these are important. The most basic knowledge that students should learn is how the seasons form. That is, students should learn why do we have summer or winter, why it blooms in the spring and fades in the autumn. They [students] need to associate them with adaptations. They [students] need to know the factors affecting the climate and what the climate is. Students need to know why people living in Antalya* rarely see snow... why people living in Ankara** and Erzurum*** see snow more. They should listen and watch the weather forecast more carefully every day. When they watch weather forecast, they should need to know the precaution to be taken toward any weather condition.

[*****_The city is located in Mediterranean region in Turkey_;

****** _The capital city is located in Central Anatolia region in Turkey_;

******* _The city is located in Eastern Anatolia region in Turkey_].

Researcher: Well, for you, what are the important ideas in this topic for students to grasp?

Burak: The factors affecting the formation of seasons are important… climate, the factors affecting climate, Earth's revolution around the sun… These concepts are also important. The concepts [in seasons, weather, and climate topic] are abstract and they [students] frequently ask "What is the value of this knowledge?". Therefore, it is important where the students will use [the knowledge related to seasons, weather, and climate topic] in daily life and how students will benefit from it. After students learn the information [related to the seasons, weather, and climate], I expect from the students to make their life easier, to take responsibility… Weather, climate, seasons, seasonal changes in life, raining… We expect that the children learn scientific definitions of these concepts and apply in their life… That's the most important point for me… Information is important, but the use of information is also important.

Researcher: How did you come to identify these ideas?

Burak: These are already located in the main plans of MoNE. The most important thing how I teach these [topics] best... This is the most critical point for me.

[PCK Pre-Interview]

According to him, seasons, weather, and climate topic is included in the curriculum because this topic is intertwined with everyday life. For example, he mentioned that he expects from students to be aware of the phenomena taking place in the environment (e.g., why winter is experienced). He also pointed out the interdisciplinary nature of the topic by saying that this topic was located both in geography and science curriculum. Therefore, he thought that students should need to learn this topic. Moreover, he mentioned that he will teach this topic as a first unit for the first time with the changes made in the curriculum [i.e., MoNE 2018]. He expressed that the factors affecting the formation of seasons, climate, the factors affecting the climate and Earth's revolution around the sun are the crucial concepts that students need to learn in addition to use of this knowledge in daily life. Moreover, he addressed to the concept of "weather forecast" and he wants students to be aware of the weather forecast. By learning these concepts, he added that he expects from students to take responsibility in their daily life and facilitate their life. These concepts are compatible with the objectives related to the seasons, weather, and climate topic stated in the science curriculum.

Researcher: What are the advantages to learn the seasons, weather, and climate topic for students? What are the contributions for students?

Burak: I believe that they [students] will listen the weather forecast more meaningfully. I believe that they [students] will be more cautious toward weather condition when going out… For instance, they [students] will know how the weather condition is…When does it rain?... When does it snow?... They [students] should need to understand how they need to take precautions in case of the snowing and raining… They [students] should know what the hail is. For example, when he/she wakes up in the morning and he/she sees wet in the top of the leaves and the grass, he/she should know that it is not a rain, actually it is a dew. It is important for them to notice the natural beauties and discover them.

[PCK Pre-Interview]

While explaining the advantages of learning the seasons, weather, and climate topic, he emphasized the relationship between this topic and its' use in daily life. From his perspective, students will follow the weather forecast more meaningfully and take precautions against weather conditions thanks to learning this topic. Moreover, he drew attention to the importance of discovering and being aware of the phenomena occurred in nature for students such as rain, snow, hail, dew.

In the following part, Burak's knowledge of materials as a sub component of knowledge of curriculum is presented.

4.1.3.2.2 Burak's Knowledge of Materials

In this section, to reveal his knowledge of materials, Burak was asked which resources he uses in the lesson in the pre-interview.

Researcher: What are the sources that you use in the seasons, weather, and climate topic?

Burak: Textbook [approved by MoNE]. We don't use any source book.

Researcher: Well, for what purpose do you use textbook?

Burak: Hmm… We use the textbook approved by MoNE to know our limitations [regarding the seasons, weather, and climate topic]. What we teach?... How we teach?...

[PCK Pre-Interview]

Similar to his reported PCK, his enacted PCK showed that he used science textbook approved by MoNE frequently, and asked students to read related points from the science textbook. The students' science textbooks were always on their desks throughout the lesson. He, also, gave homework to the students from the science textbook and he wanted the students to draw the figures (e.g., about the Earth's revolution around the sun) found in the science textbook to their notebooks. In addition, he wanted students to do the unit evaluation questions included at the end of the seasons, weather, and climate topic in the science textbook. (See Table 4.16).

Table 4.16 *Burak's Knowledge of Materials*

Sources that teacher use	**Aim of using source (PCK Pre-Interview)**	**Classroom Observation**
Science Textbook [MoNE, 2018]	To know our limitations regarding the seasons, weather, and climate topic. ▪ What we teach?... ▪ How we teach? ...	The science textbook approved by MoNE was used. From the textbook; ▪ homework was given, ▪ the visuals were shown, ▪ readings were done.

In the next part, Burak's knowledge of students' understanding of science is presented.

4.1.3.3 Burak’s Knowledge of Students’ Understanding of Science

Burak’s knowledge of students’ understanding of science regarding the seasons, weather, and climate topic was reported under two sub-dimensions as knowledge of requirements for learning and knowledge of students’ difficulties. The data regarding Burak’s knowledge of students’ understanding of science were collected with using pre-interview and classroom observation.

4.1.3.3.1 Burak’s Knowledge of Requirements for Learning regarding the Seasons, Weather, and Climate

In this section, Burak’s knowledge of requirements for learning regarding the seasons, weather, and climate topic was reported.

> Researcher: What kind of prerequisite knowledge and skills do you think students need to learn the seasons, weather, and climate topic successfully?
>
> Burak: Students have learned the Earth, planets, Sun and moon in previous grade level [before Grade 8]. They have learned how Earth, planets, Sun, and moon rotate… they have learned sunlight, energy, landforms ...
>
> [PCK Pre-Interview]

Findings revealed his awareness about the students’ prerequisite knowledge. For example, in the interview, he correctly mentioned that students should know the concepts of the planets, Earth, Sun, moon, sunlight, energy and the movements of the planets as prerequisite knowledge. While teaching the unit, he started to teach the seasons, weather, and climate topic by reminding students that *the Earth, Sun and Moon* topic were located in 5th grade in the science curriculum and drew the Sun and Earth on the blackboard by taking their real size into consideration. This helps students appreciate the differences in their size relative to each other (See figure 4.6). Moreover, he mentioned about other concepts that the students have learned at the previous grade levels such as *the Earth’s shape* at 3rd grade level, *the movements of the Earth* at 4th grade level, *the concept of rain* at 5th grade level, *lunar eclipse* at 6th

grade level, *mixtures* at 7th grade level (See detail in vertical relations in knowledge of curriculum section). Table 4.17 shows Burak's knowledge of requirements for learning about the seasons, weather, and climate topic. This table also indicated consistent as well as inconsistent points between his reported PCK and enacted PCK.

Table 4.17 *Burak's Knowledge of Requirements for Learning*

	PCK Pre-Interview	**Classroom Observation**
Burak's knowledge of requirements for learning	The Earth, planets, Sun and moon The rotation of Earth, planets, Sun, and moon Sunlight Energy Landforms	The Earth's shape (3rd grade) The Movements of the Earth (4th grade) The Sun, Earth, and Moon (5th grade) The concept of rain (5th grade) Lunar Eclipse (6th grade) The Mixtures (7th grade)

Burak's knowledge of students' difficulties as a sub component of knowledge of students' understanding of science is presented in the following part.

4.1.3.3.2 Burak's Knowledge of Students' Difficulties regarding the Seasons, Weather, and Climate

Burak's knowledge of students' difficulties regarding the seasons, weather, and climate topic was reported.

> Researcher: Now I want to talk about the students' think about the seasons, weather, and climate topic. Can you tell me about which difficulties do students have while learning the seasons, weather, and climate topic?
>
> Burak: I think that the students do not have any difficulty in understanding [the seasons, weather, and climate topic]. This is not a topic that children have difficulty in understanding.

Researcher: Do your students have misconceptions about the seasons, weather, and climate? If yes, what are the students’ misconceptions regarding the seasons, weather, and climate?

Burak: It [misconception] can be about [Earth’s] tilted axis. Sometimes students may not understand how the Earth stand as obliqued. But in general, there's no misconception.

Researcher: What are the sources of those misconceptions?

Burak: …Due to "abstract thinking." In other words, the children have difficulty in animating what they [children] cannot see...

Researcher: How do you identify students’ misconceptions? Which methods do you use to identify misconceptions?

Burak: Students’ misconceptions can be identified during discussion with dialogue. While eliciting their prerequisite knowledge by asking questions like "What do you think? What can you do? What do you know? ", the misconceptions reveal, if there are… or you can use the concept map.

Researcher: Do you eliminate students’ misconceptions?

Burak: Of course.

Researcher: How do you eliminate students’ misconceptions regarding the seasons, weather, and climate?

Burak: Before teaching the correct concept, it should be detected first. … and we should assess the students. We explain scientifically correct ideas... We discuss their [students’] wrong ideas… We.... We continue teaching until they [students] have persuaded… We show the many models… We can give different examples until they [students] have understand.

Researcher: Do you think that those methods are enough to eliminate misconceptions?

Burak: In general, these methods are enough to eliminate misconceptions since there are not many students who have misconceptions.

Researcher: Well, why do you think it's enough?

Burak: According to the children's feedbacks.

Researcher: How do learners' difficulties and misconceptions in the seasons, weather, and climate topic influence your teaching?

Burak: As I said, they [students] have not many misconceptions. Therefore, they [students' difficulties and misconceptions] do not affect [my teaching].

[PCK Pre-Interview]

During the interview, he considered that students have no difficulty in understanding the seasons, weather, and climate topic. But he stated that they have misconception about the Earth's tilted axis which can be stemmed from abstract thinking. He added that he identifies students' misconceptions using concept map, discussion with dialogue, and asking questions, and that he eliminates those misconceptions through discussion, explaining concepts correctly, giving examples and showing models. He stated that the methods that he uses to eliminate misconceptions are enough and the feedback receiving from the students made him think so. Moreover, he argued that students do not possess many misconceptions and therefore, his teaching will not be affected.

Contrary to his pre-interview response, during the dialogues occurred with the students in his lesson, he noticed from students' responses that they had difficulty in understanding the causes of the seasons. For example, one of the students stated that *"I could not understand the Earth's revolution around the sun and [the Earth's] tilted axis that cause the seasons to occur."*. So, in order to eliminate their learning difficulties, he tried to show the causes of seasons by role playing activities. In these activities, one of the students animated the Earth, the other one animated the Sun, and then students demonstrated the revolution of the Earth around the Sun, in turns how the seasons occur. Then, he made an analogy to enable his students to comprehend the role of Earth's tilted axis in the formation of seasons. Regarding this analogy, the dialogues were occurred between teacher and student as follows;

Burak: I am the Earth, this [all wall of the classroom] is the Sun. According to you, if I [always] looked at the wall [the Sun] like that (Looking at the wall upright), what would happen?

S_1: It would be only one season for there… there wouldn't be another season.

Burak: What would happen if the [Earth's] axis were not tilted?

S_2: Winters and summers would be lasted very long.

S_3: There would be no temperature differences. Sunlight would fall everywhere at right angles.

S_4: It would be day and night all the time.

S_5: It [sunlight] would fall intensely on the Earth.

Burak: The Sun is a source of heat and light energy. If I [he represented himself as Earth] stood up as upright, it [sunlight] would always fall at the same angle. If I [Earth] stood obliquely, it [sunlight] wouldn't come with the same angle.

[Classroom Observation]

During the exam performed in the classroom, he also noticed that students had another difficulty related to the difference between [the Earth's] rotation axis and revolution axis. Accordingly, to overcome their learning difficulty, he explained the concept scientifically by drawing about the Earth's rotation around its' axis and revolution around the Sun. For example, he said that;

The axis of rotation is the rotation of the Earth around its' axis. The axis of revolution is the revolution of the Earth around the Sun.

[Classroom Observation]

As he stated, in his teaching, he continued his lecture with questioning method frequently in order to identify students' misconceptions, tried to make communication with students, and asked different questions related to the seasons, weather, and climate topic. While teaching the unit, through students' responses, he noticed a students' misconception regarding the association between the formation of seasons and the Earth's distance from the Sun (e.g., Tsai, & Chang, 2005). Through students' responses, he recognized another misconception that the Earth's rotation around itself is defined as one of the causes of seasons (Atwood, & Atwood, 1997). Then, he tried to remediate students' misconceptions only through making scientific explanation (i.e., teacher-centered method), but he did not use any topic-specific strategies. In his teaching, the dialogues between the teacher and students were occurred as follows;

> Burak: Now, let's repeat the seasons. Two main factors are directly influential in the formation of the seasons. What are the factors that affect the formation of the seasons?
>
> S_1: Earth's rotation…
>
> Burak: What do you mean by the rotation of the Earth?
>
> S_1 and S_2: Earth's rotation around itself and revolution around the Sun.
>
> Burak: The revolution of the Earth around the sun and the [Earth's] tilted axis are two main factors in the formation of the seasons. Earth's rotation [around itself] causes the formation of day and night, and daily temperature differences occur. Are there any other factors indirectly influencing the formation of different seasons and different temperatures?
>
> S_1: Day and night.
>
> S_2: Earth's revolution around the Sun.
>
> S_3: Earth's distance from the Sun.
>
> Burak: Is the Earth's distance from the Sun effective [on the formation of seasons]?
>
> S_4: No.

Burak: Absolutely not. The Earth sometimes closes [to the Sun] and sometimes moves away [from the Sun] … you should not associate this situation with seasons. There is no such thing like "If the Earth closes [to the Sun], it is summer. If the Earth moves away [from the Sun], it is winter.". It [seasons] is not related to the Earth's distance to the Sun.

[Classroom Observation]

During the dialogues between the students and teacher, another common misconception regarding the causes of global warming was revealed. Students tended to relate the causes of global warming to the depletion of the ozone layer (e.g., Daniel, Stanisstreet, & Boyes, 2004). Burak, however, failed to detect this misconception, and thereby, he did not eliminate it. Related dialogues occurred between the teacher and students were as follows;

Burak: What is global warming?

S_1: Global warming…Hmmm… I cannot define….

S_2: [Global warming is that] the sun's rays come into the Earth in a more harmful way due to the depletion of the ozone layer. As a result, the Earth warms up.

[Classroom Observation]

Overall findings revealed that there are some inconsistencies between his reported PCK and enacted PCK. For example, although he thought that the students will have no difficulty in understanding the seasons, weather and climate topic, he realized in his teaching that students had some difficulties in understanding the seasons concept. He tried to eliminate them with analogy and role-playing activities or making scientific explanations. As stated in the pre-interview, through questioning method, he identified two misconceptions that students had about the seasons concept but made only scientific explanation to eliminate them. Also, he failed to notice another misconception about the concept of global warming. Lastly, his teaching showed that as he stated, students' misconceptions and learning difficulties about the seasons, weather, and climate topic did not have much influence on his teaching but caused him to repeat the concepts. Burak's knowledge of students' difficulties was shown in Table 4.18.

Table 4.18 *Burak's Knowledge of Students' Difficulties*

Burak's Knowledge of Students' Difficulties			
PCK Pre-Interview		**Classroom Observation**	
Learning Difficulties	**Methods for Elimination**	**Learning Difficulties**	**Methods for Elimination**
Not mentioned	Not mentioned	Understanding the causes of the seasons	Role-playing activities Analogy
		The difference between the Earth's the rotation axis and the revolution axis	Scientific explanation Drawing figure
Misconceptions	**Methods for Elimination**	**Misconceptions**	**Methods for Elimination**
Not understanding how the Earth stand as obliqued	Explaining scientifically correct ideas Discussing students' wrong ideas Showing the many models Giving different examples	Associating the formation of seasons with the Earth's distance from the Sun (e.g., Tsai, & Chang, 2005).	Scientific explanation
		Expressing the Earth's rotation around itself as one of the causes of seasons (Atwood, & Atwood, 1997).	Scientific explanation
		Relating the causes of global warming with the depletion of the ozone layer (e.g., Daniel, Stanisstreet, & Boyes, 2004)	**He neither detected nor eliminated this misconception**

In the following part, Burak's knowledge of instructional strategies is presented.

4.1.3.4 Burak's Knowledge of Instructional Strategies

Burak's knowledge of instructional strategies was reported under two parts which are *knowledge of subject specific strategies* and *knowledge of topic specific strategies*. The knowledge of representation and knowledge of activities were reported under the knowledge of topic-specific strategies. Related data were collected through pre-interview, post-interview, teacher documents and classroom observation.

4.1.3.4.1 Burak's Knowledge of Subject Specific Strategies

In this section, Burak's knowledge of subject specific strategies regarding teaching of science as well as seasons, weather, and climate topic based on pre-interview were reported (see Table 4.19). When asked his knowledge regarding subject-specific strategies, he generally addressed general strategies in addition to topic-specific one. Table 4.19 depicted his all responses regardless whether topic specific or not.

Table 4.19 *Burak's Knowledge of Strategies*

Dimensions	**Science Topics**	**Seasons, Weather, and Climate**
Subject Specific strategies	Direct instruction Drama* Simulation* Poster activity* Daily life examples* Visuals* Experiment*	Direct instruction Investigation Discussion Drama* Videos* Visuals* Poster activity*
The Reasons of Selecting the Strategies	Make learning more permanent	Provide long term retention Make topic to more concrete Facilitate learning
The Sources of Learning Strategies	The students' feedback Undergraduate Education	The students' feedbacks Undergraduate Education

***Indicate topic-specific strategies**

Researcher: Which teaching method/strategy do you prefer to use while teaching science?

Burak: We use direct instruction while summarizing the topic. Then, I use mostly drama, simulation, smart board, visuals, posters and experiment… I give examples from daily life or give examples related to their [students'] life.

Researcher: Why do you prefer to use these methods?

Burak: To make learning more permanent.

Researcher: How did you learn to use this teaching strategy?

Burak: … We learned them [teaching strategies] from educational courses in undergraduate education. According to students' feedbacks, for example, if they [these teaching strategies] are effective in students' learning, we continue [with those methods]. If not, we use other methods.

Researcher: What about the teaching of seasons, weather, and climate topic? Which methods do you use to teach the seasons, weather, and climate topic?

> Burak: We use direct instruction. Then, we use visual… In addition, we show videos from the smart board … We use drama… investigation, discussion… We use all of them. In drama, for example, some students animate the Earth, and others play the role of the sun. Then, we ask them [students] to prepare posters…
>
> Researcher: Do you have particular reasons for using those teaching methods?
>
> Burak: Because they [teaching methods] facilitate long term retention. I believe those teaching methods make it [the seasons, weather, and climate topic] more concrete, make learning easier.
>
> [PCK Pre-Interview]

He emphasized that the reason for choosing teaching methods for science topics is to provide students' learning to be more permanent, and he primarily prefers to use direct instruction method. Then, he prefers to perform drama and poster activities, use visuals, show videos or simulations, give daily life examples and perform experiments. He attributed the reason for choosing the methods to be used in teaching the topic of seasons, weather, and climate to concretize the topic which in turn facilitate learning and added that he uses the investigation and discussion methods specifically for teaching of this topic. Lastly, he stated his undergraduate education and students' feedback as the source of learning these methods. However, he generally mentioned about topic-specific strategies, and he did not mention about subject-specific strategies such as conceptual change approach, 5E learning cycle.

Although Burak mentioned both student-centered (e.g., discussion) and teacher-centered teaching methods in his pre-interview, his teaching practices were mostly teacher-centered; he frequently used direct instruction and questioning. So, his reported PCK and enacted PCK showed both consistencies and inconsistencies. For example, similar to his reported PCK, he showed several figures from the science textbook approved by MoNE. He also performed drama activity yet gave directions to students to play their role. In contrast to his reported PCK, his enacted PCK revealed that he did not show videos, perform poster activity, implement discussion and investigation methods. Therefore, in the post-interview, he was asked why he did not use investigation and discussion as teaching methods or activities during his teaching *(The reasons why he did not show video and perform poster activity were explained in knowledge of topic-specific strategies section)*. He thought students do not take enough responsibility toward the ‘investigation’ homework, thus he did not prefer to use it. The related excerpts from the post-interview were as follows;

> Researcher: During pre-interview, you said that you will use several teaching methods such as discussion, direct instruction, investigation. But, in your teaching you did not use the discussion and investigation as teaching methods or didn't do any activity. What changed your mind?
>
> Burak: [Majority of] students have difficulty in taking responsibility. Only a few always fulfill their responsibilities. Therefore, I did not prefer to use investigation as a homework [in my teaching of the seasons, weather, and climate topic].
>
> [PCK Post-Interview]

Lastly, Burak was asked about the connection between the goals and the methods he chose for teaching the seasons, weather, and climate topic. He thought that his goals are congruent with the methods he selected and added that he understands whether he reaches his goal through feedbacks received from their students:

> Researcher: What is the connection between your goals in teaching and the methods you choose? If any.
> Burak: Hmmm… I apply a method to achieve the goal. I understand whether I reach my goal according to the feedback given by the student. If students learn topic, they give positive feedback which means that I have reached my goal.
> Researcher: To what extent do you think it reflects your goals?
> Burak: Generally, I can say that they [my goals and the methods I selected] are compatible with each other and this is a positive effect to my teaching.
>
> [PCK Pre-Interview]

In the following part, Burak's knowledge of topic-specific strategies as a sub component of knowledge of instructional strategies is presented.

4.1.3.4.2 Burak's Knowledge of Topic Specific Strategies

Findings were reported under the two parts which are knowledge of representations and activities.

4.1.3.4.2.1 Burak's Knowledge of Representations

In the pre-interview, he stated that he will use analogy, visuals, show simulation and videos from EBA [Education Information Network]. While teaching related topic, he drew figures, used analogy, gave examples and also showed figures from the science textbook approved by MoNE to enrich his teaching, but he did not show any simulation and videos. Burak's knowledge of representations was shown in Table 4.20.

Table 4.20 *Burak's Knowledge of Representations*

Types of Representations		
PCK Pre-Interview	**Classroom Observation**	**Examples used in the Classroom Observation**
Illustrations		
Visuals		
Figures	*Figures*	He showed figures from the science textbook approved by MoNE such as the formation of seasons.
Simulations and Videos (i.e., EBA)	Not Observed.	-
-	Drawing figures	The formation of seasons The Earth's tilted axis The formation of wind Global warming and Greenhouse effect
Analogy	Analogy	The greenhouse analogy Compared greenhouse effect with greenhouse The analogy showing the impacts of the Earth's tilted axis on the seasons Compared the Earth with his body Compared the Sun with the wall of the classroom
-	Daily life examples	Weather events and climate experienced in different cities in Turkey Types of weather events Factors causing the environmental problems in daily life Different kinds of wind

Researcher: Do you use illustrations, examples, models, drawings, and analogies to assist students' learning in the seasons, weather, and climate topics and concepts?

Burak: We use analogy… simulation, smart board. We use EBA. Let's say the topic is the Earth's revolution around the Sun…We show the visuals related to it... the formation of the day and night, the formation of the seasons… we show the visual from the smart board. We show videos from the smart board …

[PCK Pre-Interview]

He stated that he will use analogy, visuals and show simulation and videos from EBA (e.g., about the Earth's revolution around the Sun) in the seasons, weather, and climate topic. While teaching the unit, similar to his reported PCK, he used analogies, and from the science textbook, he showed several figures related to the concepts of seasons. Also, he gave daily life examples, and drew several figures. However, contrary to his reported PCK, his enacted PCK showed that he did not show videos and simulation from EBA. In the post-interview, therefore, researcher asked to him the reasons of this discrepancy between pre-interview and classroom observation. He stated that he did not prefer to use smart board (e.g., EBA), show videos and simulation because he couldn't find the simulation related to the seasons, weather, and climate topic and that the students understood the topic from the figures he drew on the blackboard. The related excerpts from the interview were as follows;

Researcher: During pre-interview, you mentioned that you will use simulations, smart board, EBA [Education Information Network], and videos while teaching the seasons, weather, and climate topic. You did not use them during your teaching. What changed your mind?

Burak: We did not find anything about the simulations [related to the seasons, weather, and climate topic]. We didn't use the smart board because we drew the figures related to the concepts then students gave feedback that they [students] understood the topic. That's why, we didn't feel the need for use different methods because it [seasons, weather, and climate topic] was understood [by the students].

[PCK Post-Interview]

As a representation, he gave several examples related to the concepts in the seasons, weather, and climate topic in his teaching (See Table 4.21).

Table 4.21 *Burak's Examples Regarding the Seasons, Weather, and Climate Topic*

Topic	**Burak's Example**
Weather events and climate experienced in different cities in Turkey	Ankara, Antalya, Istanbul*, Mugla**, Yozgat***
Types of weather events	Wind, rain, hail, snow, dew, rime, fog, typhoon, hurricane, tornado, tsunami.
Factors causing the environmental problems in daily life	Forest fire, atomic bombs, oil spill.
Different kinds of wind	Northeaster, Northwester, Southwester, Breeze.

[***:** *The city is located in Marmara region*; ****:** *The city is located in Mediterranean region in Turkey*; *****:** *The city is located in Central Anatolian region in Turkey*].

Burak used some simple analogies regarding the seasons, weather, and climate topic in his teaching. However, in his analogies, he did not emphasize the breaking points between analog and target concepts.

- In first analogy, while he likened his body to the Earth, he likened the wall of the classroom to the Sun (*familiar concept:* his body/the wall of the classroom - *target concept:* The Earth/the Sun). He wanted to explain to the students what happen when the sunlight strikes Earth at an oblique angle. In other words, he tried to provide the students to understand the Earth's tilted axis and its' impacts on the formation of seasons visually (See more about Burak's analogy in knowledge of students' difficulties section).
- He used another analogy to enable students to understand how the greenhouse effect occurs. In this analogy, the target concept is the layer

formed by greenhouse gases or atmosphere, while the familiar concept is greenhouse. Another target concept is the greenhouse effect occurring when some of the sun's rays remain in the atmosphere, while the familiar concept is heating the greenhouse by reaching the sun’s rays into greenhouse (See detail regarding the greenhouse analogy in Burak’s substantive knowledge section).

In his teaching, he drew various figures regarding the seasons, weather, and climate topic on the blackboard. For example, he drew a figure regarding the formation of seasons (See Figure 4.1). He drew another figure regarding the Earth provides students to understand the Earth’s axis and its’ tilted axis (See Figure 4.7). He drew Earth on the blackboard, drew a line in the middle and then he drew an axis on the middle of the Earth. He asked the students what the name of this line is, but they did not know the name of the line in the middle of the Earth. Then, he said that there is a 23.5° tilt and this is Earth’s tilted axis.

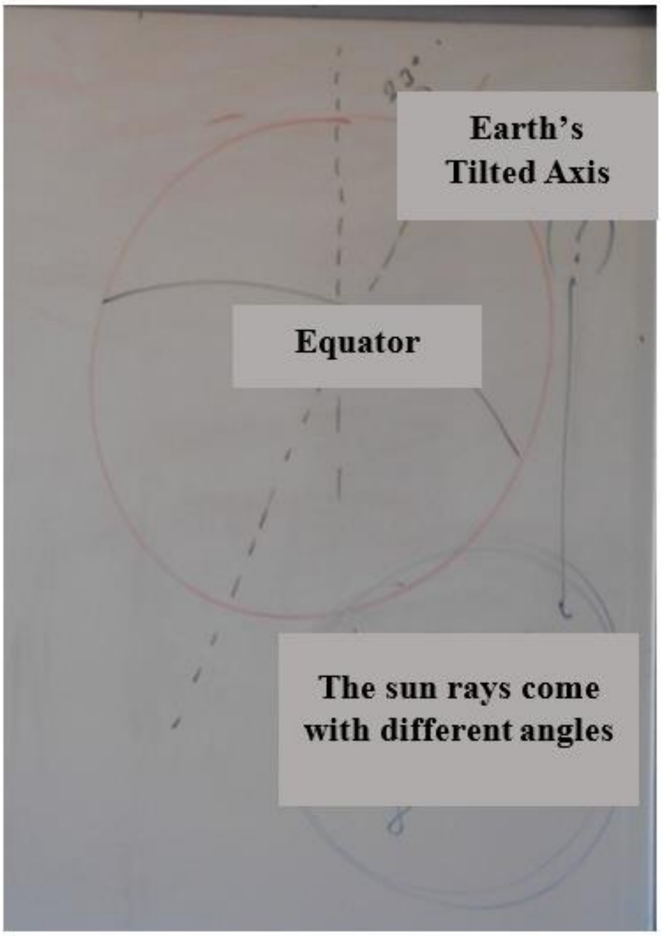


Figure 4.7 Burak's Drawing a Model Regarding Earth's Tilted Axis

After drawing Figure 4.7 above, he directed his students several questions about the Earth's tilted axis and its' relationship with the formation of seasons. The dialogues were occurred between the teacher and students as follows;

Burak: What can you say about the [Earth's] tilted axis?

S_1: The [Earth's] tilted axis forms seasons.

S_2: Because the sunlight come obliquely…

Burak: [Response to S_2] Not true…

S_3: Seasons form based on the angle of incoming sunlight.

S_4: [Earth's] tilted axis allows the sun rays to come with different angles.

Burak: Yes. What does it affect?

S_5: It [Earth's tilted axis] causes the different seasons to occur.

[Classroom Observation]

He drew another figure of the seasons on the blackboard, and then, he indicated the concepts of the Tropic of Cancer, the Tropic of Capricorn, North Pole Point, South Pole Point, Northern Hemisphere and Southern Hemisphere on this figure (See Figure 4.8).

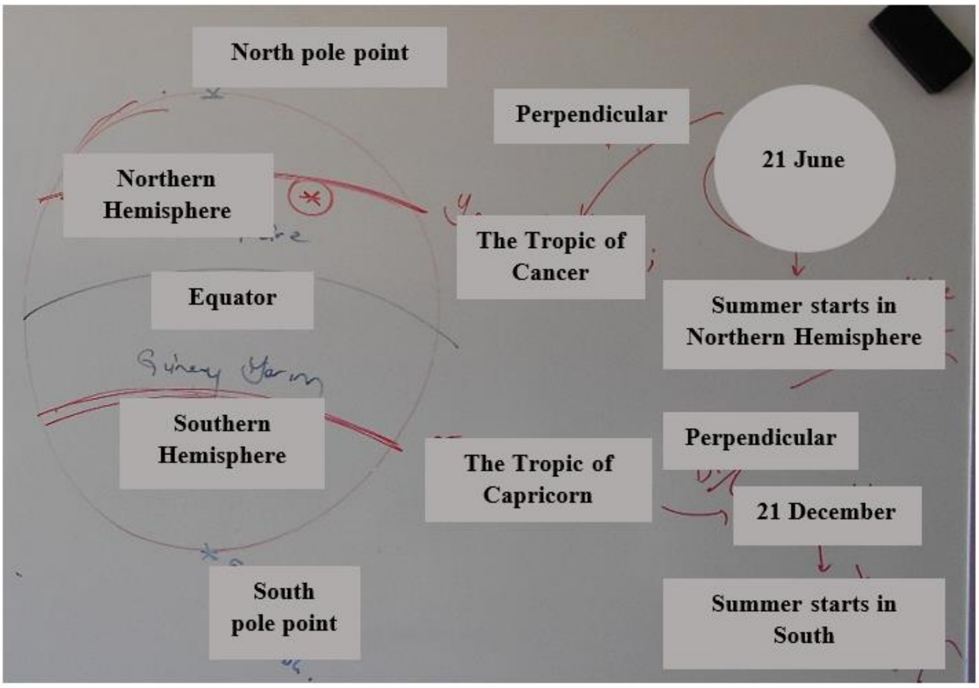


Figure 4.8 Burak's Drawing About the Seasons

Since the formation of wind related to the concept of climate, he showed how wind occurs to his students by drawing the formation of wind on the blackboard (See Figure 4.9). He wrote the high-pressure area and low-pressure area on this figure that he drew (See his explanation of wind in substantive knowledge section).

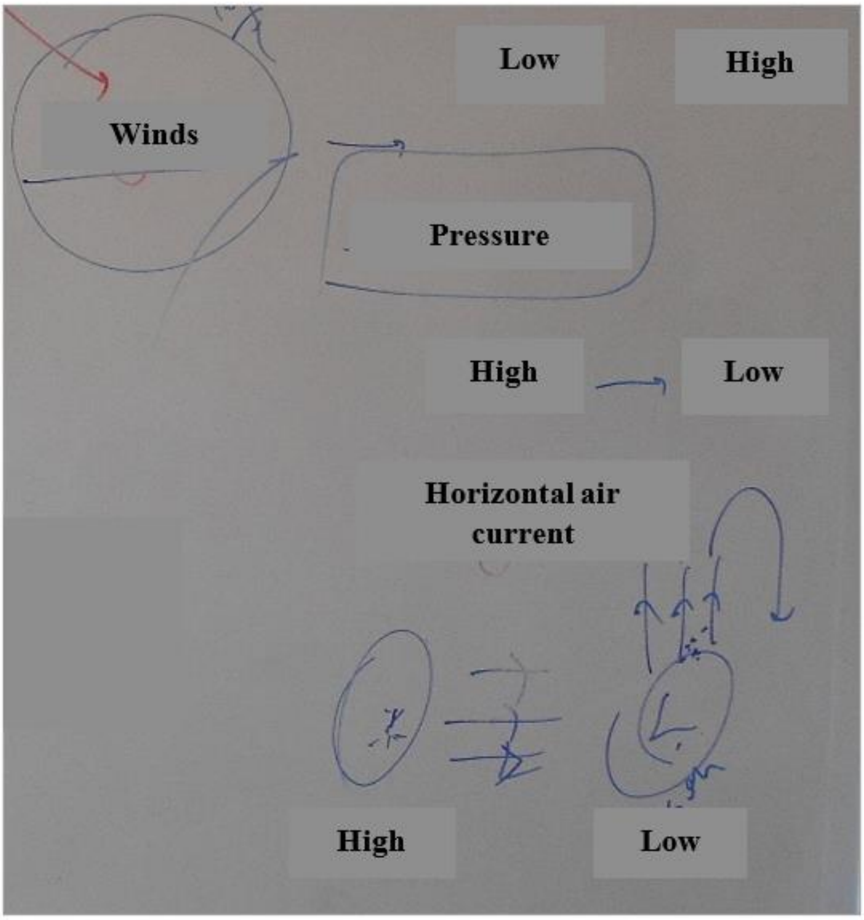


Figure 4.9 Burak's Drawing About the Formation of the Wind

Also, he drew another figure to demonstrate how the global warming and greenhouse effect occur. In this figure, he gave examples of how greenhouse gases are released into nature with drawings on the blackboard (See Figure 4.5).

In the following part, Burak’s knowledge of activities as a sub-component of knowledge of instructional strategies is presented.

4.1.3.4.2.2 Burak's Knowledge of Activities

In this section, Burak's knowledge of activities regarding the seasons, weather, and climate topic was reported. In the pre-interview, he stated that he will use the drama, poster, demonstration and concept map activities in the classroom. Although he mentioned in the pre-interview, he did not perform the poster activity and demonstration in his teaching. Burak's knowledge of activities was summarized in the Table 4.22.

Table 4.22 *Burak's Knowledge of Activities*

Pre-Interview	**Classroom Observation**	**Post-Interview (Reason)**
Demonstration	*Not Observed.*	Since the seasons, weather and climate topic was simpler than he expected.
Types of Activities		
Drama Activity	The students animated the Earth's revolution around the Sun and Earth's rotation around itself to show how the seasons and the day and night occur. The students animated how tornado form.	
Poster Activity	*Not Observed.*	Since the seasons, weather and climate topic was simpler than he expected and the worksheet he distributed showed that the students have learned the topic, he did not prefer to do a poster or any other activity.
Concept map Activity	He created a concept map related to the types of weather events.	

In the following question, Burak was asked about whether he conducts activities about the seasons, weather, and climate topic.

> Researcher: Do you conduct activities in the class regarding the seasons, weather, and climate?
>
> Burak: Yes.
>
> Researcher: What kind of activities do you perform?
>
> Burak: We construct a concept map activity. We use demonstration… Then, fill in the blank activity, poster… We ask [students] to prepare posters… We perform all of them.
>
> Researcher: What are the teaching strategies that you will use to help students develop an understanding of these concepts?
>
> Burak: We do drama... [In drama activity], for example, one student animates the Earth; another student animates the Sun. Then, they [students] revolve around each other. Then, we want students participating in this activity to ask the questions to each other related to the topic. [For students], drama activity may remain a bit more abstract than analogy. However, it [performing drama activity] makes the classroom environment more comfortable. Also, children enjoy it.
>
> [PCK Pre-Interview]

Similar to his reported PCK, his enacted PCK showed that he created a concept map related to the weather events, and performed drama activities *(Fill in the blank activity was explained in knowledge of methods of assessment).* However, he did not implement some of the activities related to this topic found in the science textbook approved by MoNE. Also, although he mentioned about the poster activity and demonstration in the pre-interview, he didn't perform these activities in his teaching. In the post-interview, thereby, he was asked the reason why he did not perform poster activity and demonstration. The related excerpts from the post-interview were as follows;

Researcher: You mentioned that you will do poster, drama, concept map activities and demonstrations regarding the seasons, weather, and climate topic in the classroom during the pre-interview. Although you did concept map and drama activities, you did not perform poster activity and demonstration in your classroom. What changed your mind?

Burak: In this grade level (8th grade), we did not make any poster activity or any other activities. Because the topic [seasons, weather, and climate] was simpler than I expected and therefore I didn't need to use different methods. I distributed a worksheet to students before moving on to the next topic, which is DNA. In this worksheet, there were fill in the blank activity, true/false activity… If students correctly do these activities, we understood that students learned the topic and related objectives. Therefore, [I decided that] there is no need to continue with the topic [seasons, weather, and climate] and therefore, I moved on to the new unit [DNA unit].

[PCK Post-Interview]

In his teaching, he created a concept map concerning types of weather events (e.g., fog, rime, snow, hail). However, while he was creating the concept map, the students were passive in this process (See Burak's original concept map in Appendix R).

Besides, he performed three drama activities; one was related to seasons concept, the other was related to the formation of day and night, and the other one was related to the formation of tornado.

- In first drama activity, he wanted to explain the Earth's revolution around the Sun and the angle of the incoming sunlight to the Earth. For this purpose, he selected two students; while one student animated the Sun, the other one animated the Earth. Students animated the Earth's revolution around the Sun; the student who animated the Earth revolved around the student who animated the Sun. Thus, how the seasons occur was visually animated.
- In second drama activity, the same students who animated the formation of the seasons played role. Then, the student who animated the Earth rotated

around himself/herself. Thus, how the night and day occur was visually animated. After that, he said that;

> Burak: The event that occurs every 24-hour period as a result of the Earth's rotation around itself is called the day and night formation. The day occurs when the Earth rotates once around itself.
>
> [Classroom Observation]

- In another drama activity, he selected two students and asked them to animate the tornado which is one of the weather events. He asked the students to run towards each other quickly and then both students ran towards each other. By this way, he showed to the students how the tornado form in a visual way.

Lastly, Burak was asked about how he understood the effectiveness of the activities he has planned. He understood the effectiveness of the activities according to the feedbacks received from students. Then considering the feedbacks, he either applies another activity or improves the old one. He sees himself well in finding effective activity. The related excerpts from the interview were as follows;

> Researcher: How do you come to realize that the activities you planned will work?
>
> Burak: We apply [the activities] according to the feedbacks provided by students. If they [the students] do not give positive feedback [if the activities are not fruitful], we change [the activities] …or if their feedbacks are positive, we continue with that activity and tried to improve it [activity].
>
> [PCK Pre-Interview]

In the following part, Burak's knowledge of assessment is presented.

4.1.3.5 Burak's Knowledge of Assessment

Burak's knowledge of assessment was reported under two sub-dimensions as knowledge of dimensions of science learning to assess and knowledge of methods of assessment. Related data were collected through pre-interview, teacher documents and classroom observation.

4.1.3.5.1 Burak's Knowledge of Dimensions of Science Learning to Assess

In this section, Burak's knowledge of dimensions of science learning to assess regarding the seasons, weather, and climate topic was reported (See Table 4.23).

Table 4.23 *Burak's Knowledge of Dimensions of Science Learning to Assess*

Knowledge of Dimensions of Science Learning to Assess	**PCK Pre-Interview**	**Classroom Observation**
Knowledge on the seasons, weather and climate	Mentioned	Assessed
NOS Understanding	Not Mentioned	Not Assessed
Science Process Skills	Not Mentioned	Not Assessed
Knowledge of Dual Perspective	Not Mentioned	Assessed

> Researcher: What do you want to assess in depth when you assess your students' knowledge in terms of seasons, weather, and climate?
>
> Burak: [I want to assess] whether the objectives [related to the seasons, weather, and climate topic] were learned or not [by the students]. We assess whether we reach our goal or not... whether we gained students to the ability to interpret.... We assess these.
>
> [PCK Pre-interview]

Consistently, after he completed the seasons, weather, and climate topic in classroom, the students took a written exam (known as performance exam). The exam included eight open-ended questions five of which were as follows;

1) Explain the causes of seasons.
2) What is the difference between the rotational axis and the revolution axis?

3) Draw the positions of the Earth around the Sun and indicate the dates and seasons.
4) Write down the characteristics of weather events.
5) How can global warming be prevented?

[Teacher Document_Written Exam Questions]

As seen, these questions were compatible with the objectives related to the seasons, weather, and climate topic in the curriculum. Similar to his opinions regarding pre-interview, he only assessed students' knowledge and did not assess students' knowledge on science process skills, or NOS understanding. Contrary to reported PCK, his enacted PCK showed his tendency to assess students' knowledge of dual perspective through question which is *"How can global warming be prevented?"*. In this question, he specifically asked students to define how the global warming occurs by writing an essay. After the students answered these exam questions, he explained the points that students had difficulty in understanding in the next lesson. In the following part, Burak's knowledge of methods of assessment as a subcomponent of knowledge of assessment is presented.

4.1.3.5.2 Burak's Knowledge of Methods of Assessment

In this section, Burak's knowledge of methods of assessment regarding the seasons, weather, and climate topic was reported (See Table 4.24). He focused only on traditional assessment methods in his pre-interview, and used traditional assessment methods in his teaching. He neither mentioned about alternative assessment methods in the pre-interview nor used in his teaching. He assessed students' understanding through different type of questions such as matching, multiple choice at the end of the unit (i.e., summative assessment) and through questioning method during the lesson (i.e., formative assessment).

Table 4.24 *Burak's Knowledge of Methods of Assessment*

Dimensions	**PCK Pre-Interview**	**Classroom Observation**
How to assess?	Visual Fill in the blank True/False Open-ended Multiple choice Written exam Question-answer method	Questioning method Unit evaluation questions (e.g., fill in the blank, multiple choice) Written exams including open-ended questions Preparing a worksheet including several types of questions (e.g., true/false) Giving homework Illustrating seasons through drawing
The reasons of selecting assessment strategies	to…… not only memorizing but also interpreting the process.	Assessing students' knowledge of seasons, weather and climate, and knowledge of dual perspective
When to assess?		
Formative assessment (During the lesson)	Mentioned	Applied
Summative assessment (At the end of the unit)	Mentioned	Applied

Researcher: Which assessment techniques do you use to assess their understanding in seasons, weather, and climate topic?

Burak: We ask questions in different styles. We ask visual… we ask all kinds of questions about fill in the blank, true/false, test, classic… open-ended, multiple choice…

Researcher: Well, what are the particular reasons for using them to assess students' understanding?

Burak: … Because everyone has own style. The test contains multiple choices questions, and the students choose the correct answer from the options. Sometimes, we asked essay type questions, which require students to write or interpret [the questions]. While some questions are based on rote (recalled questions), others require interpretation. Therefore, I like to use different methods in measurement-assessment tools because I want the student not only memorize but also interpret.

Researcher: Well, when do you assess your students regarding seasons, weather, and climate?

Burak: There is no predetermined time [to assess students' learning] … [I assess students' learning] at different times… I frequently use the question-answer method. If no answer comes [from students], we explain it [the answer]. The dates for written exams are already scheduled. I administer two written exams within a semester (i.e., general evaluation). One is in the middle of the semester, the other one towards the end of the semester… Apart from general evaluation, I do the unit evaluations at the end of each unit.

Researcher: How do you use the assessment results?

Burak: Hmmm… There are written exams. Apart from, sometimes I do [assessment] for only one topic to understand whether students understood the topic or not. If not [students do not understand the topic], we give feedback. We reteach the missing points that they [students] do not understand. In this regard, we use [students' assessment results] as feedback as well.

Researcher: What do the results tell you?

Burak: These results tell me whether teaching of the topic is successful or not… Did I able to teach or not teach?... How much they [students] learned?... Were there any topic or concept that they [students] did not understand?... As far as possible, I try to be objective [while assessing students]. There are evaluation criteria for this [assessing students' learning].

[PCK Pre-interview]

Burak's responses indicated that he tends to use traditional assessment methods such as fill in the blank, true/false, multiple choice to assess students' understanding. He stated that he uses questioning method at different times of the lesson as formative assessment, and that uses the written exams at the end of the semester as summative assessment. He added that he tries to determine how much the students understood the topic through their assessment results as feedback.

Lastly, Burak was asked how he feels in finding assessment ways to evaluate his teaching. He stated that he feels himself good because he uses various question types (e.g., open-ended, test) which provides him to assess students' understanding better. He added that he assesses whether the students learned the objectives. So, his responses indicated that he assesses students' conceptual understanding. The related excerpts from the interview were as follows;

Researcher: How do you see yourself in finding assessment ways to evaluate your teaching?

Burak: We [as teachers] are good in general [in finding assessment ways to evaluate our teaching].

Researcher: Why do you think you're good? How did you come to this opinion?

Burak: Because we provide diversity [in assessment] … That is, we don't ask just the test questions, the open-ended questions… We provide diversity and thus, we better assess children. We do it [assessment] based on the objectives [stated in the curriculum]. [We assess] whether the objectives understood or not [by the students] …

[PCK Pre-interview]

Similar to his reported PCK, his enacted PCK showed that he utilized traditional assessment methods. He used both summative (e.g., written exam including open-ended questions, and matching, true/false, fill in the blank and multiple-choice questions) and formative (e.g., questioning method) assessments. As formative assessment, during his teaching, he used questioning method at various times, and asked many questions regarding the seasons, weather, and climate topic. For example, he repeated the seasons topic he taught in the previous lesson by asking questions, and so, he assessed whether the students understood. The dialogues were occurred between students and teacher as follows;

> Burak: Let's repeat the topic again. We taught the formation of the seasons. There are two main factors for the formation of seasons. What is the first main factor?
>
> S_1: The Earth's revolution around the Sun.
>
> Burak: What is the second main factor?
>
> S_2: [Earth's] tilted axis.
>
> Burak: The absorption and reflection of the light also affect [the formation of seasons]. …. like in the desert, in the poles…
>
> Burak: What does [Earth's] tilted axis provide?
>
> S_3: [Earth's tilted axis provides] daily temperature difference.
>
> S_4: [Earth's tilted axis provides] the formation of seasons.
>
> S_5: The coming of the sun's rays [to the Earth] at different angle.
>
> Burak: Yes. The coming of the sun's rays with different angles provides different seasons to occur. What happens if the [Earth] rotated around its' axis?
>
> S_6: Day and night [occur].
>
> [Classroom Observation]

In his teaching, as summative assessments, he used several types of questions to assess students' understanding related to the seasons, weather, and climate topic. For example;

- He asked students to complete the unit evaluation questions related to the seasons, weather, and climate found in the science textbook approved by the MoNE. In the unit evaluation questions, there are different types of questions including matching type, open-ended, true/false, fill in the blank, multiple choice questions.
- He performed a written performance exam including eight open-ended questions at the end of the seasons, weather, and climate topic. The some of the exam questions were reported on page 248-249.
- He prepared and distributed a worksheet including different types of questions (e.g., fill in the blank, true/false, open-ended).
- Students were requested to write down the important points from the science textbook in their notebooks in addition to drawing the figures such as the formation of seasons. In the next lesson, he checked the students' homework whether they drew the figures correctly.
- He invited two students to the blackboard and then, asked them to illustrate how the seasons occur through drawing. They drew the Earth and Sun on the blackboard, and then wrote down which seasons occur in both Northern and Southern hemisphere relative to the Earth's position around the Sun. After students drew the figures regarding the formation of seasons, he checked whether they correctly drew the figures or not.

4.1.3.6 General Summary of Burak's PCK

In this section, Burak's PCK general summary related to teaching the seasons, weather, and climate topic was reported in Table 4.25.

Table 4.25 *Burak's PCK in Teaching Regarding the Seasons, Weather and Climate Topic*

	Orientation Toward Science		Knowledge of Curriculum	Knowledge of Students' Understanding	Knowledge of Intsructional Strategies	Knowledge of Assessment
Burak	**Central Goal** Subject matter goal Schooling goal	**Peripheral Goal** Schooling goal Affective goal	**Goal and Objectives** Expressed all objectives ***Vertical Relations*** The Earth's shape at 3rd grade The movements of the Earth at 4th grade The Sun, Earth, and Moon at 5th grade The concept of rain at 5th grade The Lunar eclipse at 6th grade The mixtures at 7th grade ***Horizontal Relations*** Matter cycles and Environmental problems at 8th grade **Materials** Science Textbook	**Prerequisite Knowledge** (See Vertical Relations) **Students' Difficulties** Comprehending the causes of seasons →Eliminating with role-playing activities and analogy The differences between the Earth's revolution axis and rotation axis →Eliminating with scientific explanation and drawing figure. **Misconceptions** The relationship between the Earth's rotation on its' axis and the seasons The relationship between the seasons and distance of the Earth to the sun →Eliminating through scientific explanation Failed to recognize students' misconception as to weather and climate concepts	**Subject-Specific Strategies** Direct instruction Questioning **Topic-Specific Strategies** **Representations** Drawing figures Giving examples Analogy Showing visuals from the science textbook Showing videos and simulation were stated in pre-interview, yet not used in teaching. **Activities** Concept map activity Drama activities Poster activity and demonstration were stated in pre-interview, yet not performed in teaching.	**Dimensions of Science Learning to Assess** Assessing students' knowledge on the seasons, weather and climate topic Assessing students' knowledge regarding dual perspective **Methods of Assessment** ***Formative assessment*** Questioning method ***Summative assessment*** Performing unit evaluation questions (e.g., true/false, matching type) Preparing written exams Preparing and distributing worksheets which contain several types of questions (e.g., fill in the blank, open-ended) Illustrating seasons through drawing Giving homework

4.1.4 Burak's Teaching in terms of Dual Perspective

Under this heading, as in Clausen's study (2017), findings regarding Burak's teachings of the seasons, weather, and climate topic, were reported from dual perspective utilizing, all data set collected from interviews (i.e., PCK pre-interview and SMK interview), classroom observation and teacher documents (e.g., written exams, tests questions) (table 4.20). Overall findings indicated his sensitivity toward importance of raising students who realize their own tasks and responsibilities toward caring of environment as well as their own role in preventing environmental problems.

For example, for him, meaning of teaching seasons, weather, and climate topic to students *is to teach the environment and environmental problems, not to throw rubbish on the ground, ...to keep the environment clean.* Similarly, he responded to the one of the questions asking about his *expectation from students to have which knowledge and skills by teaching science* as *knowing what will happen next if they pollute the environment, learning why they should behave pro-environmentally and protect the environment, plants, trees, animals and living things.* He also added that *these are important things.*

[PCK Pre-interview-Orientation Towards Science Teaching Section]

In interviews, he also mentioned about human- and government-based actions to prevent and mitigate the adverse effects of the climate change and global warming. At first, he highlighted the importance of educating people who are conscious about the climate change and global warming. He thought that teaching students how to behave environmentally friendly manner, such as protecting the environment, living things is a way of preventing the adverse effects of climate change and global warming. He drew attention to the necessity of installing filters in factories and use of the natural gas to prevent the release of harmful gases, including the amount of carbon dioxide. He mentioned about individual tasks and responsibilities to mitigate and prevent the effects of the climate change and global warming such as avoiding throwing the garbage to the classroom, cutting down trees, harming animals and hunting. Related to the government-based actions, he mentioned that world's countries made some agreements and protocols to prevent the climate change and he said Kyoto Protocol as an example. Examples of excerpts were provided below:

> Researcher: Do you think that is there anything to do to mitigate and combat with the effects of climate change and global warming?
>
> Burak: Of course, there is... I believe that human can do many things... I trust my students for this aspect… When you teach appropriate behaviors [to children], children do everything to prevent the climate change. Forestation should be the first thing to do. Before it [forestation], we [as a teacher] should raise conscious individuals…. raising conscious individuals is one of the most important things for me… Throughout my professional life, for example, I always say my students that it is important to raise conscious people and also, I try to do it [raise conscious people] in my personal life … We [as a teacher] need to teach students that they [students] should sensitive to nature, the environment, people as well as animals. If the students take the necessary actions to protect the environment, there will be a cleaner world… If you want to build factories, you should take some precautions. The simplest one is use of filter… As far as we [as a teacher] know, the filter prevents harmful gases from escaping [to atmosphere] and it [filter] decreases them [the amount of harmful gases]. Therefore, it [filter] reduces the emission of [harmful] gases released to the nature. For example, natural gas is now being used instead of coal, which is one of the fossil fuels… [By this way], the carbon dioxide emissions are reduced. Majority of people has a car. If the cars are not taken to maintenance, or the filters are not used in the factories, the environment is polluted. In short, if the necessary precaution is not taken, human beings are affected [negatively]… This [raising conscious people] is the main factor in this case…

Researcher: According to you, what are the duties and responsibilities of individuals in preventing climate change?

Burak: Hmmm… I think that individual has responsibility in each instance. After all, if you are a citizen, you have responsibilities. In other words, we [humans] have to fulfill our responsibilities. What does a citizen do?... Let me start from the simplest one: garbage. There is a garbage bin in the class. Garbage should not be thrown to the ground [in class]. For example, in picnics…. We [Turkish people] enjoy making barbecue more often in the picnic. Some people make barbecue generally around the trees, ... grasses… These events [in fact] adversely affect the nature and the environment… Apart from, cutting down the trees… harming the animals... hunting... illegal hunting still exists. Unfortunately, and, …there is some efforts for combatting with illegal hunting.

Researcher: Well, what are the precautions taken by the world's countries to prevent global climate change?

Burak: Frankly, I am not very familiar with the content of the protocols… But we [humans] also hear news about environmental issues. We [humans] hear the protocols are signed. I think there is Kyoto protocol if I remember correctly… It must be Kyoto... we [humans] know that agreements have been signed. But I don't know much [information] about the contents [of the agreement].

As it was seen in the interview, he mentioned about the knowledge aspects of action competence and tasks and responsibilities to be taken toward environmental issues.

Likewise, while teaching the seasons, weather, and climate topic, Burak addressed the knowledge, vision, commitment and action experience aspects of action competence (See Burak's knowledge aspect of action competence more in Burak's substantive knowledge section related to the seasons, weather, and climate in detail).

While he was trying to develop students into action competent citizens, he mentioned about the environmental problems and precautions taken to the prevent the environmental problems (i.e., knowledge). For example, he stated that people cut down trees, use coals, and they do not use filter in factory chimneys (i.e., knowledge). As reported in SMK section, he drew a figure to show how the global warming and greenhouse effect occur (See Figure 4.5) and addressed the impact of global warming on several areas such as ecosystem, biodiversity (i.e., knowledge). Then, he expressed solutions and his opinions to prevent the climate change and global warming based on human-based actions (i.e., knowledge). He drew attention to the use of the natural gas, creating awareness for environmental problems, using public transport and protecting trees (i.e., commitment), and he stated that by applying these actions, it would be a clean environment and the Earth would be saved (i.e., vision). He gave several examples related to students' daily life in the school in order to enhance their environmental awareness. For example, he stated that the garbage should not be thrown to the classroom. He also mentioned that school staff's cleaning work take a long time in the school because of the garbage thrown to the classroom by the students and for this reason, he warned his students about the keeping the environment clean. In this example, he highlighted the students' action experience in the school on the way of becoming an action competent citizen. That is, in these examples, he touched on the knowledge, commitment, vision and action experience aspects. While emphasizing dual perspective, he used questioning method and during giving information about the environmental problems, few students participated to the lesson by asking questions (e.g., "Is natural gas good source of energy?"). Only one student expressed the use of electrical car as a solution toward the preventing the environmental problems (i.e., commitment). That is, classroom observation data indicated that students could not adequately participate in the lesson to demonstrate their vision, commitment, knowledge and action experience. At the end of the lesson, he applied a written exam including eight open-ended questions and last question was that *"How can global warming be prevented? Answer this question by writing their essays explaining what the global warming is,* *the causes of the global warming and how the global warming occurs"*. Apparently, this question was aimed at assessing students' knowledge related to global warming and precautions taken to prevent the global warming (i.e., dual perspective).

While he was mentioning about how the greenhouse gases causing the greenhouse effect are released, as an example of the dialogues where he emphasized the dual perspective were as follows;

> Burak: What do people do [as wrong behavior for environment]?
>
> S_1: [People use] deodorant.
>
> Burak: …People don't do regular maintenance of their car [people neglect basic maintenance on their car] ... In winter time, they [people] are using coal and natural gas in homes. They [people] don't use filters in factory chimneys. Yet [factories] release carbon dioxide, nitrous oxide, nitrogen dioxide to the atmosphere. They [people] are even doing something worse…they [people] cut down trees…trees are the only living things that remove carbon dioxide. [Trees] make photosynthesis.... What about people? They [people] breathe. They [people] are increasing carbon dioxide [level], and reducing oxygen [level]. Respiration is a natural phenomenon… you will give carbon dioxide [to the air] because the plant does photosynthesis… The problem is about releasing too much [carbon dioxide into nature]. You will use fuel. However, people can make their own choices. I want my daughter to live in a cleaner environment...
>
> S_2: Well, what will we use?
>
> Burak: For example, they [people] may prefer to use natural gas but not coal...
>
> S_3: Is natural gas good [source of energy]?
>
> Burak: Natural gas is fossil fuel, but cleaner [compared to coal] … Coal releases more carbon dioxide [to the air]. While the carbon dioxide content of coal is 1/2, [carbon dioxide content of] the natural gas is 1/40. [The coal]

pollutes the environment more than natural gas does…. Other issues such as oil wells also pollute the air. Burning of the forest [by humans] … You can prevent those only by …creating awareness. To save the Earth, people should be conscious. There is only one power that can stand against them… trees [at this moment, he showed “the tree” on figure 4.5 in Burak’s substantive knowledge section]. You should behave in an environmentally friendly manner. [For example], you can use public transport.

S_4: There's no place to sit on buses…

Burak: Generally, in Turkey and also in the world, there is heavy traffic especially during rush hours. When buses are overcrowded during the day, if requested by people, two buses can be departed instead of one [bus].

S_5: The electrical car can be used.

[Classroom Observation]

As a result of all data, it could be concluded that he addressed the knowledge dimension as well as the students’ development into action competent citizens throughout his lesson and therefore, dual perspective was emphasized in his lesson. He particularly emphasized the students’ own responsibilities along with human-based and government-based actions regarding the precautions to be taken against global warming and climate change. Summary of Burak’s views regarding human-based and government-based actions to be taken to prevent the climate change and global warming based on interview and classroom observation data were shown in Table 4.26.

Table 4.26 *Burak's views regarding Human-based and Government-based Actions to be taken to prevent the Climate change and Global warming*

	Interview Data	Classroom Observation Data
Human-based Actions	▪ Raising conscious people regarding the climate change and global warming ▪ Teaching students the right behaviors about protecting the environment and living things ○ not to harm living things, protect nature, being sensitive to animals and people ○ Installing filters in factories (e.g., filter reduces the emission of harmful gases released to the nature.) ○ Using natural gas rather than using coal as a fossil fuel (e.g., the carbon dioxide emissions are reduced.) ○ Forestation ○ Avoiding throwing garbage to the ground ○ Avoiding cutting down trees ○ Avoiding harming animals ○ Avoiding hunting	▪ Raising awareness related to the environmental problems ▪ Behaving pro- environmentally ○ Protecting trees ○ Using public transport ○ Using electrical car ○ Using natural gas ○ Avoiding using coal
Government-based Actions	▪ Signing agreements and protocols among World's countries ○ Kyoto Protocol.	-

Summary of Burak's dual perspective based on interview and classroom observation data was shown in Table 4.27.

Table 4.27 *Summary of Burak's Dual Perspective*

PCK Pre-Interview				Substantive Knowledge Interview	
				Types of Actions	
"Meaning of teaching seasons, weather, and climate topic to students is to teach the environment and environmental problems, not to throw rubbish on the ground, …to keep the environment clean" [Orientation Toward Science Teaching]				**Human-based Actions**	**Government-based Actions**
				Mentioned	Mentioned
Classroom Observation					
The Aspects of Action Competence				**Types of Actions**	
Knowledge /Insight	**Vision**	**Commitment**	**Action Experience**	**Human-based Actions**	**Government-based Actions**
Mentioned	Mentioned	Mentioned	Mentioned	Mentioned	Not mentioned

4.2 CASE 2: Beyza’s Subject Matter Knowledge and Pedagogical Content Knowledge Regarding the Seasons, Weather, and Climate: from the Dual Perspective

4.2.1 Beyza’s Background Knowledge and Her Classroom Environment

Beyza is a forty-eight years old female teacher. She was graduated from biology department of faculty of arts and science in one of the universities in Turkey. Overall, she has twenty-five years teaching experience and has been working for twenty-four years in the public school where current study was conducted. In the year of data collection [2018], she was teaching science to 7th and 8th grade students. Classroom environment included smart board, one blackboard and students’ posters related to the seasons, weather, and climate topic. The desks were arranged in rows. There were almost forty students in her classroom. Although attended an in-service training program on consultant teaching, smart board education and first aid training, she did not participate any in-service training related to the seasons, weather, and climate topic. Nevertheless, she indicated her interested in these topics.

4.2.2 Beyza’s Subject Matter Knowledge Regarding the Seasons, Weather, and Climate

Beyza’s SMK was reported under two subtitles which are substantive knowledge and syntactic knowledge. First, findings regarding Beyza’s substantive knowledge, which were collected through interview, classroom observation and teacher documents, were reported separately for seasons, weather, and climate respectively. Second, findings regarding Beyza’s syntactic knowledge, which were collected through interview and classroom observation, were reported.

4.2.2.1 Beyza's Substantive Knowledge Regarding the Seasons, Weather, and Climate

4.2.2.1.1 Beyza's Substantive Knowledge Regarding Seasons

Beyza was asked several questions to reveal her knowledge regarding seasons concept:

> Researcher: How can you define seasons?
>
> Beyza: Seasons is the weather events like temperature, humidity and wind, which are experienced in different regions of the Earth. Hmmm… There are causes for the seasons.
>
> Researcher: What are those causes?
>
> Beyza: We teach in the school that seasons form because the Earth revolves around the Sun, however, it is not exactly like that... Earth's tilted axis… 23°27´ Earth's tilted axis forms seasons. In other words, seasons form when the sun's rays strike Earth at different angles and with different intensity. The seasons are experienced differently in different places of the Earth such as the Northern Hemisphere, the Southern Hemisphere. By this way, the continuity of life is ensured. If [Earth's] axis was not tilted, the seasons would not occur and the same weather conditions would be existed all over the world; same living conditions and same biodiversity. Earth would not have biodiversity and would become inhabitable [without the tilt of Earth's axis]. For example, it would be always summer in one place, the winter would be experienced constantly in another place. Even the migratory birds would not migrate to elsewhere.

During the teaching of the seasons, consistent with interview, she talked about the causes of seasons by saying that;

This is the Earth [showing the model of the globe in classroom]. Earth’s axis is tilted. Earth rotates with a 23° 27′ tilt. Earth revolves around the Sun every 365 days. Thus, seasons form.

[Classroom Observation]

In line with the science curriculum, Beyza also drew the figure relevant to the formation of seasons on the blackboard and showed the solstices dates including December 21 (winter solstice), June 21 (summer solstice) and equinoxes dates including March 21 (spring equinox), September 23 (autumnal equinox). She wrote that the longest day- shortest night took place on June 21 and shortest day-longest night took place on December 21 on the figure. She specified the seasons that experienced on solstices and equinoxes dates in each Hemisphere on the figure (See Figure 4.10). Furthermore, as a part of the science curriculum, she also mentioned that the day and night is resulted from Earth’s rotation around itself in her teaching practice.

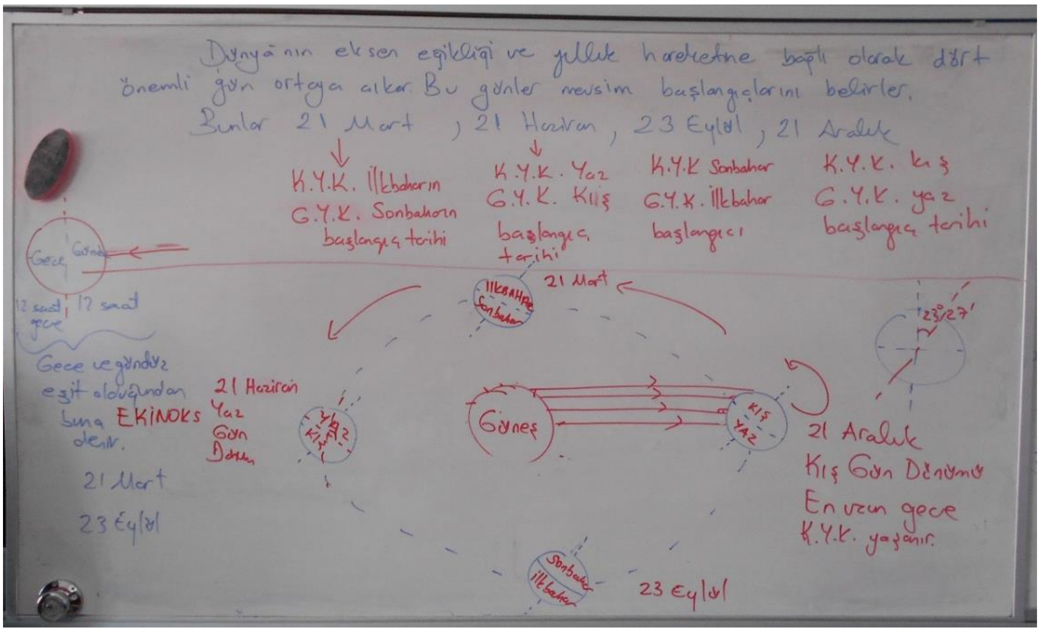


Figure 4.10 Beyza's Drawing a Model Regarding the Formation of Seasons

Furthermore, as a part of the science curriculum, she mentioned about the concepts of the Tropic of Capricorn and the Tropic of Cancer saying that;

> Beyza: Above the equator, there is the Tropic of Cancer and below the equator, there is the Tropic of Capricorn. On December 21, when the sun's rays strike as perpendicular to the Tropic of Capricorn, the summer starts in the Southern Hemisphere and the winter starts in the Northern Hemisphere.
>
> [Classroom Observation]

Overall, Beyza correctly expressed the causes of seasons as Earth's tilted axis and Earth's revolution around the Sun. Consistent with the curriculum, she expressed the Earth's tilted axis as 23° 27′. The classroom observation data confirmed that she was aware of the causes of the seasons and related concepts such as equinox, solstices dates, the Tropic of Capricorn and the Tropic of Cancer. Beyza's knowledge regarding the seasons was shown in Table 4.28.

Table 4.28 *Beyza's Knowledge Regarding the Seasons*

The Concepts	**Response**
The Seasons	Seasons form because; a) The Earth revolves around the Sun b) 23°27′ Earth's tilted axis c) The sun's rays strike Earth at different angles and with different intensity.

In the following part, Beyza's substantive knowledge regarding weather was presented.

4.2.2.1.2 Beyza's Substantive Knowledge Regarding Weather

First question asked to clarify her knowledge on weather and weather events. Both the interview and classroom observation data showed that Beyza possessed a good understanding of these concepts.

At first, Beyza was asked what the weather is;

> Beyza: Weather events are short-term phenomena. Weather events can show variation…
>
> [Interview]
>
> Beyza: It is the atmospheric conditions that experiencing in short-term at a particular place are called weather events. Weather events show variation more.
>
> [Classroom Observation]
>
> Researcher: Well, what comes to your mind when I said weather events? Can you explain?
>
> Beyza: The winds, then the precipitations come to my mind... Hurricane, storm, snow, rain, hail, dew, rime…
>
> Researcher: What about when I say weather?
>
> Beyza: When saying the weather, the atmosphere first comes to my mind of course… Weather and atmosphere are consisted of gas mixture. The gas mixture is a homogeneous mixture. For example, oxygen comes to my mind at first… Life comes to my mind… Weather events like storm, precipitations, winds come to my mind, for example…

She correctly expressed the weather events saying that they deal with short-term phenomena and they can change. Also, classroom observation data confirmed that she was aware of the definition of weather/weather events. Her list of weather-related words included atmosphere, gas mixture, oxygen, life, weather events, storm, wind and precipitation. Overall, she associated weather with atmosphere and gases, but mostly with weather events. Then, she was requested to construct a concept map with using those words. However, she constructed a broader concept map by adding extra words (e.g., meteorologist, climatologist). Beyza's concept map regarding the weather was shown in Figure 4.11.

> R: Can you construct a concept map by using the concepts you mentioned above? Please explain your map briefly.

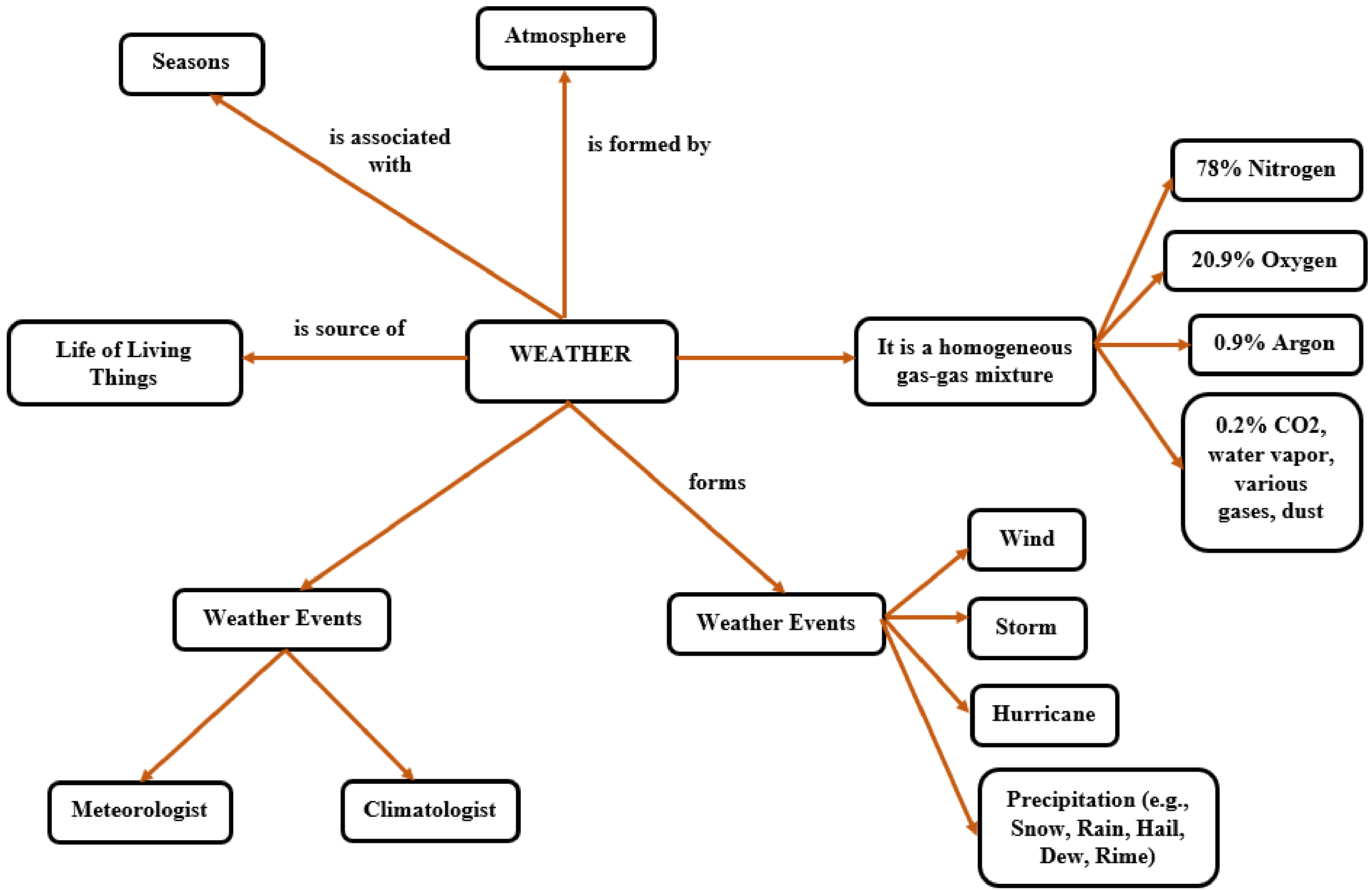


Figure 4.11 Beyza's Concept Map Regarding Weather

As seen from Figure 4.11, she created ***a spoke structure*** (Kinchin, Hay, & Adams, 2000) by putting the concept of weather at the center of the concept map. In her concept map, other concepts were radiated from the weather which is central concept. To make it clear, her concept map possesses a radial structure and all concepts regarding the weather were directly linked only with the weather. That is, each concept was positioned separately from each other, and there was no connection among the other concepts. But only some concepts (e.g., weather events) were elaborated within themselves. For example, she expressed that 'the weather forms the weather events', and gave examples for weather events (e.g., wind, storm). She associated weather events with the climatologist, a concept related to climate, with the help of an arrow, but did not use any link indicating the connection between them. She also linked the weather to the seasons, which is the part of the unit, by saying that *'Weather is associated with seasons'*.

To elaborate her understanding on weather events, Beyza was asked about the nature of weather events. Although not stated explicitly, her response implied that weather events / movements are not static but dynamic. She expressed that weather events show variation, and she attributed the change in weather events to factors that are temperature, wind, humidity, and pressure. For example, she addressed the temperature factor by giving example that the weather becomes warm when striking sun's rays perpendicularly to the Earth.

> Beyza: The weather events show variation depending on the angle of the sun... In other words, when the sun's rays strike [to the Earth] perpendicularly, the weather becomes warm. The weather gets cold as the sun's rays strike [to the Earth] indirectly at an oblique angle. It is the amount of water vapor in the environment that determines the weather events. It [humidity] is the rate of the water vapor in the air. As the temperature, wind, humidity, and pressure change, the weather changes constantly. Pressure, humidity, wind, temperature difference cause [to form] weather events.

In addition to what she said during the interview, she said the precipitation as another factor affecting the weather events in her teaching. For example, while teaching of the unit, she underlined the water vapor that means humidity saying that *"Water vapor in the air is the leading factor [that affecting the weather events]. The seaside gets plenty of rainfall. Why? [Because] water evaporates from the sea."*.

Overall, her teaching generally confirms her interview findings (Table 4.29). For example, she was knowledgeable related to the weather and weather events. She was aware of the dynamic nature of weather events and correctly expressed the wind, humidity, pressure, and temperature as factors leading to change in weather events. While teaching the unit, besides these factors, she added precipitation as another factor.

Table 4.29 *Weather Events that Beyza Mentioned in Interview and Classroom Observation*

The Concepts	Interview	Classroom Observation
Weather	Weather events are short-term phenomena. Weather events can show variation…	It is the atmospheric conditions that experiencing in short-term at a particular place are called weather events. Weather events show variation more.
Types of Weather Events		
Rain	As the water vapor accumulates in the air, it [water vapor] cools after a while and forms clouds. As the clouds form, the water droplets cannot stay in the air and they [water droplets] become heavier after a while… density increases. As the water vapor accumulated in that air condenses, it [water vapor] falls as rain.	There's a water cycle. Groundwater emerges to the Earth's surface. It [groundwater] evaporates with the effect of the sun on the Earth's surface. As they [evaporated groundwater] rise to the atmosphere, they encounter layer of air at various temperatures. If they encounter with a layer of cold air, water droplets form. As they [water droplets] do not stay in the cloud, they fall to the Earth's surface as rain, snow, and hail.
Dew	A lot of water vapor accumulate in the air… the weather is hot. Early in the morning, it [water vapor] is condensed as the dew on objects where close to the Earth surface such as on cars, houses, trees...	Not mentioned.
Rime	If the air suddenly cools, the water vapor freezes suddenly, and rime occurs.	When the weather is very cold in spring and autumn, it [rime] occurs on the objects on the Earth's surface such as on trees, grass, cars.

Table 4.29 *(cont'd)*

Types of Weather Events	Interview	Classroom Observation
Snow	Snow are ice crystals… If the water droplets, forming the clouds in the air, encounter a very cold air, they [water droplets] suddenly freeze and form ice crystals.	It [groundwater] evaporates with the effect of the sun on the Earth's surface. As they [evaporated groundwater] rise to the atmosphere, they encounter layer of air at various temperatures. If they encounter with a layer of cold air, water droplets form. As they [water droplets] do not stay in the cloud, they fall to the Earth's surface as rain, snow, and hail.
Hail	The winds suddenly cause drift movement with vertical movements in the air and the hail occurs.	If water droplets freeze suddenly, they [water droplets] form ice particle and the hail occur.
Wind	Low pressure is the area where the temperature is higher, and the density is lower. The winds move from high pressure [area] to low pressure [area].	It [wind] is the horizontal air movement that moves from an area of high air pressure to an area of lower air pressure…
Storm	If the winds are too strong, storms occur.	Not mentioned.
Hurricane	Especially in countries where there are boundaries to the ocean, hurricanes occur with very violent cyclone movement, that is, the movement of rotation around itself.	The intensity of the hurricanes exceeds 120 km.
Sea Breeze	Not mentioned.	During the day, while the land heats up faster, the sea heats up later. Then, the sea breeze occurs.

In the following section, Beyza’s substantive knowledge regarding the climate was presented.

4.2.2.1.3 Beyza’s Substantive Knowledge Regarding Climate

Beyza’s substantive knowledge, obtained from interview and classroom observation, regarding the climate was summarized under three subtitles: knowledge on climate, climate system and climate change, global warming and greenhouse effect, respectively.

Beyza first was asked her opinions regarding the definition of the climate and stated that;

> Beyza: We can say that the climate is weather events that experienced in long-term period.
>
> [Interview]
>
> Beyza: The long-term average of meteorological events such as humidity, temperature, precipitation and pressure in a region is called climate. In our country, the Mediterranean, Black Sea, terrestrial and Marmara transition climate are seen. Marmara transitional climate is seen in our country [Turkey] yet not specified in our [MoNE] textbook. In Ankara*, summers are dry and hot. When it rains in July, we should not change our minds about Ankara's climate, because we are talking about the average of meteorological elements in 30-40 years period in climate.
>
> **: a capital city of Turkey*
>
> [Classroom Observation]

In the interview, Beyza could not accurately describe the climate. In contrast, in her teaching, she correctly defined the climate as long-term average of meteorological events such as humidity, temperature. Also, she enriched her teaching by giving examples regarding the types of climates experienced in Turkey such as Mediterranean, Black Sea, terrestrial, and Marmara transitional climate.

Later, Beyza was requested to indicate what comes her mind regarding climate concept:

> Beyza: When saying the climate, climatology comes to my mind first… Climatologist… Then, 30-40 years process come to my mind… Then, regions come to my mind. [For example], the climate in Mediterranean region*... Countries come to my mind, for example… Then, weather events come to my mind…
>
> ***:** *is a geographical region located in south of the Turkey*

As seen from the interview, her list of climate related words included climatology, climatologist, 30-40 years process, region, country, and weather events. Then, she constructed a concept map by using these words. Beyza's concept map regarding the climate was shown in Figure 4.12.

> R: Can you construct a concept map by using the concepts you mentioned above? Please explain your map briefly.

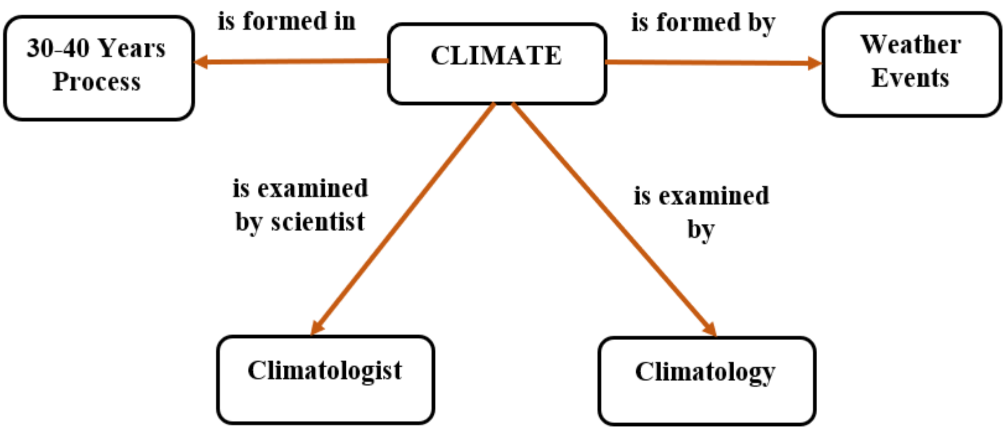


Figure 4.12 Beyza's Concept Map Regarding the Climate

She created ***a spoke structure*** (Kinchin, Hay, & Adams, 2000) through putting climate at the center. Her concept map possesses a radial structure. To make it clarify, all climate related concepts were positioned to directly connect only with the climate, and these concepts were radiated from the central concept (i.e., climate). Besides, there was no connection among other concepts. It was seen that her connection between the concepts of climate and weather events was restricted to the idea that *'climate is formed by weather events'*.

Since Beyza frequently associated climate with weather or vice versa, she was asked to combine both concepts in a single concept map (See Figure 4.13).

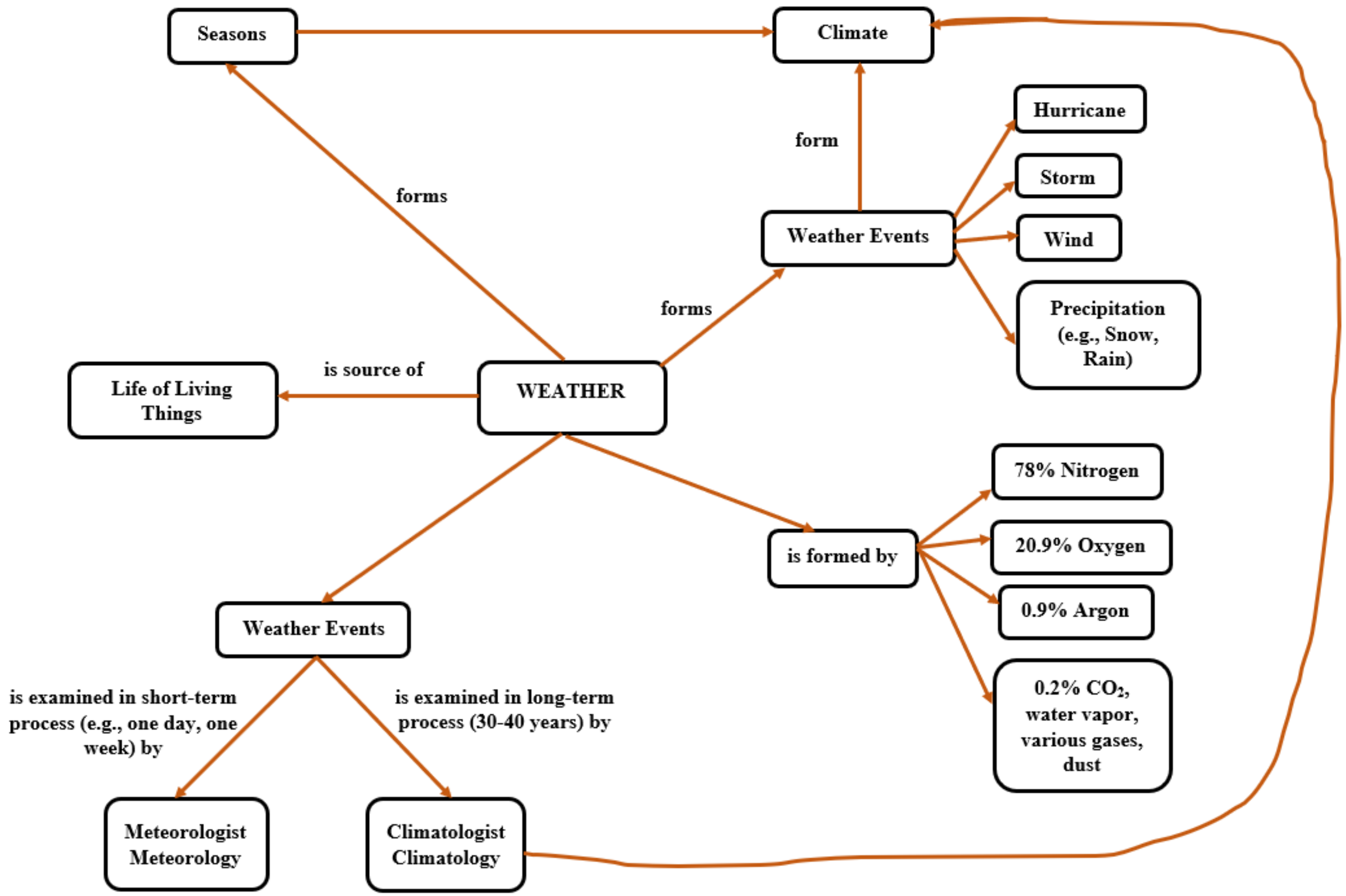


Figure 4.13 Beyza's Concept Map Regarding the Relationship Between Weather and Climate

As seen from figure 4.13, Beyza created a ***net framework*** (Kinchin, Hay, & Adams, 2000). Stated differently, her concept map includes integrated concepts and hierarchical network to some extent. In particular, she located the "weather" in the middle of the concept map (i.e., central concept) with saying that weather is source of life of living things. In her concept map, the connection among weather, weather events and climate were limited with the idea that *'Weather forms weather events. Weather events form climate'*. Also, she made a connection among the concepts of seasons, weather and climate that were included together in the unit.

> Researcher: Are climate and weather events the same concepts or different concepts? Why/Why not?
> Beyza: No… It [climate] is weather events experienced in long-term. Weather events that have been experienced in 30-40 years form the climate. They [climate and weather events] are not the same concepts. Stated differently, weather events form climate. For example, it is said that summer is very dry and hot in one region. Then, climatologists say [concluded] that in summer, the climate in that region is dry and hot. For example, a region has been rainy for 30-40 years… same type of weather condition is experienced... Climatologists say [concluded] that the winter season is very cold and snowy in that region.

Likewise, while teaching of the unit, she mentioned about the differences between the weather events and climate saying that;

> Beyza: Climate is the average of weather events in the long-term. Weather events are atmospheric phenomenon that occur in the short-term. Meteorology is the science discipline that examines weather events. Scientists examining weather events are called meteorologists. The science discipline that deals with climate is called climatology. Scientists dealing with this [climate] are called climatologists.

[Classroom Observation]

Also, during her teaching, she drew a table on the blackboard comparing and contrasting weather events and climate (See Table 4.30). (Beyza’s original table regarding the differences between weather events and climate was located in Appendix S, in Turkish).

Table 4.30 *Beyza's Table about the Difference Between Weather events and Climate*

Climate	**Weather events**
It is the average of atmospheric events in a long-term.	It is the short-term atmospheric events.
It occurs in a wide area.	It occurs in a particular place.
Examines the average of atmospheric events in the long term (30-40 years).	Examines short-term atmospheric events (e.g., daily, weekly).
Climate shows less variation.	Weather events show high variation. Weather events are based on prediction.
While talking about climate, dry, rainy, hot, and cold expressions are used.	The expressions such as rainy, snowy, sunny, and windy are used.
The science discipline that studies on climate is climatology.	The science discipline that studies on weather events is meteorology.

Throughout the interview, Beyza was asked the several questions regarding seasons, weather/weather events and climate concepts. However, the unit is consisted of all these concepts together, it is important to clarify participants’ understanding of possible relationship among the seasons, climate, and weather events. Hence, as a last question, she was asked to make connection among the seasons, weather events, and climate. According to her, seasons, climate, and weather events are connected to each other; because they change depending on each other. She believed that when seasons change, climates also change which led to changes in weather events. The sample related excerpts from the interview were as follows;

> Beyza: The reason for all of them [seasons, climate and weather events] is actually the Sun… Without the Sun, neither seasons nor the life would be

possible… Nothing would have happened [without the Sun] ... The Earth's revolution around the sun and Earth's tilted axis cause to form seasons. The climate changes due to the formation of seasons. The weather events change as well. In other words, they [seasons, climate, and weather events] change, depending on each other.

Overall, her teaching partly confirms her interview findings, but there are some differences. For example, despite she had difficulty in defining the concept of climate in the interview, she correctly defined the climate in her teaching. On the other hand, she correctly addressed the differences between climate and weather events in her teaching and showed their differences by drawing a table. Moreover, she tended to establish a relationship among the seasons, weather and climate concepts by stating that these concepts can alter based on each other. Beyza's knowledge regarding climate based on interview and classroom observation data were presented in Table 4.31.

Table 4.31 *Beyza's Knowledge of Climate*

The Concepts	Beyza's Responses
Climate	The long-term average of meteorological events such as humidity, temperature, precipitation and pressure in a region is called climate.
The Differences Between Weather and Climate	**Weather;** Weather events are atmospheric phenomenon that occur in the short-term. It occurs in a particular place. Weather events show high variation. Weather events are based on prediction. Meteorology is the science discipline that examines weather events. Scientists examining weather events are called meteorologists. **Climate;** Climate is the average of atmospheric events in a long-term. Climate shows less variation. It occurs in a wide area. The science discipline that deals with climate is called climatology. Scientists dealing with climate are called climatologists.

Since climate is a complex system, specifically, in this part, findings related to whether Beyza perceived climate as a complex system or not were reported.

> Researcher: Up to now, we talk about climate. Do you think that climate is a system? Why/why not?
>
> Beyza: Hmmm… Climate is an interdependent process. We can say that it [climate] is a system…. Hmmm… We're talking about something that is interdependent… For example, why do we define the ecosystems as a system?... [In ecosystems], there is an environment that interacts with each other. There are living things... There are non-living things... They [living things and non-living things] interact with each other. There is a working system in ecosystems… All in one process… Life continues with the

> continuous functioning of this system [ecosystem] … We said that climate is a system. There are weather events… there is environment that affected by weather events. In environment, there are living and non-living things… weather conditions... As I said, the wind, temperature, and the pressure form weather events and then, they [wind, temperature, pressure] form the climate of that region…. Weather events form climate.

Then, she wrote the components of the climate system schematically (See Figure 4.14). (Original Turkish version can be seen in Appendix S).

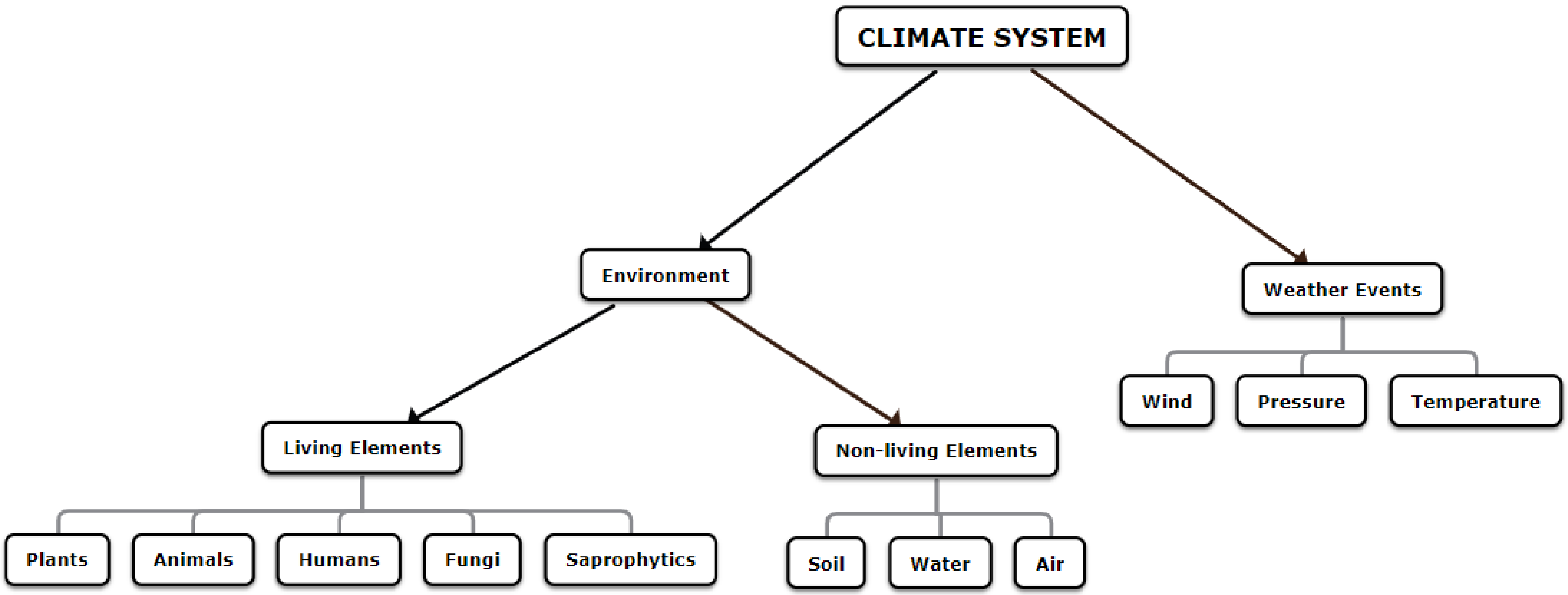


Figure 4.14 Beyza's Components of the Climate System

Researcher: What about processes involved in the climate system?

Beyza: Hmmm… As a result of interaction with the environment, weather events occur. Occurrence of natural phenomena are inevitable component of a [climate] system. The weather events affect living and non-living things. The climate is long-term average of weather events. Climate that occurs in long period of time affects the diversity of living things and the biological diversity... Climate determines the landforms, the lifestyle, the type of plants grown as well as the economic situation of the people living in that area…

Researcher: Well, assume that, one of the components of the climate system has changed. What happened? How these change influence climate system? Can you give an example?

Beyza: Hmmm… For example, [if] there is no rain fall…. drought occurs… or [if] it's raining too much, [then] … Flood occurs... They [flooding and drought] damage the agricultural crops. When the agricultural crops are damaged, people who depend on that crop for their living suffer from great distress. This situation influences both quality and quantity of the crop and us as consumers.

Beyza's knowledge of the climate system was shown in Table 4.32. The findings implied that she seems to be knowledgeable about complex nature of climate. She perceived climate as a system. Also, she elaborated her idea of the systems thinking approach by defining the ecosystem in which living and non-living things interact with each other as a dynamic system. According to her, climate system included many components like weather events including wind, pressure, and temperature, and environment including living things (i.e., plants, animals, humans, saprophytic, fungi) and non-living things (i.e., soil, air, water) (See Figure 4.14).

Regarding the processes in the climate system, she stated that wind, temperature and pressure constitute weather events, and there are impacts of weather events on the environment. Then, she said that the change in precipitation patterns (e.g., no rainfall, or raining too much) lead to floods or droughts, which in turn negatively impact the agricultural products and humans' life. Based on the findings, she seems to be aware that the climate system is affected when there is a change in one of the components in the climate system.

Table 4.32 *Beyza's Knowledge of Climate System*

Component	**Description**
Weather events ▪ Wind ▪ Pressure ▪ Temperature	The wind, temperature, the pressure. Rain fall.
Environment	
a) Living Elements ▪ Plants, Animals ▪ Humans ▪ Fungi ▪ Saprophytic	Adverse effect on biological diversity, agricultural crops. Influenced adversely (i.e., Lifestyle, economic situation).
b) Non-Living Elements ▪ Soil ▪ Water ▪ Air	
Landform	Flooding, drought

Overall, data obtained from Beyza can be summarized as a whole depending on categorization by Shepardson et al. (2014), and also, the interactions she established among the components of climate system were presented based on Shepardson et al. (2014) (See Table 4.33).

Table 4.33 *The Categorization of Beyza's Knowledge of Climate System depending on Shepardson et al. (2014)*

Component	**Description**
Human	Influenced negatively (economy, lifestyle)
Atmosphere	Weather events Temperature Winds Rainfall Pressure Water Air
Life (plants and animals)	Adverse effect on biological diversity, agricultural crops
Land	Landforms Soil Flooding Drought
The Interactions among the components of climate system based on Shepardson et al. (2014)	
Atmosphere (more rainfall) → Land (flood) → Life (agricultural crops) → Human (people who depend on that crop for their living)	
Atmosphere (no rainfall) → Land (drought) → Life (agricultural crops) → Human (people who depend on that crop for their living)	

Beyza’s response to questions pertaining to climate change, global warming and greenhouse effect gave more details about her perception of climate as a complex system (see the following section).

4.2.2.1.3.1 Beyza’s Substantive Knowledge Regarding Climate Change, Global Warming and Greenhouse Effect

When asked to explain the climate change, she stated that;

Beyza: Climate change is the result of the greenhouse effect. What is the greenhouse effect?... The sun's rays coming down to Earth reflect back to the space. But due to the air pollution, greenhouse gases accumulate in the atmosphere and prevent the return of the sun's rays [to the space]. Therefore, the sun's rays stay in the Earth and heat the Earth.… It causes the heat the Earth excessively, which lead to global warming. The global warming causes climate change. In the poles, glaciers are beginning to melt… they [glaciers] are melting rapidly… The temperature of the ocean decreases. This [greenhouse effect] changes all the climates of other ocean-shore countries. It also affects other countries. In other words, global warming causes climate changes that affect all countries…

Researcher: Well, do you think that climates have changed?

Beyza: I think [climate can change]. Last year, for example, it is not normal for Ankara* to not snow or falling too much rain … drought on the other sides… I give example from Ankara because we live in there. In general, climate change will have a negative impact on our lives.

***:** *is a capital city located in Central Anatolia region of Turkey*

Researcher: Well, you mentioned about the greenhouse effect and greenhouse gases. Can you explain greenhouse effect by drawing?

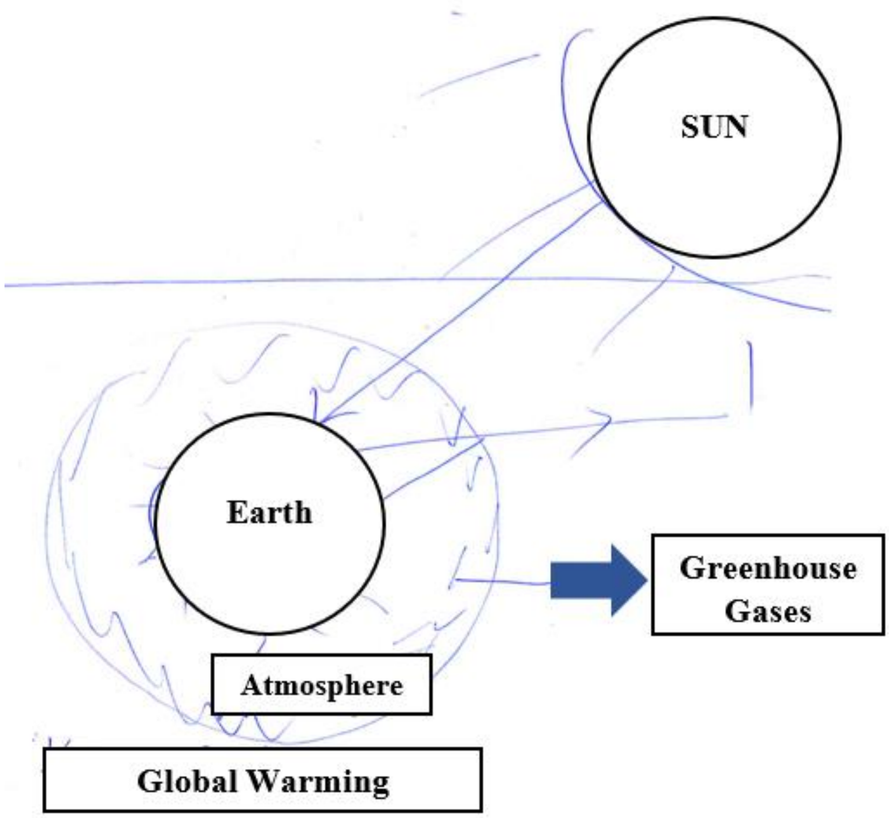


Figure 4.15 Beyza's Drawing Regarding Greenhouse Effect

She believed the existence of climate change. She supported her ideas by giving example from her experiences in daily life. She attributed the causes of climate change to the global warming and greenhouse effect, and the cause of global warming to greenhouse effect. Her idea that the greenhouse effect, global warming, and climate change have influence on all countries indicated that she had an understanding of the systems thinking. Then, while mentioning about the process of the greenhouse effect, she stated that sun’s rays could not reflect back to space due to the greenhouse gases caused by air pollution accumulate in the atmosphere and thereby, sun’s rays remained in there heat the Earth excessively. However, she seems to have a lack of knowledge and misconceptions regarding the climate change, global warming and greenhouse effect. For example, she used the concept of sun's rays instead of sun's incoming short-wave radiation and earth's outgoing long-wave heat radiation and mentioned about sun's rays remaining on Earth, but not mention about bouncing back or passing through the atmosphere. She wrongly associated release of greenhouse gases with pollution, which lead to the greenhouse effect, global warming and thus climate change. Therefore, she had a misconception as to association between the pollution and the global warming, climate change and greenhouse effect. While defining the greenhouse effect, figure 4.15 drawn by her indicated another misconception that a layer formed by greenhouse gases, which she associated with pollution, in the atmosphere surrounding the Earth that trap sun’s rays. Furthermore, while addressing consequences of the climate change, she has also incorrect idea that due to climate change, *“The temperature of the ocean decreases.”*.

In the following question, Beyza’s ideas regarding the consequences of the climate change and its’ impact on our daily life was elaborated. She expressed that she said the consequences of the global warming and climate change under this question together. She stated that the shortage of water, warmer summer, colder winter and extreme weather events such as the floods, droughts are consequences of the climate change and global warming. She addressed the impacts on agricultural area saying that farming will be affected by the climate change. She also reminded of the need to take precautions toward climate change. However, she did not mention about the impact of climate change and global warming on humans’ health, ecosystems, and the chemistry of ocean water. The sample excerpts from the interview were as follows:

> Beyza: Climate changes have direct influence on farming … Winter will be colder... Summer will be warmer... Hail will occur. When we leave our cars outside, hail will give damage to our cars. Floods will occur… Drought will occur. I'm thinking about how to live without water… of course... shortage of water is a terrible thing for human being and all living things. If no precautions are taken against climate change, life will become really tough…

Since Beyza mentioned about greenhouse gases in previous questions, she was subsequently asked questions regarding the greenhouse gases.

> Researcher: What are the greenhouse gases?
>
> Beyza: Greenhouse gases are carbon compounds that accumulate in the atmosphere and are produced mostly by combustion of fossil fuels. For example, carbon dioxide, carbon monoxide... Nitrogen dioxide and Sulphur dioxide are greenhouse gases as well… As I said, they [greenhouse gases] prevent the [sun's] rays reflecting back to the space [sun's rays stay in the Earth]. They [greenhouse gases] accumulate [in the atmosphere], which causes the greenhouse effect.
>
> Researcher: What do you think about that whether the amount of the greenhouse gases change in air?
>
> Beyza: Of course, the amount of greenhouse gases change… If fossil fuels continue to be burned and if no precautions are taken, the greenhouse gases increase... If precaution is taken [toward the reduce using of fossil fuel], the amount of the greenhouse gas decreases gradually.

She attributed the change in greenhouse gases to both using and burning the fossil fuels. She also addressed the view that precautions should be taken to reduce the amount of greenhouse gases. Her responses showed that she correctly expressed carbon dioxide as a greenhouse gas, but had an incorrect idea that nitrogen dioxide, Sulphur dioxide, and carbon monoxide are greenhouse gases.

Next question asked a possible relation between greenhouse gases and the matter cycles:

> Beyza: Of course, yes... It [changes in amount of greenhouse gases] directly affect the carbon cycle… It affects the water cycle… movement of water vapor … the changes in the amount of greenhouse gases directly affect the oxygen cycle. It [greenhouse gas] is not much associated with nitrogen cycle… the changes in the amount of greenhouse gases disturb the balance

> [of the matter cycles]. Well, what is the role of green plants?... green plants photosynthesize… Plants give oxygen to the air. All living things use that oxygen. Green plants take up carbon dioxide. What happens if we reduce the number of green plants and we release excess carbon dioxide to the air? The air cannot be cleaned… Carbon dioxide begins to accumulate in the atmosphere. It [carbon dioxide] is one of the leading greenhouse gases. It [carbon dioxide] has direct impact on global warming…

She thought that the changes in the amount of greenhouse gases negatively affect the matter cycles which are carbon cycle, water cycle and oxygen cycle. She explained how the changes in the amount of greenhouse gases affect matter cycles with giving example regarding oxygen cycle. For example, she said that when the number of plants that produce oxygen is reduced, the carbon dioxide content in the air increases and therefore, the air cannot be cleaned. On the other hand, she stated that nitrogen cycle is not associated with the changes in the amount of greenhouse gases. In fact, nitrogen cycle is affected by the changes in amount of greenhouse gases.

As final questions, Beyza was asked whether the presence of greenhouse gases is a natural phenomenon and what would happen if there were no greenhouse gases:

> Beyza: It is not a natural phenomenon [that greenhouse gases exist in nature] … Because their [greenhouse gases] presence [in nature] cause global warming. If humans had not used these fossil fuels so much, or if the industry hadn't advanced so fast, there would have been no pollution in the air and no greenhouse gases. If we had gone back century or two centuries ago, we would have not been talking about greenhouse gases, air pollution or global warming. It is understood that the developments in technology and industry caused greenhouse effect to occur. Human caused it [greenhouse effect] …
>
> R: So, what would happen if there were no greenhouse gases?
>
> Beyza: It would be so fabulous if there were no greenhouse gases … The natural balance of the Earth would not be disturbed… The glaciers in poles

would not melt… Climate change would not occur... Global warming would not occur.

Her responses showed that she failed to perceive the presence of greenhouse gases in nature as natural phenomenon. According to her, if the greenhouse gases were not existed, the nature's balance would not be disturbed for example climate change and global warming would not occur. Therefore, she appeared be to not aware that in case greenhouse gases do not exist, the planet would become uninhabitable because the global temperature would be nearly -17 °C (Dove, 1996). Also, her responses pointed out a misconception that she seemed to perceive the greenhouse effect as harmful environmental phenomena for the Earth, not a naturally occurring phenomena.

Up to this section, the interview findings were presented. Next section the findings were reported obtained from classroom observation.

4.2.2.1.3.1.1 Beyza's Substantive Knowledge Regarding Climate Change, Global Warming and Greenhouse Effect: Classroom Observation Findings

Her responses to interview questions partly supported by classroom observation. For example, while teaching of the weather and climate topic, she addressed the relationship among the climate change, global warming and greenhouse effect by stating that;

> Beyza: The result of the greenhouse effect is global warming. Global warming results in climate change …
>
> [Classroom Observation]

She attributed the causes of climate change to the global warming and greenhouse effect and that of global warming to the greenhouse effect. Both the interview and classroom observation data indicated that she appeared to aware of the cause-effect relationship among climate change, global warming, and greenhouse effect.

Parallel to her interview, she showed the process of greenhouse effect with drawing a figure on the blackboard (See Figure 4.16). Then, she defined the greenhouse effect saying that the greenhouse gases formed with the burning of fossil fuels accumulate in the atmosphere, which provide sun’s rays to stay in the Earth. But she again used the concept of sun's rays instead of sun's incoming short-wave radiation and earth's outgoing long-wave heat radiation and did not address sun’s rays bouncing back or passing through the atmosphere. Unlike from interview, while teaching of the unit, she correctly expressed the nitrous oxide (N_2O), methane (CH_4) and ozone gases (O_3) as the greenhouse gases existed in nature. The related excerpts from the classroom observation were as follows:

> Beyza: Do you remember the greenhouse effect?... Nitrous oxide (N_2O), methane (CH_4) and ozone gases (O_3) are formed by the combustion of fossil fuels. As these gasses [N_2O, CH_4 and O_3] accumulate in the atmosphere, they prevent returning of the sun’s rays to the space. The sunlight strikes the Earth… and warms the Earth...

[Classroom Observation]

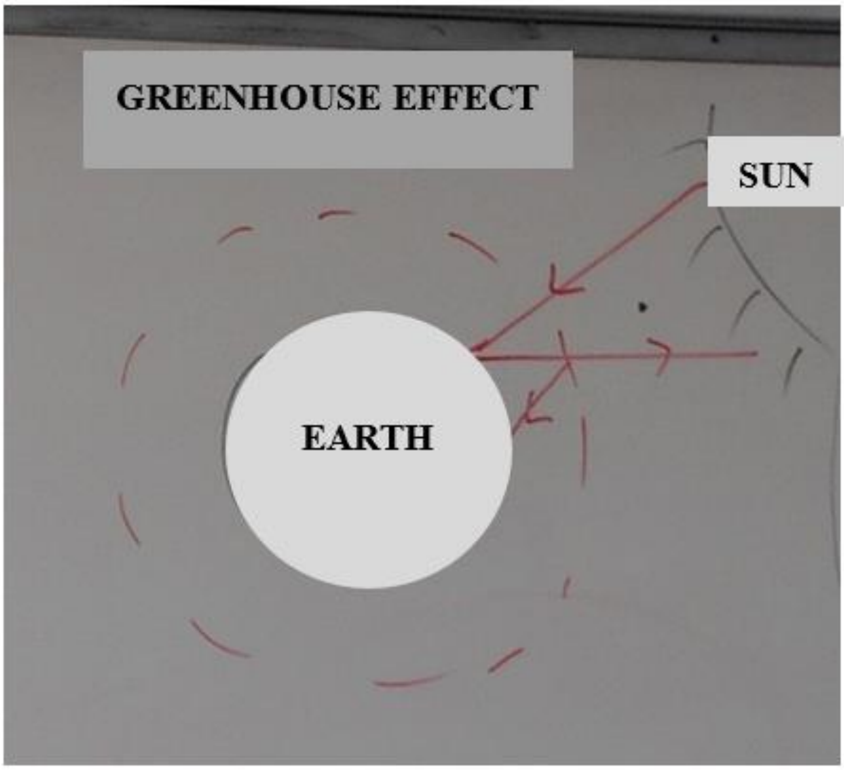


Figure 4.16 Beyza's Drawing Regarding the Greenhouse Effect

As well as in the interview, during her teaching of the unit, she addressed the consequences of the climate change saying that;

> Beyza: The water level is rising… the water temperature is increasing… the floods occur... droughts occur… the biological diversity is decreasing…agriculture is affected …farmers harvest relatively small amount of product... There are a lot of adverse effects.
>
> [Classroom Observation]

In addition to the interview, in her teaching, she mentioned other consequences of the climate change such as increasing of the water level and the water temperature, decreasing of the biological diversity.

Also, she addressed the consequences of the global warming while teaching of the unit such as the melting of glaciers, decreasing of the water resources, increasing of the desertification, changes in seasonal conditions, climate change. In addition to the interview, she added the extinction of some species and damaging of the habitats of living things as another consequences.

Briefly, above findings indicated that although she considered cause-effect relationship among climate change, global warming and greenhouse effect, she had difficulty in explaining these concepts. For instance, she incorrectly associated the greenhouse gases with pollution. Since she associated with greenhouse gases, she had a misconception about associating climate change, global warming and greenhouse effect with pollution. She seemed to be not aware of the natural existence of greenhouse gases in nature, because she believed that greenhouse gases disrupt the balance of nature by causing global warming and climate change. On the other hand, she addressed the consequences of global warming and climate change such as flood, drought, decreasing of biodiversity. Beyza’s knowledge of climate change, global warming and greenhouse effect were based on interview and classroom observation data were presented in Table 4.34.

Table 4.34 *Beyza's Knowledge of Climate Change, Global Warming and Greenhouse Effect*

The Concepts	Beyza's Responses
The Causes of Climate Change	Greenhouse effect Global warming Greenhouse gases Air pollution
The Consequences of Climate Change	Colder winter Warmer summer Melting of glaciers Rising of the water level Shortage of water Floods Drought Increasing of the water temperature Decreasing of the biological diversity Decreasing in the amount of product in the agricultural area
The Causes of Global Warming	Greenhouse effect Greenhouse gases Air pollution
The Consequences of Global Warming	Colder winter Warmer summer Melting of glaciers Floods Drought Decreasing of the water resources Increasing of the desertification Extinction of some species Changes in seasonal conditions Damaging of the living things' habitats Climate change
Greenhouse Effect	Due to the air pollution, greenhouse gases accumulate in the atmosphere and prevent the return of the sun rays to the space. Therefore, the sun's rays stay in the Earth and heat the Earth. It causes heat the Earth excessively.
Greenhouse Gases	Carbon dioxide (CO_2) Carbon monoxide (CO) Nitrogen dioxide (NO_2) Sulphur dioxide (SO_2) Nitrous oxide (N_2O) Methane (CH_4) Ozone gases (O_3)

Table 4.34 *(cont'd)*

The Function of Greenhouse Gases	It is not natural phenomenon that greenhouse gases exist in nature. Greenhouse gases' presence in nature cause global warming. It would be so fabulous if there were no greenhouse gases. The natural balance of the Earth would not be disturbed.

4.2.2.1.4 General Summary for Beyza's Substantive Knowledge Regarding the Seasons, Weather, and Climate

Under this heading, general summary for Beyza's substantive knowledge regarding the seasons, weather, and climate was presented.

Regarding the concepts included in seasons, Beyza was able to express both two causes of seasons as Earth's tilted axis and Earth's revolution around the Sun both in the interview and classroom observation. She correctly defined the weather and mentioned about lots of weather events both in the interview and classroom observation such as rime, snow, hail, wind, rain. She stated the factors that are wind, pressure, temperature, precipitation, and humidity lead to change in the weather events. She was aware of the concept of the meteorologist and meteorology. She tried to link the weather with the climate. Despite her definition of climate was incomplete in the interview, she correctly described the climate as long-term average of meteorological events such as humidity, temperature in her teaching, and was able to state the differences between the weather and climate. She was aware of the concepts of the climatology and climatologist. She defined the climate as a system by mentioning about most of the components of the climate system and some interactions among the components. Regarding the causes of the climate change, her responses were limited only anthropogenic causes and she did not mention related to the natural causes (e.g., solar variability). She also holds misconceptions as to the relationship between pollution and climate change (Table 4.35). She mentioned about several consequences of the climate change, for instance, flood, decreasing of biological diversity, rising of the water level. Similar to climate change, she also linked global warming with pollution (Table 4.35). She mentioned about several consequences of the global warming such as drought, flood, melting of glaciers. As far as greenhouse effect was considered, data showed that she was able to identify some greenhouse gases (e.g., methane, ozone, nitrous oxide), and she cited the use of fossil fuels and advancement in industry as sources of greenhouse gas emissions to nature. However, she wrongly associated the increasing the amount of greenhouse gases in the atmosphere with air pollution. Also, she holds misconceptions as to the process of greenhouse effect (See Table 4.35). For example, she associated the greenhouse effect with pollution because of its' association with greenhouse gases, and she appeared to not perceive the greenhouse effect as naturally occurring phenomena because she thought that nature's balance would not be disturbed in case of absence of the greenhouse gases.

Table 4.35 *Beyza's Misconceptions*

Beyza's Misconceptions	**Supporting References**
A layer formed by greenhouse gases in the atmosphere surrounding the Earth that trap sun's rays.	(Papadimitriou, 2004)
Relating the global warming and climate change with air pollution.	(Papadimitriou, 2004)
Her perception of the greenhouse effect as harmful environmental phenomena for the Earth.	(Arslan, Cigdemoglu, & Moseley, 2012)
Relating the greenhouse effect with pollution.	(Papadimitriou, 2004)

Overall, it was concluded that she seemed to be more knowledgeable about the basic concepts of seasons, weather, climate and climate system compared to climate change, global warming, and greenhouse effect (See Table 4.36).

Table 4.36 *Summary of Beyza's Substantive Knowledge*

Concepts	**Beyza's Substantive Knowledge**
Seasons	Knowledgeable
Weather	Knowledgeable
Climate	Knowledgeable
Climate System	Knowledgeable
Climate Change	Lack of knowledge
Global Warming	Lack of knowledge
Greenhouse Effect	Lack of knowledge

4.2.2.2 Beyza's Syntactic Knowledge

In this section, Beyza's syntactic knowledge regarding the aspects of nature of science both separately and in the context of weather and climate was reported by using VNOS-C questionnaire (Lederman et al., 2002).

Firstly, Beyza was asked her opinions regarding the science and what distinguishes science from other disciplines.

> Beyza: Science involves detailed investigations in any field…. and performing experiments, making observations and collecting data to provide evidence for the formulated hypotheses. Science is a process involving all kinds of research…
>
> Researcher: What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines (e.g., philosophy)?
>
> Beyza: In fact, it [science] is not separated from religion and philosophy … Hmmm…to be scientific, there should be a team and a subject to investigate. If there is a team to make research in religion, it makes religion scientific. That research produces results and leads to some conclusion... In fact, we

cannot say that religion completely separated from science. The subject of science is so broad that everything can be a subject of science. The most important thing is that it should be produced provable, observable and measurable results [in science].

Researcher: Do you think that is there a sequence of steps (that scientists follow) in their research?

Beyza: Of course… scientific…science processes…hypothesis… Hmm…. Scientist wonders about a subject. Scientist becomes curious... makes research…. Then, they [scientists] formulate a hypothesis about a subject. Then, they [scientists] start to do research to prove it [the hypothesis]. They [scientists] make all kinds of experiments and observations to prove [the hypothesis]. Then, they [scientists] check whether the hypothesis is correct or not. Then, they [scientists] reach a conclusion. If science processes are not followed, the study cannot be scientific…

Researcher: Does the development of scientific knowledge require experiments? Why/ Why not?

Beyza: Absolutely [experiment is necessary] … Hmmm… How will it [scientific knowledge] be proved without doing experiments?... It [scientific knowledge] depends on the hypothesis. For all [scientific knowledge], the experiments are not needed, but this time observation is needed [to prove scientific knowledge]. There needs to be something to provide evidence…. It [scientific knowledge] needs to be proved by observation, research and experiment. Experiments will be conducted in different context and at different times. Of course, controlled experiments should be conducted… Dependent variables, independent variables and controlled variables are determined. The result is reached by doing experiments continuously...

Beyza's responses gave some clues about her understandings of science as well as empirical NOS. She explained what the science is by emphasizing only one aspect of science which is ‘science is a process and method’ (Faikhamta, 2013). She stated that she defined the science as a process that involves experiment, observation and data collection to prove the scientific knowledge. She added that everything can be a subject of science as long as the results are measurable, provable and observable. Although she thought that experiments are necessary for development of scientific knowledge, she later said that experiments could not be carried out to prove every scientific knowledge and therefore, observations are necessary. She considered role of observation in performing experiment. Her responses also indicated her tendency to accept the existence of single scientific method by claiming that *If science processes are not followed, the study cannot be scientific*.

Her understanding of above-mentioned aspects of science also was evaluated in the context of weather and climate. She adequately explained *meteorology as a science discipline examining the weather events, and meteorologists as scientists who study on weather events* both in the interview and her teaching.

> Researcher: What is the science discipline that make research on the weather events? Who is the scientist that make research on weather events?
>
> Beyza: Meteorology and meteorologist.
>
> Researcher: How do meteorologists predict weather events?
>
> Beyza: Hmmm… Meteorologists have a lot of tools and equipment [to make measurement regarding weather]. For example, they [meteorologists] measure the air pressure with a barometer, air temperature with a thermometer, wind with anemometer, humidity in the air with a hydrometer. Meteorologists use air balloons to monitor daily weather events. Meteorologists examine [the data regarding weather].
>
> Researcher: How do meteorologists analyze data? How do meteorologists reach a conclusion?
>
> Beyza: They [meteorologists] examine the humidity in the air and temperature. For example, if the humidity in the air increases, they

[meteorologists] say that “It will be rain today.”. If the weather is cold, they [meteorologists] say that “The snowfall is expected.”. Generally, all predictions [made by meteorologists regarding weather] become correct…

Researcher: Do you think the weather forecast made by meteorologist is accurate?

Beyza: Hmmm… We [humans] cannot say certain for the phenomenon taking place in nature, but it [weather forecast] is mostly true. They [meteorologists] announce the time when the rainfall is expected in Ankara tomorrow. They [meteorologists] generally predicted correctly 99%- due to the advances in technology. Now, scientists work with too many tools and collect data and evaluate it, yet nature is not a machine and different conditions can be emerged…

In the same way, Beyza’s teaching provided important clues about her understanding of certainty in science saying that:

Weather events are predictable. These predictions may be correct or not.

[Classroom Observation]

Similarly, Beyza defined *climatology as a science discipline examines the climate and climatologists as scientists who study on climate* both in interview and in her teaching. Following question reveals her idea about how climatologists collect data, analyze data and reach a conclusion.

Beyza: Climatologists conduct long-term research. Climatologists examine the temperatures and precipitation in an area over a period of 30-40 years… They [climatologists] examine the data regarding precipitation pattern, and changes in temperature… For example, they [climatologists] say that “In this region, the climate is hot, drought… and humid.”. They [climatologists] present all these data and determine the climate. They [climatologists] make use of the data collected by meteorologists daily. Meteorologists provide daily, weekly and monthly weather reports and make research [regarding the

> weather]. After that, the data are accumulated and they become annual, biannual, ….5 or 10 years… They [climatologists] do research regarding the past, not the future. Climatologists examine the weather conditions in the past. Then, they [climatologists] determine the climate… Climatologists analyze the data... They [climatologists] have several scales to evaluate the data.

Since Beyza mentioned performing experiment and making observation to prove scientific knowledge and also making prediction depending on the available data, it was seen that she was aware of the empirical NOS. When asked how meteorologists predict weather events and climatologists collect data on climate, similar to the previous questions, her responses such as making measurements, making observation, evaluating data, and reaching a conclusion showed that she had the idea of the existence of single scientific method. She expressed that meteorologists make measurements related to weather with various tools, examine the data obtained regarding weather, and make prediction about the weather events based on available data. She thought that weather forecast is generally accurate with the help of the advancement in technology but added that weather forecast is not certain because unexpected situations can happen in the nature. She stated that climatologists make investigation in the long-term (e.g., 30-40 years), that examine weather-related data in the past, evaluate the data with various scales, and that determine the climate depending on the past data. It means that climatologists make inferences regarding climate based on the past data. Beyza's responses revealed her understandings of inferential nature of science as well as empirical nature of science.

In the following parts, Beyza's responses to a scientific theory and a scientific law were revealed.

> Researcher: Is there a difference between a scientific theory and a scientific law?
>
> Beyza: The law is a proven knowledge and undeniable… Unquestionable...everything has been found related to that knowledge… The

scientist made detailed investigation and provided evidence for the scientific knowledge... For example, the laws of reflection… There is no need to discuss this law [laws of reflection] any longer [because laws of reflection have been proven]. The theory is knowledge that can change… it needs further study … the different knowledge can be found related to it [theory].

Researcher: What makes you think that theories can change?

Beyza: Hmmm… The data can change… conditions for observation can change... Maybe, it [theory] changes depending on the person… Sometimes, there may be also errors.

Researcher: Ok, what about the scientific laws? Do they change over time? Why / Why not?

Beyza: Actually, some of them [scientific laws] change... However, I've never seen a law that changed so far... Of course, scientific data can change in the light of new discoveries. For example, science curriculum changes frequently…this year they [some information in the curriculum] are true, next year they are wrong…. Science changes……is open to continuous change, discovery and development.

Beyza’s responses enlightened her understandings regarding the functions of and relationships between theory and law, and tentative NOS. She stated that theory is a scientific knowledge that can be changed and needs further investigation. She appeared to believe presence of a hierarchical relationship between law and theory. She believed that theory can change due to the changes of data, conditions for observation, as well as existence of mistakes. Her responses reflected her idea about the subjective nature of science by claiming that *theory changes depending on the person*. Lastly, her response showed that she was undecided whether laws change because although she said that laws are proven scientific knowledge, she also said that laws can change with new discoveries at the same time. Consequently, she appeared to be unaware that laws and theories are not same types of knowledge, and she seems to be hold naïve view regarding the functions of and relationships between the theory and law. This understanding also reflected in the following question asking whether greenhouse effect is a theory.

> Beyza: It [greenhouse effect] is a theory… They [scientists] observe the effects of it [greenhouse effect]. After that, they [scientists] feel it's effects and then, start to investigate them [the effects of greenhouse effect]. So, the greenhouse effect is still a theory... We can't say that it [greenhouse effect] is a law…
>
> Researcher: Do scientists certain about global warming? Why/Why not?
>
> Beyza: They [scientists] are certain. There are indications [for global warming] ... The glaciers at the poles are melting... Climate changes, we are experiencing with changes in the seasons… All of these are good evidences [for global warming]. Acid rain and air pollution are good evidences [for global warming] too.

This question revealed Beyza's understandings regarding certainty of scientific knowledge. She believed that scientists are certain about the existence of global warming, and she based her idea on several evidences such as melting the glaciers, climate change, acid rain. As it is apparent in the following question that she was unaware of the role of human inference, and subjectivity in science.

> Researcher: Scientists disagree about the causes of global warming. Some researchers say that the continuous use of fossil fuels by humans causes our planet to warm up, while other scientists say that natural forces that have been determining weather conditions for millions of years have caused it [global warming]. From this example, how can scientists reach the different results using the same data? Can you explain?
>
> Beyza: Frankly, I don't know...at the moment, I can't think anything … Because, for me it is not logical to use the same data and find something completely different.

Researcher: Scientists conduct scientific experiments let's say on renewable energy sources or climate change. Do scientists use their own imagination and creativity in their research?

Beyza: Scientists must have imagination. For example, the scientists [first] imagine, and then, try to prove it. They [scientists] will make research about it. Scientists need to have a high level of imagination.

Researcher: Why do you think that scientists' imagination should be high?

Beyza: Hmmm…if they [scientists] do not imagine… I do not know…. For example, a mobile phone… In the past, scientists imagined about it [phone]. They [scientists] imagine that there will be a phone in our pocket… this phone will have the camera and used as a photograph machine, we [as human] will be able to communicate with the world [by using phone] in the future... First of all, scientists need to imagine it. Then, they [scientists] need to study on what they imagine.

Researcher: Well, at what stages of their research do scientists use their imagination and creativity?

Beyza: [Scientists use their creativity and imagination] in first stages of research… First, scientists will imagine. It [research] does not progress only with imagination of course… Scientists will go into the process of scientific study to develop their ideas. They [scientists] will prove [their ideas]. They [scientists] will make new discoveries…

Beyza's responses to those questions revealed her incomplete understandings of role of creativity and imagination in the research. According to her, scientists need to have imagination, but they use their imagination only at the beginning of the research and then they focus on the process of scientific study. Despite she was aware of the importance of creativity and imagination in science, she was unaware that scientists use their creativity and imagination in all phases of the scientific investigation.

Researcher: Some argue that science is influenced by the values of the society in which it is created such as religion, social, cultural values, philosophical assumptions and intellectual norms. For some, science is universal and independent from concepts such as social, cultural values, philosophical assumptions, and intellectual norms. What do you think about that? Do you think science is independent or influenced by the values of society?

Beyza: Science is universal of course... But while science develops, it [science] is affected by all conditions of the environment...such as social, cultural, religious...Therefore, it [science] may have difficulty in developing and advancing as well.

Researcher: Can you give an example that supports your opinions?

Beyza: Hmmm… take autopsies in the field of medicine... People have suffered from serious problems while doing research with autopsies…cutting the body… because of religious reasons…touching the bodies or cutting of the dead bodies can be perceived as sin … Galileo suffered from the serious problems in his theories about the sun, Earth and planets and Galileo's theories were in contradiction with the [idea of] church. However, there was no telescope at that time [in past times when Galileo lived]. There were no such instruments to make observation easily. Maybe, they [scientists] had a very simple telescope. Maybe, there was only few scientists who used it [telescope]. Perhaps, they [scientists] could not prove it [scientific knowledge] by thinking, investigating and observing. They [scientists] put forward their thoughts and then, they [scientists] experienced with serious problems. He [Galileo] was sentenced to death. He [Galileo] gave up his own theories to survive. He [Galileo] was in serious opposition to the church at that time.

Beyza’s responses regarding socio-cultural nature of science revealed that her hesitation whether science is universal or independent from society’ values. Though accepted science as universal at first, her examples provided evidence for how science is influenced from religion.

In the following section, summary of Beyza's syntactic knowledge was reported.

4.2.2.2.1 Summary of Beyza's Syntactic Knowledge

Overall, Beyza's responses related to syntactic knowledge were evaluated based on the interview and classroom observation data together (See Table 4.37). According to the findings, it was found that she had deficiencies related to some NOS aspects. For instance, despite she believed that scientific knowledge including scientific theory could change in the light of new discoveries, she had difficulty in transforming this view for the law because she was in dilemma whether the law change. Also, she did not mention that different interpretations of scientific knowledge and technological development lead to change in scientific knowledge. Her perception of the law as proven knowledge as compared to the theory revealed a common misconception related to hierarchical relationship between them. Her failure to explain the greenhouse effect being a theory in accordance with the nature of the theory also reflected her incomplete understanding on the theory and law. She also was not certain whether science is independent or influenced from the social and cultural values. She had difficulty in explaining creative and imaginative NOS because she stated that scientists use their imagination and creativity only in the first phase of the investigation, not all phases. She had difficulty in explaining subjectivity because she claimed that the theory can change based on person, but not elaborating underlying reasons of her opinion. Her understanding about empirical NOS indicated inconsistency because, despite of addressing the role of experiment and observation in proving scientific knowledge and also prediction made based on available data, she had a common misconception that scientists follow general scientific method containing stepwise procedure. On the other hand, she was able to express inferential NOS while responding embedded NOS questions. In her teaching on the weather and climate, she briefly mentioned about the empirical NOS by emphasizing that weather events are based on prediction, and also addressed that there is no certainty in science.

Table 4.37 *Beyza's Responses Related to Syntactic Knowledge*

NOS Aspect	Example from Beyza's Responses
Tentative NOS	➢ Science changes……is open to continuous change, discovery and development. ➢ The theory is knowledge that can change… The data can change… conditions for observation can change... Maybe, theory changes depending on the person… ➢ The law is a proven knowledge and undeniable… ➢ Some of scientific laws change... Scientific data can change in the light of new discoveries.
Empirical NOS	➢ Science involves detailed investigations in any field….and performing experiments, making observations and collecting data to provide evidence for the formulated hypotheses. ➢ Absolutely experiment is necessary… For all scientific knowledge, the experiments are not needed, but this time observation is needed to prove scientific knowledge. ➢ There are indications for global warming ... The glaciers at the poles are melting... Climate changes, we are experiencing with changes in the seasons… All of these are good evidences for global warming. ➢ Meteorologists have a lot of tools and equipment to make measurement regarding weather. Meteorologists examine the humidity in the air and temperature. For example, if the humidity in the air increases, meteorologists say that "It will be rain today.".
Subjective NOS	➢ Maybe, theory changes depending on the person…
Inferential NOS	➢ Climatologists make use of the data collected by meteorologists daily. Climatologists do research regarding the past, not the future. Climatologists examine the weather conditions in the past. Then, climatologists determine the climate…

Table 4.37 *(cont'd)*

Theory and Law	➢ The law is a proven knowledge and undeniable… Unquestionable... For example, the laws of reflection… There is no need to discuss laws of reflection any longer because laws of reflection have been proven. ➢ The theory is knowledge that can change… it needs further study… the different knowledge can be found related to theory. ➢ Scientists observe the effects of greenhouse effect. After that, scientists feel it's effects and then, start to investigate the effects of greenhouse effect. So, the greenhouse effect is still a theory...
Creative and Imaginative NOS	➢ Scientists must have imagination. For example, the scientists first imagine, and then, try to prove it. ➢ Scientists use their creativity and imagination in first stages of research… First, scientists will imagine. Research does not progress only with imagination of course…
Socio cultural NOS	➢ Science is universal. ➢ While science develops, science is affected by all conditions of the environment...such as social, cultural, religious. ➢ Galileo suffered from the serious problems in his theories about the sun, Earth and planets and Galileo's theories were in contradiction with the idea of church.

4.2.3 Beyza's Pedagogical Content Knowledge Regarding the Seasons, Weather, and Climate

Beyza's PCK was examined in terms of five components of Magnusson et al. (1999) Model of PCK. PCK pre-interviews, PCK post-interviews, classroom observation and teachers' documents were used to examine teachers' PCK.

Beyza's responses to the PCK pre-interview questions regarding the seasons, weather and climate topic were summarized in Table 4.38.

Table 4.38 *Beyza's PCK Summary on Seasons, Weather and Climate Topic (Adapted from Tıraş (2019))*

Pedagogical Questions (CoRe)	**Beyza's PCK Summary**
What you intend the students to learn regarding this idea	They will learn how the seasons form, what the equinox is, climate, who provides information for us related to climate and weather, who the meteorologists are. They will learn basic concepts. Then, they will gain the problem-solving ability.
The importance for the students to know this	We inform students about everything related to life. When they [students] go to high school, the knowledge is given by deeply under the different disciplines as physics, chemistry, and biology. When they [students] enter the university, the knowledge is given even more specific, more detail. So, we are taking the initial step [in middle school].
Difficulty connected with teaching of this idea	It [teaching the seasons, weather, and climate topic] will not be difficult if we teach it with enjoyable manner like drawings and help the students to understand the topic by concretizing and drawing. Because it is not a difficult topic, it's an easy topic… an understandable topic.
Knowledge regarding student thinking which influences teaching regarding this idea	They [students] may find it difficult to make comment [on the seasons, weather, and climate topic].… [Students have difficulty in understanding] why the Earth's tilted axis exist that causes the seasons… Although it [seasons, weather, and climate topic] appears to be concrete, it includes many events which are abstract in nature. They [students] may have developed misconceptions in understanding the differences between seasons and climate or the factors affecting the length of shadows. The source of misconceptions is that they [seasons and climate] are interrelated yet different. In the previous years, students were provided with much basic information about the seasons and climate, such as the seasons form when the Earth revolves around the Sun.
Other factor that influences your teaching regarding this idea	It was presented in last units in the previous curriculum [i.e., MoNE 2013]. In the revised curriculum [MoNE 2018], it is located in the beginning of the term as a first unit... Therefore, the seasons, weather and climate topic will be grasp more easily and better understood [by the students]. Since we have a loaded curriculum, we encourage students to do their homework to learn the concepts [reinforcement with homework].

Table 4.38 *(cont'd)*

Other factor that influences your teaching regarding this idea	In order to save time regarding the topic, sometimes instead of using the blackboard, we do the activities existing on the smart board like fill in the blank, matching type questions, test, game......
Teaching procedures (and particular reasons to use of these to engage with this idea)	Our main source is the textbook approved by MoNE.... to understand what else they [students] should learn about the topic….to understand whether students learned the objectives. We use other textbooks published by different publishers to learn different perspectives and to see the different types of questions. Also, we use EBA [Education Information Network] more frequently… After that, we can use Morpa Campus website. We start with brainstorming first to understand what they [students] know [about the concept]. Then lesson is proceeded slowly… by giving the information [direct instruction] ... We continue lesson by drawing and encouraging students to take notes. We show videos related to seasons, the Earth's revolution around the Sun, it's [Earth's] rotation around itself... We will perform drama and role-playing activities [in the lesson]. In order to save time regarding the topic, sometimes instead of using the blackboard, we do the activities existing on the smart board like fill in the blank, matching type questions, test, game...... Then, we perform poster activity in many times. We are trying to make concepts more concrete by experiments. Then, we summarize the topic by asking questions toward the end of the lesson.
Ways of ascertaining student understanding or confusion regarding this idea	I assess their knowledge about the topic. For example, I assess "How much did they [students] understand?". We assess with verbal, written methods… all kinds of methods. Question and answer style, tests.… I use branching tree diagram system that proceed in the form of true or false. We do verbal exam during the lesson. I try to get their information throughout the lesson to understand what they [students] learned about the topic. When the topic is completed, we will do tests and questions-answers. We have certain written exam dates.

4.2.3.1 Beyza’s Orientation Towards Science

Beyza’s orientation towards science, her belief about goals of science teaching were investigated through pre-interview, classroom observations and analyzed under two categories which are peripheral goals and central goals.

4.2.3.1.1 Beyza’s Beliefs about Goals of Science Teaching

In this part, Beyza’s responses regarding beliefs about goals of science teaching in the pre-interview were reported. The interviews data were supported by classroom observation as well (See Table 4.39 and Table 4.40).

> Researcher: According to you, why do we teach science in middle school?
> Beyza: It [science] is life itself. I mean, it [science] is highly integrated with life... inseparable part of life… If we don't teach [science], the children become unaware of the phenomena occurring around them. [In science], they [students] learn their bodies [body systems], living things, the physical laws as well as learning of the chemistry, biology… Their life would be very difficult without learning science.
> Researcher: What does “science teaching” mean to you?
> Beyza: Well, in fact, it [science teaching] is about teaching the life... [Science teaching is] scientific explanation of daily life event.
> Researcher: Well, in your opinion, what are the goals of science teaching?
> Beyza: My primary aim is to help students to get know themselves, discover the events around them, realize how things work, become more conscious, nurture their curiosity as well as motivate them to discover, and encourage them to enjoy the science lesson.
> Researcher: Well, how do you determine these goals?
> Beyza: I didn't determine the goals [for teaching science]. It [goals for teaching science] is predetermined… It has already mentioned in the science curriculum. We are just implementing the curriculum… While implementing

the curriculum, we are trying to encourage students to enjoy the concepts, and we try to create their awareness as well.

[PCK Pre-Interview]

Table 4.39 *Beyza's Beliefs about Goals of Science Teaching*

Questions	Beyza's Response	Central Goals	Peripheral Goals
According to you, why do we teach science in middle school?	Science is life itself. I mean, science is highly integrated with life... Their life would be very difficult without learning science.	Schooling goal	-
	In science, students learn their bodies [body systems], living things, the physical laws as well as learning of the chemistry, biology…	Subject matter goal	-
What does "science teaching" mean to you?	In fact, science teaching is about *teaching the life...*	Schooling goal	-
	Science teaching is *scientific explanation of daily life event.*	-	Subject matter goal
In your opinion, what are the goals of science teaching?	My primary aim is to help students to; get know themselves, *discover the events around them*, *realize how things work*,	Schooling goal	-
	to *become more conscious*, *nurture their curiosity* as well as *motivate them to discover*, and *encourage them to enjoy the science lesson.*	Affective goal	-
As a science teacher, what is the meaning of teaching the seasons, weather, and climate topic for you?	There are the events that occur around us. Students *observe weather events*, they *explore* and *perceive their effects on both living things and nonliving things.*	Schooling goal	-
	For example, they observe seasons change… Why seasons change? What is season? What is climate? *Students will learn all of these concepts.*	Subject matter goal	-

Table 4.39 *(cont'd)*

Questions	Beyza's Response	Central Goals	Peripheral Goals
Why do you teach the seasons, weather, and climate topic as a science teacher?	For students to *become knowledgeable* about seasons, weather, and climate topic	Subject matter goal	-
	We inform students about *everything related to life*. When students go to high school, the knowledge is given by deeply under the different disciplines as physics, chemistry, and biology. When students enter the university, the knowledge is given even more specific, more detail. So, we are taking the initial step in middle school.	Schooling goal	-
What do you expect students to have knowledge and skills by teaching science?	Being *more conscious, healthier continuous* in their life…	Affective goal	-
	Science provides opportunity to students to *explore the world... How clouds form… Why is it raining*? So, science includes everything occurs in our body and the environment. I think a child with *a good science knowledge* will be *much more successful in life*.	Schooling goal	-

Her response to above questions revealed that she mostly put emphasis on schooling goal. Firstly, she stated that she teaches science in middle school because science is related to students' daily life (i.e., schooling goal as central goal) and students learn body systems, living things, physical laws (i.e., subject matter goal as central goal). She remarked the meaning of teaching science as teaching the life (i.e., schooling goal as central goal) and then, scientific explanation of events in daily life (i.e., subject matter goal as peripheral goal). Her goal of science teaching is to provide students to explore the phenomenon around them (i.e., schooling goal as central goal), raise their consciousness, enjoy the science teaching and motivate them toward discovering (i.e., affective goal as central goal). Also, it can be stated that she attaches importance to the concept of dual perspective by stating *"raising their consciousness"* and so, has a tendency to grow her students as action competent citizens. Lastly, she added that the goals for teaching science were determined by curriculum.

In the following question, Beyza was asked about what knowledge and skills she expects from students through teaching science.

> Beyza: Being more conscious, healthier continuous in their life… to discover how and why things happen. In other words, science is a broad branch and involves many concepts to teach. Of course, all of these concepts are related to each other. [Science provides opportunity to students] to explore the world... How clouds form… Why is it raining? So, science includes everything occurs in our body and the environment. I think a child with a good science knowledge will be much more successful in life. Science is really fun…very enjoyable course.
>
> [PCK Pre-Interview]

Briefly, she expects from students to become healthy and conscious (i.e., affective goal as central goal) and discover the phenomena occurs in the world (e.g., the formation of cloud) (i.e., schooling goal as central goal). Additionally, she believes that children who are knowledgeable about science are going to be more successful within life (i.e., schooling goal as central goal).

Following question, Beyza was asked about the role of the teacher and the student in science teaching.

> Researcher: How can you define the role of teacher in science teaching?
>
> Beyza: The role of the teacher is to encourage [students] to enjoy and understand the life and increase their consciousness level. We [as a teacher] help them to learn how to stay healthy as well.
>
> Researcher: How do you describe your role as a teacher in the classroom?
>
> Beyza: I am like a maestro who guides students to learn the topic. They [students] are like instruments to play. Music that will be played is topic. How do we deal with these instruments? To achieve these goals, there are various instruments and melodies... we use them to teach the topic; sometimes course will be dynamic, sometimes it will be quiet… sometimes students will be active in the course; sometimes they [students] will be passive participant, listening the topic silently.
>
> Researcher: Well, what about the role of the student in science teaching?
>
> Beyza: The students are explorer, learning the concepts [provided by the teachers]. They [students] use it [the information given] in their daily life. All course content is highly related to daily life… So, we don't have a topic that is separated from our daily life. Everything comes directly from life… For that reason, science is really fun.

[PCK Pre-Interview]

She stated that the role of the teacher is to provide students to understand the life and raise their awareness and moreover, she described her teacher role in the classroom as a guide and explained with using a metaphor example *(e.g., Teacher: maestro; Student: instrument, Music: topic)*. Then, she described the role of the students as explorer and stated that students learn the concepts taught by teacher and apply their knowledge in daily life. In fact, she said that the students discover the knowledge and described her teacher role as a guide. However, she did not express that the students structured the knowledge themselves and questioned the knowledge.

In the following question, Beyza was asked what she does maximize student learning in the classroom.

> Researcher: How do you do to maximize student learning in your classroom?
>
> Beyza: I try to encourage students to like the lesson. I try to make it [lesson] more enjoyable. In other words, I try to use all kinds of methods and techniques to attract their interest. I use technology for example... I show the videos. I use interactive teaching techniques.
>
> Researcher: Can you elaborate on these methods and techniques? What do you mean by interactive teaching techniques?
>
> Beyza: Using fill in the blank, matching type questions written on the blackboard… Children can also answer the questions. I use smart board to test the student. We solve the problems on these tests that everyone can join. I show videos as well… We play the games… I use drama. We distribute the roles, even they [students] are writing plays. They [students] make various presentations… So, we use all kinds of activities which facilitate students' active participation [to the lesson].
>
> Researcher: How do you know when your students understand?
>
> Beyza: By using various measurement and assessment techniques, either written, or verbal. Question and answer style, tests.… Classical measurement and assessment techniques. Apart from that, I use branching tree diagram which is a system that proceed in the form of true or false. By using the measurement and assessment techniques I have mentioned, we understand whether [students] learned or not.
>
> Researcher: How do you know when learning is occurring in your classroom?
>
> Beyza: It is important to get to know [students]. Everyone's learning level is different, their understanding capacity is different. Students who are hardworking come to school by being well-prepared, having read all related

materials and after completion of the topic, they [students] are given homework as a purpose of reinforcement. Therefore, the learning process is going well after doing several brief reviews. [Besides] if he/she [student] doesn't do homework at home or does not do preparatory work, he/she [student] can learn the concepts just through listening the topics…

[PCK Pre-Interview]

For maximizing students' learning, she aims to draw students' attention to the lesson and provide the lesson more enjoyable for them by using interactive teaching techniques in which the students can participate actively such as performing drama activity, showing videos, using matching type questions, playing games. Then, she added that she will benefit from the various measurement and assessment techniques (e.g., questioning, tests, branching tree diagram) to understand whether students learned the topic. Lastly, she claimed that students' understanding capacity and learning levels are different, and therefore, getting know the students is the crucial point to understand when the learning is occurring in the classroom.

Next question, Beyza was asked how she decides what to teach or not teach in the school setting. From her view, there is a curriculum that teachers need to follow, and this curriculum determines what to teach and when to move on to a new topic in the classroom. Moreover, she stated that she shares both her own experiences and beneficial information about daily life with students. Lastly, she addressed the learning differences of the students and added that she can review the topic if necessary.

Researcher: Well, in the school setting, how do you decide what to teach and what not to teach?

Beyza: Hmmm…. what to teach… We have a compulsory curriculum to follow. The restriction is curriculum [which means teaching the seasons, weather, and climate topic within the framework of the objectives specified in the curriculum.]. We are teaching based on this curriculum… We are dealing with pure science…proven ideas, certain knowledge. Apart from the teaching, we share useful information related to daily life… We share our experiences with students.

Researcher: How do you decide when to move on to a new topic in your classroom?

Beyza: We have a plan known as annual plan which included all the topic to be taught weekly. Students learn gradually… For example, some students learn faster compared to others. If time left, we review the topic. When student understands, we stop teaching.

[PCK Pre-Interview]

Lastly, Beyza was asked how students learn science best. According to her view, students learn the science best through different methods such as reading, writing, learning by experience, watching. The related excerpts from the interview were as follows;

Beyza: [Students learn science best] by doing experiments, learning by experience, writing, drawing, reading, watching. They [students] need to use all kinds of methods and techniques. Otherwise, it is difficult [for students to learn science].

[PCK Pre-Interview]

As well as collecting information regarding Beyza's beliefs about goals of science teaching through pre-interviews, researcher also collected data through classroom observation. Overall, her pre-interview data showed that she mostly mentioned about schooling goals but her affective goals, subject matter goals and schooling goals were revealed as central goals. Moreover, any peripheral goals were not identified in her responses. Beyza's beliefs about goals of teaching in the context of seasons, weather and climate was unveiled.

Researcher: As a science teacher, what is the meaning of teaching the seasons, weather, and climate topic for you?

Beyza: There are the events that occur around us. They [students] observe weather events, they explore and perceive their effects on both living and nonliving things. For example, they observe seasons change… Why? Why seasons change? What is the reason? What is season? What is climate? Who provides information for us related to climate and weather? Who are they? Which scientific disciplines…[Students] will learn all of these [concepts].

Researcher: Why do you teach the seasons, weather, and climate topic as a science teacher?
Beyza: For students to become knowledgeable [about seasons, weather, and climate topic] … We inform students about everything related to life. When they [students] go to high school, the knowledge is given by deeply under the different disciplines as physics, chemistry, and biology. When they [students] enter the university, the knowledge is given even more specific, more detail. So, we are taking the initial step [in middle school]. [In fact], students were first introduced the seasons, weather, and climate topic during their primary school years in the course called "social studies".

[PCK Pre-Interview]

When asked the meaning of teaching of the seasons, weather, and climate topic for her, she emphasized that students explore and observe the events taking place in the environment such as weather events (i.e., schooling goal as central goal) and also, learn the related concepts such as seasons, weather, climate (i.e., subject matter goal as central goal). When asked why she teaches the seasons, weather, and climate topic, she pointed out that she teaches knowledge related to daily life. Moreover, she noted that this topic was taught in middle and primary school in line with the detailed lectures students will receive in the university and high school (i.e., schooling goal as central goal). She added that she wants students to become knowledgeable about this topic (i.e., subject matter goal as central goal).
While teaching the seasons, weather, and climate topic, in line with her belief stated above, she frequently emphasized the subject matter knowledge and aimed to

transmit the related curriculum objectives to the students. For this reason, it can be concluded that her subject matter goal was observed as central goal during her teaching. A related excerpt is shown below;

> Beyza: The Tropic of Cancer and the Tropic of Capricorn is 23°27' away from the equator. They [researchers] defined the distance to the equator as latitude. The area between the Tropic of Cancer and the Tropic of Capricorn is called "Tropics". The Tropics are receiving sun rays as perpendicular throughout the years. These are clearly written in your [science] textbook [approved by MoNE]. The sun rays are coming as perpendicular on the June 21. Thus, it is summer in the Northern Hemisphere. The sun rays are coming as perpendicular to the Tropic of Capricorn on 21st of December; meaning that it is summer in the Southern Hemisphere. The four seasons are experienced in the Northern Hemisphere and the Southern Hemisphere. The Tropics are always warm.
>
> [Classroom Observation]

Additionally, she highlighted the importance of understanding of the seasons, weather, and climate topic for the scope of High school entrance exam. For example, she stated that;

> *"Concepts such as the coming of sun rays as perpendicular and oblique are very important. The more you make practice, the more problem-solving skills you gain.".*

As clearly seen, in contrast to her reported PCK, her enacted PCK showed that her schooling goal regarding the preparing students to High school entrance exam was central goal. She encouraged students to use the science textbook approved by MoNE claiming that the questions in the nation-wide exam were asked within the scope of the curriculum. Furthermore, in her lessons, she distributed several tests regarding the seasons, weather, and climate from different textbooks published by different publishers, requested from students to solve these test questions, and thus, tried to prepare her students to enter the high school entrance exam. Thus, it can be concluded that she primarily aims to draw students' attention to high school entrance exam.

In contrast with her reported PCK, her enacted PCK indicated that the relationship between the seasons, weather, and climate topic and daily life was observed as a peripheral goal in her teaching (i.e., schooling goal). For example, she addressed the importance of weather forecast in daily life. The dialogues were occurred between the teacher and students as follows;

> Beyza: If we didn't know that the temperature would drop by 10 degrees today, we wouldn't wear thick clothes… Why it is important for you to know about weather forecast if you were a captain [of a ship]?
>
> S_1: Whether to sail to the sea or not.
>
> Beyza: Assume that there is a storm appears on the route. What do you do?
>
> S_2: I cancel the sailing. I will change the route.
>
> Beyza: [Assume that] you are a pilot or a farmer … Why is the important to know weather forecast? ... To take precautions? ... Farmers, for example, harvest and sell their products. Let's say it is going to fall hail. What does the farmers do? They [farmers] will cover their crops… Knowing weather forecast is especially important for some professions… For example, the pilot, the captain, the farmers etc. take precautions. To know the weather events is important for all everyone. It is also important for us [human beings].
>
> [Classroom Observation]

Researcher also observed the indication of affective goal as peripheral goal in the classroom observation. She had her students do a poster activity regarding the seasons, weather, and climate topic in the classroom. She formed five groups, and each group prepared their own posters in this activity. After that, each group's poster was presented on classroom board. The poster activity provided students' motivation toward to the lesson.

Table 4.40 indicates Beyza's beliefs about goals of science teaching based on classroom observation during the seasons, weather, and climate topic.

Table 4.40 *Beyza's Beliefs About Goals of Science Teaching Based on Classroom Observation*

Beliefs About Goals of Science Teaching	**Central Goals**	**Peripheral Goals**	**Example**
To convey the objectives	Subject matter goal	-	Teaching the seasons
To prepare students to high school entrance exam	Schooling goal	-	Emphasizing the gaining of problem-solving skills by solving lots of questions
To establish a relationship between the seasons, weather, and climate topic and daily life	-	Schooling goal	Addressing the importance of weather forecast in daily life
To motivate students towards the lesson	-	Affective goal	To have students do poster activity

All in all, her pre-interview responses revealed that her subject matter goals, affective goals and schooling goals were central goals. In the classroom observation, her subject matter goals were found as same. By contrast, her schooling goals as central goals were found as different from the interview (i.e., equipping students toward high school entrance exam). Her schooling goal (i.e., establishing a relationship between the seasons, weather, and climate topic and daily life) and affective goals were observed as peripheral goals because these goals were less emphasized compared to other goals.

Following part, next component of PCK which is knowledge of curriculum is presented.

4.2.3.2 Beyza's Knowledge of Curriculum

Beyza's knowledge of curriculum, with collected data through pre-interview, post-interview, teacher documents and classroom observation, was reported under two sub-titles as knowledge of goals and objectives and knowledge of materials in this section. At first, Beyza's knowledge of goals and objectives about the seasons, weather, and climate topic was summarized.

4.2.3.2.1 Beyza's Knowledge of Goals and Objectives about the Seasons, Weather, and Climate

All data sources revealed that experienced science teacher was found as knowledgeable about goals and objectives about the seasons, weather, and climate. For instance, she correctly expressed all objectives determined by the MoNE, identified the vertical and horizontal relations, in addition to preceding and following topics. Yet she was not aware that there is no misconception regarding the seasons, weather and climate topic stated in the curriculum. Furthermore, she went beyond the curriculum by giving some advance knowledge such as details of Beaufort scale.

In the following question, Beyza was asked questions about the place of seasons, weather, and climate topic in the curriculum, its relation to other topics, units or classes in the curriculum. (i.e., vertical and horizontal curriculum).

> Researcher: Do you know the place of the seasons, weather, and climate in curriculum?
> Beyza: Yes.
> Researcher: In which grade level?
> Beyza: At Grade 8.

Researcher: In which unit?

Beyza: First unit.

Researcher: You stated that it is the first unit. What are the topics taught after this unit [seasons, weather, and climate]?

Beyza: This [seasons, weather and climate] is the first unit. There is no previous unit. Subsequent topics are related to biology. Well… DNA, gene, chromosome, crosses [heredity] followed by genetic diseases, mutations, modifications, and adaptations. After that, we will teach other topics gradually…

Researcher: Is there any science topic taught in earlier grades related to the seasons, weather, and climate?

Beyza: … No. I mean, different topics were taught before. We don't repeat the same topics in science lesson. In the previous years, students were provided with much basic information about the seasons and climate, such as the seasons form when the Earth revolves around the Sun. This topic is related to topics generally taught in elementary science (i.e., primary school science). But now, at Grade 8, we give more detailed and comprehensive information. This topic is not related to other topics presented in Grade 8.

[PCK Pre-Interview]

During the interview, she expressed the revolution of the Earth around the Sun as vertical relation. Similarly, in her teaching, she addressed *the shape of the Earth* (i.e., geoid) taught in 3rd grade level asking the question *"What is the shape of the Earth?"* and then, one of the students responded as *"Geoid"*. She mentioned about *the Sun, Earth and Moon* unit taught in 5th grade level saying that *"The directions of the Earth, Sun and Moon's spin are counterclockwise. They spin from the west toward the east"*. Then, she addressed *the movements of the Earth* as well as *the formation of day and night* taught in 4th grade level. The dialogues occurred between the teacher and students were as follows;

Beyza: What are the movements of the Earth?

S_1: There are two movements of the Earth. One of them is related to the rotation of the Earth around its' axis.

Beyza: When Earth rotates around its' axis, the day and night occur. Pressure and temperature differences occur… Wind occurs.

S_2: [The other movement is related to] its' revolution around the Sun.

[Classroom Observation]

During teaching, she mentioned about *"Change of state of matter"* topic taught in 5th grade level saying that *"We never talked about rain, hail, and snow. Let's talk about them... You have learned these concepts in the 5th grade."*. (See more in substantive knowledge section). Then, while explaining the formation of high pressure and low-pressure areas, she touched on *the concept of volume* in *Measurable properties of matter* topic taught in 4th grade level and *the concept of density* taught in 6th grade level.

In addition, in her teaching, she touched on *the Pure substance and mixtures* unit taught in 7th grade level by stating that;

Beyza: Air is a gas mixture. It is even gas-gas solution. Air contains 78% nitrogen, 21% oxygen, 0.1% argon, 1% carbon dioxide, water vapor and other gases.

[Classroom Observation]

However, although she did not mention about horizontal connections in the interview, she addressed the climate change, greenhouse effect and global warming taught in *Matter cycles and Environmental problems* topic in 6th unit of 8th grade level in her teaching (See more detail in substantive knowledge and dual perspective section). Also, her emphasis on these environmental problems pointed to her attempt to raise her students as action competent citizens, which indicated her tendency to integrate the dual perspective into her teaching.

Overall data revealed her awareness about place of the topic, the horizontal, and vertical relations. After correctly expressed the place of the topic in the curriculum, she expressed that students learned basic knowledge regarding the seasons, weather, and climate topic in elementary years such as the Earth's revolution around the Sun as vertical relation. Similarly, in her teaching, she addressed *the Earth's shape* in 3rd grade level, *Earth's movements* and *the formation of day and night* in 4th grade level, and *the Sun, Earth and Moon* unit in 5th grade level. Moreover, she addressed *the concept of volume* in 4th grade level, *Change of state of matter* topic in 5th grade level, *the concept of density* in 6th grade level, and *the Pure substance and mixtures* unit in 7th grade level. Regarding horizontal relationship, in the interview, she said that the seasons, weather, and climate topic is not related to any topic presented in Grade 8. In contrast to the interview, in her teaching, she addressed the climate change, global warming and greenhouse effect located in *Matter cycles and Environmental problems* topic in same grade level. It can be concluded that her reported PCK and enacted PCK seem to be inconsistent (Table 4.41).

Table 4.41 *Summary of Beyza's Knowledge of Vertical and Horizontal Relations of Seasons, Weather and Climate Topic in the Curriculum*

Beyza	**Vertical Relations**	PCK Pre-Interview	The Movements of the Earth (4th grade)
		Classroom Observation	The Earth's shape (3rd grade) The Movements of the Earth (4th grade) Measurable properties of matter (4th grade) The Sun, Earth, and Moon (5th grade) Change of State of Matter (5th grade) The concept of density (6th grade) The Pure Substance and Mixtures (7th grade)
	Horizontal Relations	PCK Pre-Interview	-
		Classroom Observation	Matter cycles and Environmental problems (8th grade)

Researcher: What are the objectives with respect to seasons, weather, and climate found in curriculum?

Beyza: There are only three objectives in the curriculum. For example, children make predictions about the formation of seasons. How [seasons] form? What is the climate?... How does the climate determine?... Who make research [related to climate]?... They [objectives regarding the seasons, weather, and climate topic] are also presented in our annual plans…. all of the objectives are important. According to our annual plans, we try to inform the children with the related objectives.

[PCK Pre-Interview]

Among three objectives, Beyza identified two of them in the interview. The objective, she did not address was about *"the difference between climate and weather events" (MoNE, 2018, p. 47)*. In her lesson, *however*, she mentioned about the differences between weather events and climate by drawing a table (See Table 4.30). Thereby, it was concluded that she was aware of all objectives related to the seasons, weather, and climate. Beyza’s understanding of objectives regarding the seasons, weather, and climate was depicted in the table 4.42. This table indicated consistency and inconsistency between her reported PCK and enacted PCK.

Table 4.42 *Beyza's Understanding of Objectives Regarding the Seasons, Weather, and Climate*

Objectives Stated in the Science Curriculum (MoNE 2018, p.47)	**Interviews**	**Does Beyza’s response meet the curriculum objectives? (Classroom Observations)**
“8.1.1.1. Make predictions about the formation of seasons.”	Mentioned	Mentioned
“8.1.2.1. Explain the difference between climate and weather events.”	Not mentioned	Mentioned
“8.1.2.2. State that climate science (climatology) is a branch of science and that experts working in this field are called climate scientist (climatologist).”	Mentioned	Mentioned

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

Beyza: There may be things that are related to the content of the topics which is not included in the textbook and curriculum. I cannot tell them now [before the teaching of the topic] … It actually appears during the teaching practice… We decide during the teaching of the topic.

[PCK Pre-Interview]

She said that the important points except the existing objectives can emerge during the teaching practice and therefore, she did not give any examples related to these important concepts.

In the following question, Beyza was asked whether there are limitations regarding the seasons, weather, and climate topic in the science curriculum.

Researcher: Is there any limitations implied in curriculum regarding the seasons, weather, and climate?

Beyza: Of course, should be… We do not teach too details regarding professional life of scientists. We teach general concepts. I mean, like a meteorologist, they [students] don't need to know everything about weather events. We will give general information and expect them to interpret the general information.

[PCK Pre-Interview]

Her degree of knowledge prescribed in the curriculum was examined through her classroom observation data. It was revealed that, however, she mentioned some advance knowledge related to weather events by going beyond the curriculum. While she was mentioning about the wind, she addressed Beaufort scale and its' content in more detail. As an example, these advance knowledges that she mentioned are as follows:

Hurricanes are very huge. They [scientists] created the Beaufort scale. "1" [on Beaufort scale] shows less severe breeze, "2" shows more moderate breeze and "3" shows stronger breeze. The storm starts in "7". A bit more *severe storm [starts] in "8". More severe storms [start] in "9". Hurricane starts in "12".*

(taught in Grade 10 Geography curriculum).

In the following question, Beyza was asked whether there is misconception about the seasons, weather, and climate topic in the science curriculum, and stated that;

> Beyza: Any misconceptions involved?... So, we will see it. It is the first time we're going to teach this topic [seasons, weather, and climate] in this year [as a first topic] in the curriculum [MoNE 2018]. We can realize the misconceptions during the teaching process.

[PCK Pre-Interview]

She did not mention about any misconceptions because she stated that she will teach the seasons, weather, and climate as a first unit for the first time and added that she will understand whether there is a misconception during the lesson. Her response showed that she was not aware that there are no misconceptions about the seasons, weather, and climate topic both in the curriculum and science textbook. However, similar to her pre-interview, in her teaching, she noticed from student's response that they incorrectly associated the formation of seasons with distance of Earth from the Sun. Then, she tried to eliminate this misconception by stating that there is no relation between distance of the Earth to the Sun and the formation of seasons (See more detail in Beyza's knowledge of students' difficulties section).

> Researcher: In your view, why do seasons, weather, and climate topic place in curriculum?
>
> Beyza: Similar to other programs [teaching programs] … It's required so. Because this topic [seasons, weather, and climate] is within daily life, they [students] need to learn it. It was presented in last units in the previous curriculum [i.e., MoNE 2013]. In the revised curriculum [MoNE 2018], it is located in the beginning of the term as a first unit... located as a first topic. Therefore, the seasons, weather and climate topic will be grasp more easily

and better understood [by the students]. It [teaching the seasons, weather, and climate topic] will not be difficult if we teach it with enjoyable manner like drawings and help the students to understand the topic by drawing, and concretizing with experiment. Because it is not a difficult topic, it's an easy topic… an understandable topic.

Researcher: So, what do you intend the students to learn about the seasons, weather, and climate unit?

Beyza: They [students] first will learn the [new] concepts. They should match the concept and definitions correctly. They will learn climate, who the meteorologists are, what the equinox is, how the seasons form. They will learn basic concepts. Then, they will gain the problem-solving ability.

Researcher: Well, for you, what are the important ideas in this topic for students to grasp?

Beyza: In science, all of the concepts are equally important. All concepts included in the seasons, weather, and climate are important too. For example, if they [students] do not know the concept of the equinox, they will not realize the importance of the seasons. Similarly, if they don't know who the climatologist is, they can have difficulty in understanding who examine the climate. So, they have to know about all concepts included in the seasons, weather, and climate topic [to explain the phenomena around them]. As I said, they [students] will be knowledgeable about the seasons. They will explain why the Southern Hemisphere is experiencing summer, while the Northern Hemisphere is experiencing the winter.

[PCK Pre-Interview]

She stated that the seasons, weather, and climate topic is included in the curriculum because due to related to daily life, and with the changes in the curriculum, locating this topic as a first topic is important for the students to better comprehend this topic. She stated that this is not only an easy topic to teach but also enjoyable, and teaching this topic will not be difficult when teaches through drawing and concretizing by experiment. Then, she thought that all concepts in the seasons, weather, and climate topic are crucial and so students need to learn all basic concepts such as climate, climatologist, equinox, meteorologist and seasons to understand the events around them. The concepts that she mentioned are consistent with the related objectives in the science curriculum. Furthermore, she added that she wants students to get the problem-solving ability after learning the concepts.

In the following part, Beyza's knowledge of materials as a sub-component of knowledge of curriculum is presented.

4.2.3.2.2 Beyza's Knowledge of Materials

In this section, to reveal her knowledge of materials, Beyza was asked which resources she uses in the lesson in the pre-interview.

> Researcher: What are the sources that you use in the seasons, weather, and climate topic?
>
> Beyza: First of all, our main source is the textbook approved by MoNE.... Apart from that, we use other textbooks published by different publishers. Also, we use EBA [Education Information Network] more frequently… EBA is our educational information network.
>
> Researcher: For what purpose do you use these resources?
>
> Beyza: To learn different perspectives and to see the different types of questions, to understand what else they [students] should learn about the topic….to understand whether students learned the objectives. Then, we examine those resources in terms of objectives of the course. As long as the curriculum allows, we try to give the more information.
>
> [PCK Pre-Interview]

She stated that she will use science textbook approved by MoNE, other textbooks published by different publishers and EBA. Similar to her reported PCK, her enacted PCK showed that she used science textbook approved by MoNE frequently. The students' science textbooks were always on their desks throughout the lesson. For example, she showed visuals related to the seasons, weather, and climate topic in the science textbook. As a homework, she wanted the students to draw the figures related to the seasons found in science textbook to their notebooks for the next lesson. Furthermore, she had students to do the unit evaluation questions included at the end of the seasons, weather, and climate topic in the science textbook. Then, she used other textbooks published by different publishers and from those textbooks, she distributed tests to the students to solve the questions as a homework. She showed videos regarding the seasons from EBA through smart board (See Table 4.43). Moreover, contrary to her reported PCK, her enacted PCK showed that she used a globe model and flash lamp to show the Earth's tilted axis, its' influences on the seasons, and angle of incoming sunlight to the Earth in her teaching. In the post-interview, thereby, she was asked why she used a globe model in the lesson.

> Researcher: During the pre-interview, you didn't mention that you will use a globe model. What changed your mind?
>
> Beyza: It [globe model] was an educational material and should be used during the teaching process. It would be more appropriate to teach the concept by the help of the [globe] model. By this way, it is more meaningful to show the Earth's tilted axis [with the globe model] for students. The more materials you use, the more effective you are in the classroom.
>
> [PCK Post-Interview]

In the post-interview, she stated that she preferred to use a globe model because it is a necessary education material for the lesson, and also claimed that showing the Earth's tilted axis through the globe model is more effective.

Table 4.43 *Beyza's Knowledge of Materials*

Sources that teacher use	**Aim of Using Source (PCK Pre-Interview)**	**Classroom Observation**	**PCK Post-Interview (Reason)**
Science Textbook [MoNE, 2018]	▪ to understand what else students should learn about the topic, ▪ to understand whether students learned the objectives.	The science textbook approved by MoNE was used. From the textbook; ▪ homework was given, ▪ the visuals were shown.	-
Other textbooks published by different publishers	▪ to learn different perspectives, ▪ to see the different types of questions.	From other textbooks published by different publishers, she distributed tests to the students to solve the questions as a homework.	-
EBA [Education Information Network]	EBA is our educational information network.	EBA was used to show videos regarding the seasons.	-
Globe Model	*(Beyza did not mention in PCK Pre-interview)*	The globe model was used to demonstrate the Earth's tilted axis and its' impact on the seasons.	Through the globe model, it is more effective to show the Earth's tilted axis.

In the next part, Beyza's knowledge of students' understanding of science is presented.

4.2.3.3 Beyza's Knowledge of Students' Understanding of Science

Beyza's knowledge of students' understanding of science regarding the seasons, weather, and climate topic was reported under two sub-dimensions as knowledge of requirements for learning and knowledge of students' difficulties. The data regarding Beyza's knowledge of students' understanding of science were collected with using pre-interview, and classroom observation.

4.2.3.3.1 Beyza's Knowledge of Requirements for Learning regarding the Seasons, Weather, and Climate

In this section, Beyza's knowledge of requirements for learning regarding the seasons, weather and climate topic was reported.

> Researcher: What kind of prerequisite knowledge and skills do you think students need to learn the seasons, weather, and climate topic successfully?
> Beyza: There are several concepts which are new to the students [in the seasons, weather, and climate topic]. They [students] will learn those concepts at first. They [students] will know the concepts depending on this prior knowledge. We will teach the topic starting with basic ideas/concepts, they [students] will learn the concepts with increasing complexity. Then, they [students] start to solve problems [make practice].
> Researcher: You said new concepts. What are they?
> Beyza: The equinox. They [students] will learn it for the first time. …Latitude, longitude and so on. They [students] will learn them [key concepts].
> Researcher: Why do you think so?

> Beyza: They [concepts about the seasons, weather and climate] serve as a prerequisite knowledge form students' prior knowledge. New knowledge will be constructed on preexisted knowledge. They [students] will construct new information.
>
> [PCK Pre-Interview]

She emphasized the importance of prior knowledge and knowledge construction. She stated that students should know the concepts such as equinox, latitude, longitude which will be learned in 8th grade level. She did not, however, give examples regarding the prerequisite knowledge that students have learned in the previous grade level.

Her reported and enacted PCK appears to be inconsistent. For example, while teaching the unit, she mentioned about the other concepts that students have learned at the previous grade levels such as *the Earth's shape* at 3rd grade level, *the Earth's movements* at 4th grade level, *the concept of volume* at 4th grade level, *the direction of Earth, Sun and Moon's rotation* at 5th grade level, *the concept of density* at 6th grade level, *the Pure substance and mixtures* unit at 7th grade level (See detail in vertical relations in knowledge of curriculum section). Hence, findings revealed her awareness about the students' prerequisite knowledge. Table 4.44 shows Beyza's knowledge of requirements for learning about the seasons, weather, and climate topic.

Table 4.44 *Beyza's Knowledge of Requirements for Learning*

	PCK Pre-Interview	Classroom Observation
Beyza's knowledge of requirements for learning	Not mentioned	The Earth's shape (3rd grade) The Movements of the Earth (4th grade) Measurable properties of matter (4th grade) The Sun, Earth, and Moon (5th grade) Change of State of Matter (5th grade) The concept of density (6th grade) The Pure Substance and Mixtures (7th grade)

Beyza's knowledge of students' difficulties as a sub component of knowledge of students' understanding of science is presented in the following part.

4.2.3.3.2 Beyza's Knowledge of Students' Difficulties regarding the Seasons, Weather, and Climate

Beyza's knowledge of students' difficulties regarding the seasons, weather, and climate topic was reported.

> Researcher: Now I want to talk about the students' think about the seasons, weather, and climate topic. Can you tell me about which difficulties do students have while learning the seasons, weather, and climate topic?
>
> Beyza: They [students] may find it difficult to make comment [on the seasons, weather, and climate topic]….We expect students to make comment [on the seasons, weather, and climate topic] .....interpret…. [Students have difficulty in understanding] why the Earth's tilted axis exists that causes the seasons…or What would happen if the Earth's axis were not tilted?... or What would happen if it [Earth's tilted axis] was less than 23.5°? If they [students]

learn the concepts, they can make comments on these concepts. Therefore, it is important for students to solve different kinds of questions from different sources [prepared by different textbook publishers]. These topics [seasons, weather, and climate] are very abstract. We are familiar with the seasons and weather events. [We are experiencing with these events in our daily life] ... Students should know the causes of seasons, the Earth's position [to the Sun], [Earth's] continuous rotations in the elliptical path, oblique sun rays… We are trying to make them [concepts] more concrete by experiments. What happens when the sun rays come as perpendicular [to the Earth]?... What happens when the sun rays come as oblique [to the Earth]?... [During experiment], they [students] will see those events visually. Thus, they [students] will be able to make interpretation about these concepts.

Researcher: What do you think about the reasons for these difficulties?

Beyza: Because it [seasons, weather, and climate topic] is a completely new topic [she means that this topic was located first time as a first unit in MoNE 2018]. Although it [seasons, weather, and climate topic] appears to be concrete, it includes many events which are abstract in nature. [For example, during the lesson], we're going to describe the [Earth's] tilted axis, but they [students] don't see it [Earth's tilted axis]. We benefit from scientific data. [We will say that] scientists measured it [Earth's tilted axis]; we will construct the knowledge on this information. Nevertheless, the topic will remain still abstract.

Researcher: Do your students have misconceptions about the seasons, weather, and climate? If yes, what are the students' misconceptions regarding the seasons, weather, and climate?

Beyza: Yes, they have [misconception]. They [students] will confuse the climate and the seasons. What is the difference between seasons and climate? They [climate and seasons] are both related to the weather events, but what does the season about?... what does the climate about?... They [students] may have developed misconceptions in understanding the differences between seasons and climate or the factors affecting the length of shadows.

Researcher: What are the sources of those misconceptions?

Beyza: Hmmmm…They [seasons and climate] are related to each other. They [seasons and climate] are interrelated yet different.

Researcher: How do you identify students' misconceptions? Which methods do you use to identify misconceptions?

Beyza: Well…. We will determine the misconception by trial and error, observing their behavior, testing them, investigating their wrong answers. Students generally tended to more mistakes when comparing the concepts. We will eliminate it [misconception] by creating tables, elaborating on their misconception. We will use a variety of methods. We will see… I correct it by teaching the correct [scientifically accepted] one, by showing [visuals or demonstration], by giving examples… It needs to be corrected [immediately], otherwise it remains… It shouldn't remain intact for a long period of time. We can give several examples, teach the correct concept, show [visual or demonstration] when students' get confused…

Researcher: For example, you said that you will create tables. What will this table be about?

Beyza: Table… For example, we will create a table like this. First, we will say climate. Then, we will say seasons. Then, we create a table with 2 columns. One column is climate, while the other is the seasons. Next, we fill related the columns by comparing and contrasting the climate and seasons. We will repeat them over and over again. For example, we will say that "In the Black Sea region, the summer is rainy and humid. Yesterday in the Black Sea region, heavy rain and flood occurred.". It is [example regarding Black Sea] not about the climate because flood is not related to the climate. It's a daily event. We will progress by continuous repetition by encouraging them to write examples on their notebook.

Researcher: Do you think that those methods are effective enough to eliminate misconceptions?

Beyza: Well… for me, any method can be used.

Researcher: Do you think that they are effective?

Beyza: So, if not, we use other kinds of methods. We teach it [the concept] again and again until being effective [until all misconceptions were eliminated].

Researcher: How do learners' difficulties and misconceptions in the seasons, weather, and climate topic influence your teaching?

Beyza: So…Yes in this way: it forces us to repeat the concepts… We have to review the concepts again and again until they [students] learn….

Researcher: I mean how do you use the learners' difficulties and misconceptions during planning the lesson?

Beyza: After preparing lesson plan, we continuously repeat the topic as long as we can…. since we have a loaded curriculum, we encourage students to do their homework to learn the concepts [reinforcement with homework]. After that, we continue to repeat the content by asking questions, by making quizzes for the purposes of reinforcement and assessment.

[PCK Pre-Interview]

During the interview, she stated that students may have difficulty in making interpretation about the concepts in the seasons, weather, and climate topic and understanding the role of the Earth's tilted axis on the seasons. She attributed students' learning difficulties to this topic being placed as a first unit as a first time in the curriculum and the containing abstract concepts. She added that by conducting experiments, she could make the concepts more concrete for the students to understand and so enable the students to make comment on the concepts. She stated that students may have a misconception as to the differences between the concepts of climate and seasons because they are interrelated concepts. She stated that she identifies students' misconceptions with testing them, observing their behavior and examining their wrong answers, and that she eliminates those misconceptions by creating a table, making scientific explanation, showing the visuals and giving examples. She said that she could use all kinds of methods in case the methods were not effective. She argued that students' misconceptions and learning difficulties cause her to repeat the topic in her teaching, and she added that she asks questions, gives homework and performs quizzes with the aim of both assessing students' understanding and helping them to reinforce concepts.

Similar to her interview, while she was asking questions about what the Earth's tilted axis is in her teaching, she recognized from students' responses that they had difficulty in understanding the Earth's tilted axis and its' impact on the formation of seasons. Therefore, she tried to eliminate students' learning difficulties by drawing a figure on the blackboard, giving scientific explanation, and following performing experiment. First, she drew a figure on the blackboard (See Figure 4.17) and then made scientific explanation as follows;

> Beyza: The Earth orbits around the Sun. The equator and the orbital plane are not coincident. The Earth's axis is tilted as 23°27′. If the Earth's tilted axis was not existed, the temperature values would always remain constant. The length of day and night would always be equal. For example, it would be always summer or always winter in Turkey. The angle of incoming sun rays would not change throughout the year.

[Classroom Observation]

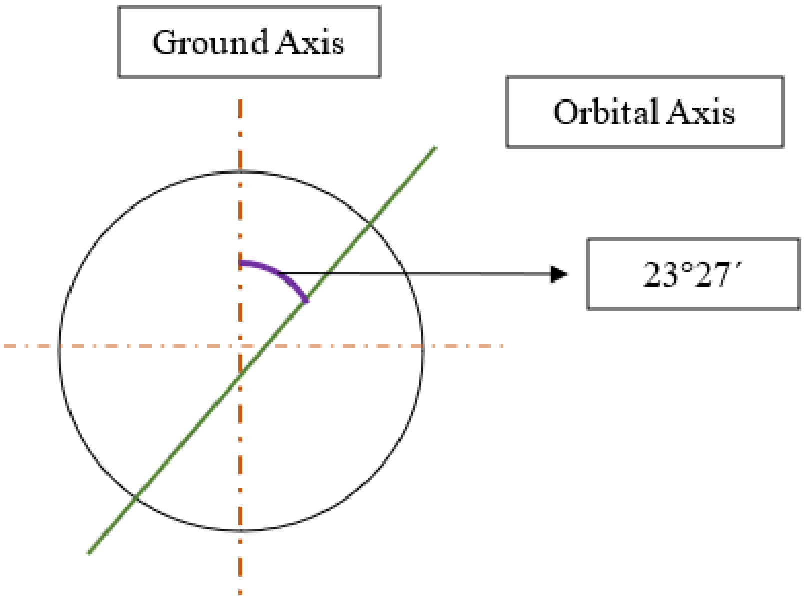


Figure 4.17 Symbolic Representation of Beyza's Drawing Regarding the Earth's Tilted Axis

Moreover, to eliminate students' learning difficulties related to the impacts of Earth's tilted axis on the seasons, she made an experiment using a globe model and a flash lamp in her teaching. The flash lamp represented the Sun. She turned off the classroom lights, turned on the flash lamp and then, showed the Earth's tilted axis, how it influences the formation of seasons and at what angles each hemisphere receives sunlight. Figure 4.18 represents her experiment symbolically she performed in the classroom.

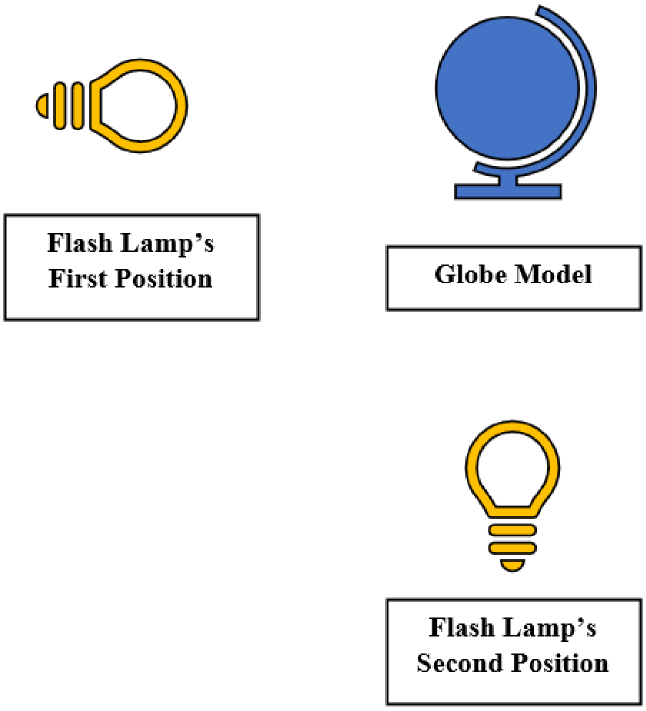


Figure 4.18 Symbolic Representation of Experiment in the Classroom

Following are the conversations that occurred between students and Beyza during the activity;

Beyza: **For the first position,** which hemisphere stands more obliqued to the Sun?

S_1: Southern Hemisphere.

Beyza: On December 21st, the sun rays fall as perpendicular to the Tropic of Capricorn on the Southern Hemisphere and the summer starts in the Southern Hemisphere.

Beyza: **In the second position,** in what way do the sun's rays come to the Northern Hemisphere and the Southern Hemisphere?

The students could not answer this question. Therefore, the teacher provided the answer:

Beyza: The sun rays are coming as oblique and both hemispheres are experiencing the spring. Which seasons occur in the Southern Hemisphere after the summer?

S_1: Autumn.

Beyza: What about in the Northern Hemisphere?

S_2: Spring.

Beyza: This tilt [Earth's tilted axis] causes seasons to occur (Beyza explained by pointing the model that Earth's tilted axis causes different seasons to occur.).

[Classroom Observation]

As she stated, in her teaching, she asked various questions to the students, and through students' responses, she recognized a students' misconception related to the association between the formation of seasons and the Earth's distance from the Sun (e.g., Tsai, & Chang, 2005). Then, she tried to remediate students' misconception only through making scientific explanation (i.e., teacher-centered method), yet she did not use any topic-specific strategies. In her teaching, she expressed that;

Beyza: There is no relationship between the formation of seasons and the Earth's distance to the sun.

[Classroom Observation]

Overall findings revealed that similar to pre-interview, she realized in her teaching that students had difficulty in understanding the Earth's tilted axis as the causes of the seasons. She tried to eliminate it by performing experiment, making scientific explanation, and drawing a figure. As stated in the pre-interview, using questioning method, she identified a misconception that students possessed regarding the seasons concept but to eliminate this misconception, she made only scientific explanation. Lastly, her teaching showed that as she stated, students' misconceptions and learning difficulties regarding the seasons, weather and climate topic affected her teaching because they caused her to repeat the concepts. Beyza’s knowledge of students’ difficulties was shown in Table 4.45, which also showed consistent and inconsistent points between her reported PCK and enacted PCK.

Table 4.45 *Beyza's Knowledge of Students' Difficulties*

Beyza's Knowledge of Students' Difficulties			
PCK Pre-Interview		**Classroom Observation**	
Learning Difficulties	**Methods for Elimination**	**Learning Difficulties**	**Methods for Elimination**
Difficulty in making comment on the seasons, weather and climate Difficulty in understanding the impact of the Earth's tilted axis on the formation of seasons	Experiments Solving different kinds of questions from different sources prepared by different textbook publishers	Understanding the Earth's tilted axis and its' impact on the formation of seasons	Drawing figure Scientific explanation Performing experiment
Misconceptions	**Methods for Elimination**	**Misconceptions**	**Methods for Elimination**
Confusing the climate and seasons Factors affecting the length of shadows	Creating tables Showing visuals or demonstration Giving examples Teaching the correct concept	Associating between the formation of seasons and the Earth's distance from the Sun (e.g., Tsai, & Chang, 2005).	Scientific explanation

In the following part, Beyza's knowledge of instructional strategies is presented.

4.2.3.4 Beyza's Knowledge of Instructional Strategies

Beyza's knowledge of instructional strategies was reported under two parts which are *knowledge of subject specific strategies* and *knowledge of topic specific strategies*. The knowledge of representation and knowledge of activities were reported under the knowledge of topic-specific strategies. Related data were collected through pre-interview, post-interview, teacher documents and classroom observation.

4.2.3.4.1 Beyza's Knowledge of Subject Specific Strategies

When asked her knowledge about subject-specific strategies, she generally mentioned about general strategies in addition to topic-specific one. Table 4.46 depicted her all responses regardless whether topic specific or not.

Table 4.46 *Beyza's Knowledge of Strategies*

Dimensions	**Science Topics**	**Seasons, Weather, and Climate**
Subject Specific Strategies	Direct Instruction Questioning Brainstorming Giving homework	Direct Instruction Questioning Brainstorming Experiment* Drawing figure*
The Reasons of Selecting the Strategies	Depending on the content, we can use any method.	Depending on the content, we can use any method.
The Sources of Learning Strategies	Her teaching experiences	Her teaching experiences

***Indicate topic-specific strategies**

Researcher: Which teaching method/strategy do you prefer to use while teaching science?

Beyza: Well, I use the traditional one, that is, direct instruction. The teacher teaches [transmit the knowledge], and the student listens. So, the student is passive in this process. With the help of group works and activities, the student becomes active [in the lesson] … Student [in my class] comes to lesson by being well prepared....by reading the topic… This makes them familiar with that day's topic. Then, we teach the content according to the curriculum and then, students are given homeworks at the end of the course. Homeworks are given as a purpose of reinforcement… Homeworks are either mandatory, like reinforcement, or nonmandatory, it is up to students whether to do it or not... I want students to do homework which is given by me. Then, I check their homeworks. Furthermore, I say that "You can solve any additional questions [from the 3 or 4 test books] regarding the topic that will be controlled by your parents" … [Actually] my class hour allows me solve questions only from two or three tests. I leave the rest [of the questions] to student to be completed at home. When they [students] come to school next day, we check what they [students] have learnt…I ask either a few questions or start introducing the new topic. At the beginning of each topic, I start with brainstorming, or by sentences which attract students' attention…

Researcher: How did you learn to use this teaching strategy?

Beyza: Nobody can learn the profession from other. Because while internship [in teaching practice course at university], there was a very short internship period. For example, I had 4 weeks internship period, each included 2 class hours. Teaching is a profession that you can develop your own skills by yourself... You develop yourself and revise your teaching strategies through the experience within the years... Teachers who improve themselves can become much more active in their teaching profession within the years.

Researcher: What about the teaching of seasons, weather, and climate topic? Which methods do you use to teach the seasons, weather, and climate topic?

Beyza: We use all kinds of teaching methods... We start with brainstorming first to understand what they [students] know [about the concept]. There is no right or wrong answers in this activity. We try to elicit students' prior ideas about seasons, climate, weather events, poles of the Earth… Why do we have different seasons?... In other words, I expect from them to say any single word about the topic. Then, I start the topic by asking interesting question to attract their interest. Then lesson is proceeded slowly… by giving the information [direct instruction] … next. We use the smart board and students follow the lesson on the screen. We continue lesson by drawing and encouraging students to take notes. After that, we start activities. If there is an experiment [in the curriculum], we do it. Then, we summarize the topic by asking questions toward the end of the lesson.

Researcher: Do you have particular reasons for using those teaching methods?

> Beyza: Depending on the content, we can use any method. For example, some topics are very well understood with drama. Others are by the experiment. For example, it is very important to do the experiment when teaching of the length of a shadow. The drama is very effective in the teaching digestive system… it is really enjoyable. If the students find the lesson enjoyable, they [students] listen….and participate to the lesson. It is very important to create learning environment which allows maximum participation.
>
> [PCK Pre-Interview]

She tended to prefer direct instruction and questioning methods based on teacher-centered teaching methods both in teaching science topics and seasons, weather and climate topics, and stated that she starts her lessons with brainstorming to reveal students' prior knowledge. She pointed out that the teaching methods can be used based on specific to topic and also drew attention to the preparing of a learning environment that encourages students to attend to the lesson. She stated that in science topics, she can do group working in which students will play an active role and give homework to promote students' learning. Moreover, she added using smart board, doing experiments, and drawing figures in teaching of the seasons, weather and climate topic. Lastly, she expressed that her teaching experiences gained within the years are the source of learning these teaching methods. Overall, she addressed general teaching strategies and topic-specific strategies yet did not mention about subject-specific strategies such as argumentation, 5E learning cycle, conceptual change approach.

Her enacted PCK seems to be consistent with her reported PCK because her teaching practices were mostly teacher-centered; she frequently used questioning and direct instruction methods. She initiated brainstorming by asking questions to elicit students’ prior knowledge. She drew several figures to enable students to visualize the concepts. She also performed an experiment yet did not include science process skills such as observation, establishing hypothesis.

For example, during her teaching, she frequently asked questions related to the seasons, weather, and climate topic and thus, she ensured that the students remained active throughout the course. The dialogues were occurred between the teacher and students as follows;

Beyza: What affects the weather events?

S_1: Global warming.

Beyza: Be more specific. [For example], what influences the weather in Ankara* in a period of 2 day? What is the weather like today?

S_1: The weather is cold [colder than yesterday].

S_2: Temperature dropped…

Beyza: The temperature dropped. So, temperature is one of the determining factors of weather [the weather you experience is influenced by many factors]. What would be another determinant? What else raised in the weather?

S_3: Cloud… [it is cloudy today].

Beyza: What forms the clouds?

S_4: Water vapor.

Beyza: Water vapor! Yeah... Humidity [in air] increased. We just mentioned about the mixture of gases in the air. The [amount of] water vapor in the air is the most important factor. Precipitation is higher at the seaside… Why is it rainy all the time in the seaside? … [Because] water is evaporating from the sea. What else can influence the weather?

S_5: Humidity.

S_6: Pressure difference.

Beyza: Yes. [Ranges] from high to low. What factors influence the climate?

S_1: Precipitation patterns.

S_2: Altitude.

Beyza: Yes. Altitude above sea level.

S_3: Daily temperature differences.

Beyza: Hmmm maybe…

S_4: Vegetation.

Beyza: Yes, definitely.

S_5: Mountains.

Beyza: Mountains… [Response to S_5] You mean that it is altitude above sea level. In fact, the most important factor affecting the climate is latitude; the distance to the equator.

[Classroom Observation]

[***:** *the capital city located in Central Anatolian region in Turkey*]

Lastly, she was asked about the connection between the goals and the methods she chose for teaching the seasons, weather, and climate topic. She considered that the methods she selected reflect her goals because children were successful and acquired many knowledges related to the seasons, weather and climate topic. The related excerpts from the interview were as follows;

Researcher: What is the connection between your goals in teaching and the methods you choose? To what extent do you think it reflects your goals?

Beyza: I think yes…. The methods I choose reflect my goals since their [children's] achievement levels increase… they [children] are successful. I think they [children] have a great deal of knowledge about the topic when they [children] left the classroom. We also raise the children's awareness level… I use any method to teach the concept to the children. I think we have reached my aim.

[PCK Pre-Interview]

In the following part, Beyza's knowledge of topic-specific strategies as a sub-component of knowledge of instructional strategies is presented.

4.2.3.4.2 Beyza's Knowledge of Topic Specific Strategies

Findings were reported under the two parts which are knowledge of representations and activities.

4.2.3.4.2.1 Beyza's Knowledge of Representations

In the pre-interview, she stated that she will use EBA [Education Information Network], Morpa Campus, draw figures and show videos as representations. While teaching the seasons, weather and climate topic, she used all of them and in addition to pre-interview, she showed visuals from the science textbook, gave examples, and used a globe model. Beyza's knowledge of representations was shown in Table 4.47.

Table 4.47 *Beyza's Knowledge of Representations*

Types of Representations		
PCK Pre-Interview	**Classroom Observation**	**Examples used in the Classroom Observation**
Illustrations		
Visuals		
Videos (i.e., EBA, Morpa Campus)	*Videos (i.e., EBA, Morpa Campus)*	The formation of seasons The Earth's movements
-	*Figures*	She showed figures regarding the concepts of seasons, weather and climate from the science textbook approved by MoNE.
Drawing figures	Drawing figures	The formation of seasons The movements of the Earth The Earth's tilted axis
-	Model *Globe Model*	She used a globe model in order to show the role of the Earth's tilted axis on the seasons.
-	Examples	Factors affecting the weather events Types of weather events

Researcher: Do you use illustrations, examples, models, drawings, and analogies to assist students' learning the seasons, weather, and climate topics and concepts?

Beyza: Yes. I do. As I said, we use EBA. After that, we can use Morpa Campus website. It is really effective… like EBA. Apart from that, there are some applications on the smart board such as textbook. We draw figures.

Researcher: What kind of activities are there in the EBA and Morpa Campus website? Or smart board.

Beyza: I don't know right now [I have not taught the topic yet] … This [seasons, weather, and climate topic] is a completely new topic [she means that seasons, weather, and climate topic is located as a first topic for the first time in MoNE 2018], which makes the interview vague. We examine the books. Many books came from the some of the publishers [to us]. We are uploading the textbook to the smart board and use it. There are some applications related to the seasons and climate as well including videos, tests, etc. We show videos related to seasons, the formation of seasons, the Earth's revolution around the Sun, it's [Earth's] rotation around itself, consequences of Earth's movements... We show the videos one by one.

[PCK Pre-Interview]

She expressed that she will use EBA, Morpa campus, textbooks uploaded to the smartboard and applications on the smart board, draw figures and show videos (e.g., about the formation of seasons, the Earth's movements). Similar to her reported PCK, her enacted PCK showed that she used all of them *(The use of applications found in smartboard such as fill in the blank were explained in knowledge of methods of assessment section).* In addition to her reported PCK, her enacted PCK showed that she gave examples, and used a globe model. By using the science textbook, she also showed various figures related to the seasons, weather, and climate topic.

In her teaching, she showed videos regarding the seasons, weather, and climate topic from EBA website. The content of the videos was related to the formation of seasons and the Earth's movements (e.g., the Earth's rotation around itself and revolution around the Sun).

She drew various figures especially regarding the seasons on the blackboard such as the formation of seasons (See Figure 4.10), the movements of the Earth (e.g., Earth's rotation around itself and revolution around the Sun) (See Figure 4.19).

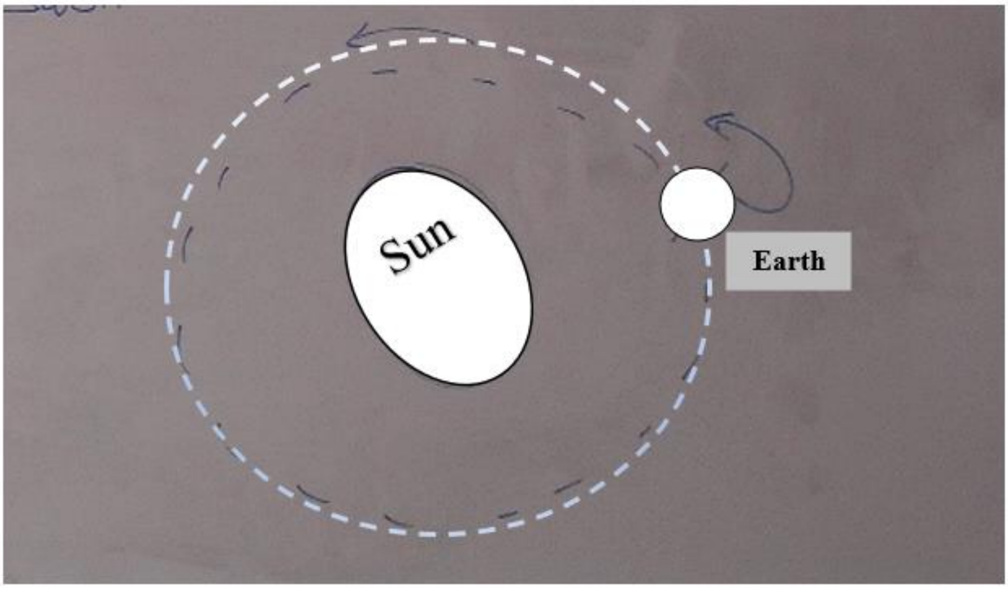


Figure 4.19 Beyza's Drawing About the Earth's Rotation around itself and Revolution around the Sun

She drew another figure on the blackboard with the aim of showing the Earth’s tilted axis (See Figure 4.20) and then, wrote the necessary knowledge regarding the Earth’s tilted axis on this figure (e.g., Earth’s rotation axis).

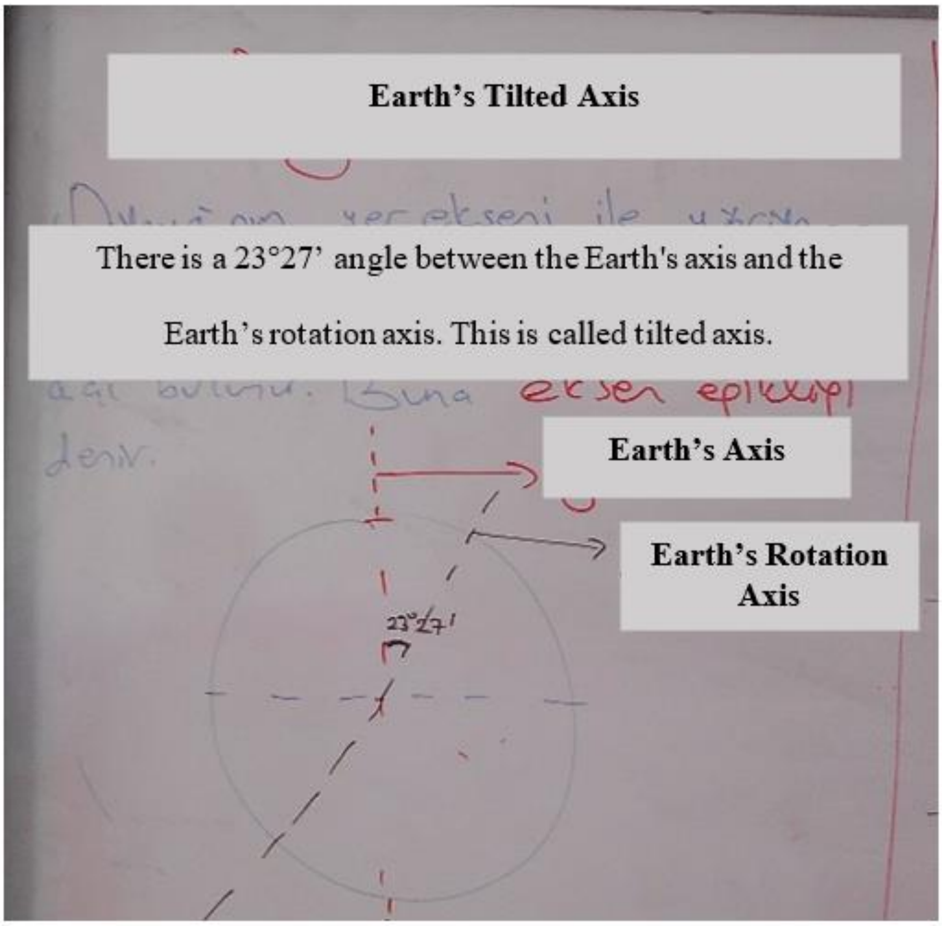


Figure 4.20 Beyza's Drawing About the Earth's Tilted Axis

She preferred to use a globe model to enable students to understand how the Earth's tilted axis affect the formation of seasons (See detail in Beyza's knowledge of students' difficulties section).

Moreover, to enrich her teaching on the seasons, weather and climate topic, she gave some examples regarding these concepts (See Table 4.48).

Table 4.48 *Beyza's Examples Regarding the Seasons, Weather and Climate Topic*

Topic	**Beyza's Example**
Factors affecting the weather events	▪ Temperature, Humidity, Wind, Rain, Pressure difference
Types of weather events	▪ Rain, Snow, Hail, Rime, Dew

In the following part, Beyza's knowledge of activities as a sub-component of knowledge of instructional strategies is presented.

4.2.3.4.2.2 Beyza's Knowledge of Activities

In this section, Beyza's knowledge of activities regarding the seasons, weather, and climate topic was reported. In the pre-interview, she stated that she will perform the drama, experiments and poster activities in her lesson. As she stated, she performed all activities while teaching the unit. Beyza's knowledge of activities was summarized in the Table 4.49.

Table 4.49 *Beyza's Knowledge of Activities*

Pre-Interview	**Classroom Observation**
Drama Activity	Students animated the Earth's rotation around itself to show how day and night occur. Students animated the Earth's revolution around the Sun and the angle of the incoming sunlight to the Earth to show how seasons occur. Students animated the formation of wind.
Experiment	She performed an experiment with using the globe model and flash lamp (used as a Sun) to show the effect of the Earth's tilted axis on the formation of seasons.
Poster Activity	Students created their posters in groups regarding the seasons, weather, and climate topic.

In the following question, Beyza was asked about whether she conducts activities regarding the seasons, weather, and climate topic.

> Researcher: Do you conduct activities in the class regarding the seasons, weather, and climate? If so, what kind of activities do you perform?
>
> Beyza: Any method is chosen depending on the content of the topic. We will perform drama and role-playing activities [in the lesson]. During the lesson, other activities can be prepared depending on the content of the topic. For example, I assign the students and they [students] prepare the activity related to the topic... In order to save time regarding the topic, sometimes instead of using the blackboard, we do the activities existing on the smart board like fill in the blank, matching type questions, test, game...... Or we do not open the smart board. [Instead of opening smart board], [for example], they [students] prepare [the fill in the blank activity on] the blackboard. I want students to do fill in the blank [activity] on the blackboard. We are trying to make the concepts related to the seasons more concrete by experiments. After topic is understood by students, we start to solve the tests. Then, we perform poster

activity in many times. They [students] make effort on poster all together. Then, they [students] present their posters. The poster competition is organized, and the winner is selected.

[PCK Pre-Interview]

Similar to her reported PCK, her enacted PCK showed that she performed drama and role-playing activities and experiments. She performed poster activities and activities in the smart board (e.g., fill in the blank, game, tests), gave homework, distributed tests including multiple choice questions from different textbook published by different publishers to the students, and also, she wanted from students to create the fill in the blank activity on the blackboard *(these were explained in knowledge of methods of assessment section)*. But she did not perform some activities regarding this topic found in the science textbook approved by MoNE.

In her teaching, she performed three drama activities; one was related to seasons concept, the other was related to the formation of day and night, and the other one was related to the formation of wind.

- In first drama activity, two students were selected; one student animated the Earth, the other one animated the Sun. While the student who animated the Earth rotated around himself/herself, how day and night occur was visually animated.
- In second drama activity, the same students who animated the formation of day and night played role. She aimed to show the Earth's revolution around the Sun, how the Earth's tilted axis impact the formation of seasons and the angle of the incoming sunlight to the Earth. The position of the students in the classroom symbolically were shown below (See figure 4.21).

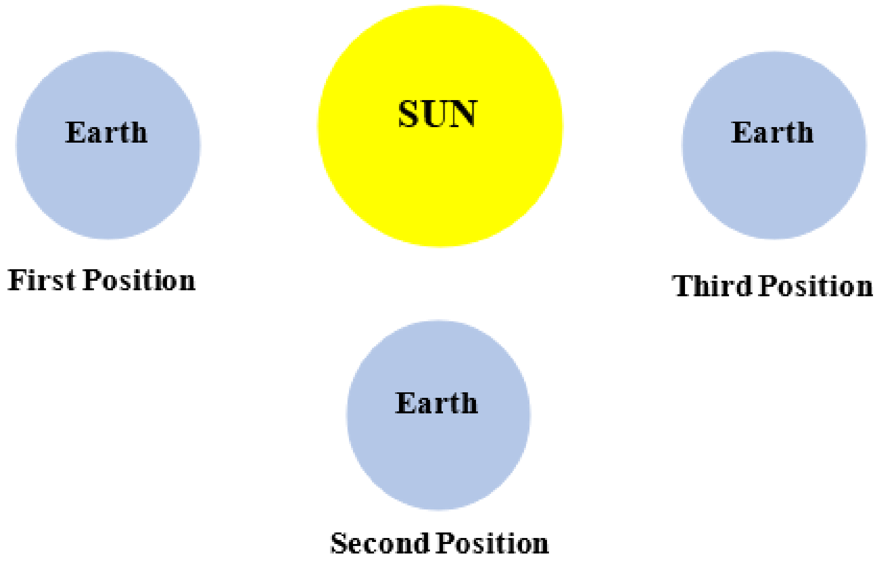


Figure 4.21 Symbolic Representation of the Position of the Earth Around the Sun

The different position of the Earth around the Sun was symbolized by the students who animated the Earth and the Sun. For each Earth's position around the Sun, she asked the questions to the students.

Teacher asked questions regarding the first position of the Earth;

Beyza: Which is the hemisphere receives the sun rays as perpendicular?

S_1: Northern Hemisphere.

Teacher asked questions regarding the third position of the Earth;

Beyza: In third position, where do the sun rays come as perpendicular?

S_1: To Southern Hemisphere.

Beyza: When the sunlight falls as perpendicular [to Southern Hemisphere], the summer is experienced in Southern Hemisphere because it [Southern Hemisphere] received solar energy. When solar energy comes into contact with the substance, heat energy occurs.

Beyza: When is the summer experienced in the Southern Hemisphere?

S_2: On December 21st.

[Classroom Observation]

- In another drama activity, eight students were selected to animate the formation of high-pressure area and low-pressure area and thus how the wind occurs was showed. She said to the students standing on the left side of the blackboard ‘‘*You represent the molecules in cold air”* and said to the students standing on the right side of the blackboard *“You represent the molecules in warm air”*. In this drama activity, the dialogues were occurred between students and teacher as follows;

  Beyza: You are the gas molecules found in the air. The molecules [in the gas] are free. [The molecules] make vibration, translation, rotational motion. This is cold air (the teacher referred to students representing the molecules found in cold air). The cold winds are blowing. What about the molecules of the air?

  S_1: They [molecules] will shrink [in cold air]. (Students who represent the molecules found in cold air approached each other).

  Beyza: The volume will be smaller. What increased?... Density increased. Pressure increased. Number of particles per unit volume increased. The air warmed up in here. The movement of the air increased. They [molecules in the air] are moving. What happened here [in warm air]?

  S_2: The air temperature increased (students who represent the molecules found in warm air moved away from each other).

> Beyza: What happened when the air temperature increased? The volume increased. Density decreased. Pressure decreased. This is a high-pressure area (teacher indicated students who represent the molecules found in cold air). This is a low-pressure area (teacher indicated students who represent the molecules found in warm air). The wind is a horizontal air current blowing from the high-pressure area towards the low-pressure area.
>
> [Classroom Observation]

She performed an experiment using a globe model and a flash lamp which represented the Sun. She did this experiment twice. She kept the flashlight on top of the globe model to show the influence of the Earth's tilted axis on the formation of seasons. She also demonstrated which seasons are experienced in Northern and Southern hemisphere when these hemispheres receive sunlight from different angles such as oblique or perpendicular angles *(see more detail in knowledge of students' difficulties section).*

Furthermore, she asked students to prepare posters in groups regarding the concepts found in seasons, weather, and climate topic within the lesson time. Students prepared and then, presented their posters *(explained as a summative assessment in knowledge of methods of assessment section).*

Lastly, Beyza was asked about how she understood the effectiveness of the activities she has planned. She recognized the effectiveness of the activities thanks to her teaching experiences, positive feedback taken from her middle school graduate students and her students' parents. She sees herself not bad in finding effective activity, but added that her colleagues, including herself, should improve themselves to teach the topic effectively. The related excerpts from the interview were as follows;

> Researcher: You mentioned the activities you planned to do. How do you come to realize that they will work?

> Beyza: [I understood activities will work] from my experiences in the past. We successfully taught lots of topics throughout the years in all grade level. Also, I receive positive feedbacks provided by their [students'] parents. The students can become successful without almost needing the re-teaching [the topic], which means that, they understand the topic in the lesson. That is, my methods are working very well. But the teacher should never say "I know everything.". They [teachers] should accept that they may have inadequacies. They [teachers] should improve themselves to compensate their deficiencies… Teacher should think how a topic can be taught more effectively. I'm not bad [in finding effective activity] … But as I said, I can improve myself. I can find more effective activities. Hmmm… My past middle school students always visit us, and we recall the past school years. For example, [when they were my middle school students], we performed a drama about the muscles and they [my past middle school students] said that this activity remained in their mind. They expressed that they were very successful in their courses by applying my methods such as my method of using notebook. I got such [positive] feedbacks provided by them.
>
> [PCK Pre-Interview]

In the following part, Beyza's knowledge of assessment is presented.

4.2.3.5 Beyza's Knowledge of Assessment

Beyza's knowledge of assessment was reported under two sub-dimensions which are knowledge of dimensions of science learning to assess and knowledge of methods of assessment. Related data were collected through pre-interview, post-interview, teacher documents and classroom observation.

4.2.3.5.1 Beyza's Knowledge of Dimensions of Science Learning to Assess

In this section, Beyza's knowledge of dimensions of science learning to assess regarding the seasons, weather, and climate topic was reported (See Table 4.50).

Table 4.50 *Beyza's Knowledge of Dimensions of Science Learning to Assess*

Knowledge of Dimensions of Science Learning to Assess	**PCK Pre-Interview**	**Classroom Observation**
Knowledge on the seasons, weather and climate	Mentioned	Assessed
NOS Understanding	Not Mentioned	Not Assessed
Science Process Skills	Not Mentioned	Not Assessed
Knowledge of Dual Perspective	Not Mentioned	Not Assessed

> Researcher: What do you want to assess in depth when you assess your students' knowledge in terms of seasons, weather, and climate?
>
> Beyza: I assess their knowledge about the topic. For example, I assess "How much did they [students] understand?". They [students] will learn the concepts… what is climate?... who is a meteorologist?... what is the equinox?... how seasons form?... They [students] will understand all the basic knowledge. Then, they [students] will have the problem-solving skills.
>
> [PCK Pre-Interview]

Consistently, while teaching the unit, she distributed the tests including multiple choice questions and matching type questions from different textbook published by different publishers to assess students' knowledge with respect to the seasons, weather, and climate. Also, she frequently used questioning method during her teaching. For example, she asked a variety of questions related to the seasons and the following dialogues were occurred between the teacher and the students as follows;

> Beyza: What are the consequences of the annual movement of the Earth?
>
> S_1: Seasons may occur.
>
> Beyza: Does just the [Earth's] annual movement cause the formation of seasons? That's what we have learned in primary school. What should we say?
>
> S_2: [Earth's] tilted axis.
>
> Beyza: The [Earth's] tilted axis allows the Sun [sunlight] to reach the Earth at different angles. What would happen if the [Earth's] axis was not tilted?
>
> S_3: One side [one of the Hemispheres] would always experience the same season.
>
> S_4: It would be too warm.
>
> Beyza: We would not be able to live four seasons [in Turkey]. It would be either too warm or too cold.
>
> S_4: Drought would be occurred because it would be experienced same season.
>
> Beyza: It [the absence of Earth's tilted axis] would affect the diversity of living things.
>
> [Classroom Observation]

As seen, these questions were consistent with the objectives related to the seasons, weather, and climate topic in the curriculum. Similar to her opinions regarding pre-interview, she only assessed students' knowledge and did not assess students' knowledge on dual perspective, science process skills, or NOS understanding. Accordingly, it can be concluded that her reported PCK and enacted PCK seems to be consistent.

In the following part, Beyza's knowledge of methods of assessment as a sub component of knowledge of assessment is presented.

4.2.3.5.2 Beyza's Knowledge of Methods of Assessment

In this section, Beyza's knowledge of methods of assessment regarding the seasons, weather, and climate topic was reported (See Table 4.51). Although Beyza generally focused on applying traditional assessment methods in her pre-interview (e.g., written exam, verbal exam, questioning), she applied both traditional and alternative assessment methods (i.e., poster activity and peer assessment) in her teaching. She assessed students' understanding with questioning during the lesson (i.e., formative assessment), and with different type of questions such as fill in the blank, multiple-choice at the end of the lesson (i.e., summative assessment). In the post-interview, she stated that she will perform written exams later.

Table 4.51 *Beyza's Knowledge of Methods of Assessment*

Dimensions	**PCK Pre-Interview**	**Classroom Observation**
How to assess?	Verbal exam Written exam Question-answer style Multiple choice questions Branching tree diagram system that proceed in the form of true or false	Questioning method Unit evaluation questions (e.g., fill in the blank, multiple choice) Various practices in the smartboard (e.g., true/false) Other textbooks published by different publishers including multiple-choice questions Having students prepare a fill in the blank activity Giving homework Poster activity
The reasons of selecting assessment strategies	To understand whether students learned or not.	Assessing students' knowledge of seasons, weather and climate
When to assess?		
Formative assessment (During the lesson)	Mentioned	Applied
Summative assessment (At the end of the lesson)	Mentioned	Applied

Researcher: Which assessment techniques do you use to assess their understanding in seasons, weather, and climate topic?

Beyza: We assess with verbal, written methods… all kinds of methods. Question and answer style, tests [multiple choice questions]…. Classical measurement and assessment techniques. Apart from that, I use branching tree diagram system that proceed in the form of true or false.

Researcher: Well, what are the particular reasons for using them to assess students' understanding?

Beyza: We can only understand students' knowledge by using verbal and written assessment methods. It is necessary to assess the children with written or verbal ways. We do verbal exam during the lesson. I try to get their information throughout the lesson to understand what they [students] learned about the topic. By using all of them [measurement and assessment techniques], I understand whether they [students] learned or not.

Researcher: Well, when do you assess your students regarding seasons, weather, and climate?

Beyza: Hmmm… After each topic is completed, we assess [students' understandings] with using tests. For example, we will complete the formation of seasons topic and then, we are going to continue with the weather events. When the topic is completed, we will do tests and questions-answers. We have certain written exam dates. We do the first written exam one and a half months after starting the schools… The [second] exam date is about the third week of November.

Researcher: Why did you prefer to use this period?

Beyza: Taking knowledge is a process and in this process, the student will take the knowledge, learn, and make interpretation. Students may not learn everything in the first lesson. The way each child takes knowledge is different… it depends on the type of intelligence. Some of them understand the knowledge by writing… some of them by just listening [the lesson] … some of them by seeing… some of them by doing all of them…

Researcher: How do you use the assessment results?

Beyza: Hmmm… I use them [assessment results] mostly as an in-class performance grade. I use them in a way that affect their [students'] grade average. But I try not to give very low grades [to the students]. After all, it is even important that students come to school to listen to the lesson. I try to gain the child by focusing more on the most disinterested one and I try to make the course attractive. We try to reach all of them [students].

Researcher: What do the results tell you?

Beyza: They [assessment results] show how much the students understood the knowledge in the classroom… show how much they [students] attended to the lesson… show what the students learned in the lesson… We understand [how much students learned] by assessing them continuously within the year.

[PCK Pre-Interview]

From Beyza's responses, it can be stated that she generally tends to implement traditional assessment methods such as verbal exam, written exam, questioning method. She stated that she applies questioning method throughout her teaching as formative assessment, and written exam or questioning method at the end of the unit or semester as summative assessments. She added that she can understand how much students understood the topic via students' assessment results, and used these results to give in-class performance grades to her students.

Following, Beyza was asked how she feels in finding assessment ways to evaluate her teaching. She believes herself good at finding assessment ways to evaluate her teaching, and she stated that she understands whether the assessment methods she used were good or not through assessing her students. She also drew attention to the importance of written exams saying that she can understand the students' knowledge and learning difficulties thanks to performing written exams. The related excerpts from the interview were as follows;

Researcher: How do you see yourself in finding assessment ways to evaluate your teaching?

Beyza: I think I'm really fine.

Researcher: Why do you think you're good? How did you come to this opinion?

Beyza: We can reach important information related to students [with assessment] that their parents can never know. We can clearly understand whether the assessment method works [by assessing students]. The written exams are very important. For example, the child does not participate to lesson… he/she is afraid to talk… In this situation, we may not be able to understand how much the children learned. In the written assessment, when the children write what they [children] think in their mind on the paper, we see very clearly how much they understood the topic in the lesson and where they had difficulty. Therefore, it is very important to assess children' written exam by ourselves. We recognize the children in the written exam environment.

[PCK Pre-Interview]

Similar to her reported PCK, her enacted PCK showed that she used both formative (e.g., questioning) and summative (e.g., matching, open-ended, true/false, fill in the blank, multiple-choice questions, homework) assessments. Regarding summative assessments, she also applied poster activity and peer assessment as alternative assessment methods in her teaching *(poster activity was mentioned in knowledge of activities section but explained as a summative assessment in detail in this section).* As formative assessment, she used questioning method throughout the lesson, and asked many questions to the students related to the seasons, weather, and climate topic. The examples of these questions were reported on page 370-371.

In her teaching, as summative assessments, she benefitted from several types of questions and activity to assess students' understanding regarding the seasons, weather, and climate topic. For example;

- She asked students to complete the unit evaluation questions related to the seasons, weather and climate topic found in the science textbook approved by the MoNE as a homework. In the unit evaluation questions, there are different types of questions including matching type, open-ended, true/false, fill in the blank, multiple choice questions. In the next lesson, she solved these questions with students to understand whether the students learned the seasons, weather, and climate topic. She formed 7 groups in which each group included 4 or 5 students. She said that the students will receive a personal grade in return for the answers of students to the question and also, students will gain points on behalf of their groups. One student from each group came to the blackboard and answered the questions asked by the teacher. For example, she asked questions related to the difference between climate and weather events in unit evaluation questions and students answered.

- She made the activities found in the smart board including different type of questions such as multiple choice, true/false, matching type with students. She solved the true/false type of questions with students. For example, when she asked *"The change of Earth's distance from the Sun has no effect on the formation of seasons. What do you think about that?"*, student responded that *"Right"*. This question also aimed to assess whether students had a misconception as to the relationship between the formation of seasons and Earth's distance from the Sun. Then, she made a scientific explanation that;

  > Beyza: The Earth is far away from the Sun in the winter. The Earth is closest position to the Sun in the summer. [This is not a correct statement because] there is no connection between the formation of seasons and the distance of the Earth to the Sun.
  >
  > [Classroom Observation]

- She distributed the tests containing multiple choice and matching type questions from different textbooks published by different publishers as a homework. In the next lesson, she checked the students' homework and solved the questions which they had difficulty in understanding in the lesson.
- She performed fill in the blank activities on the blackboard. Firstly, she drew a figure on the blackboard to show the formation of seasons and wrote the essential

knowledge regarding the seasons such as March equinox (March 21), September equinox (September 23), June solstice (June 21) and December solstice (December 21) (See Figure 4.10). Furthermore, she filled the figures in which she drew on the blackboard with the students. That is, she asked questions to the students and then, she wrote their responses in the necessary place specified on the figure. The following dialogues were occurred between the teacher and students as follows;

Beyza: What happens in the Northern Hemisphere on June 21?

S_1: [June 21 is] the starting of summer [in the Northern Hemisphere].

Beyza: What happens in the Southern Hemisphere [on June 21]?

S_2: [June 21 is] the starting of winter [in the Southern Hemisphere].

Beyza: What happens in the Northern Hemisphere on September 23?

S_3: Autumn.

Beyza: What happens in the Southern Hemisphere [on September 23]?

S_4: The starting of spring.

Beyza: December 21... The shortest day and the longest night are lived on 21st December [in Southern Hemisphere]. What happens on December 21 in Northern Hemisphere?

S_5: Winter.

Beyza: What happens in the Southern Hemisphere [on December 21]?

S_6: It [December 21] is the summer starting date [in the Southern Hemisphere].

[Classroom Observation]

Also, she asked students to write knowledge regarding the formation of wind on the blackboard. She informed the students about the information needed to write and the shapes needed to draw on the blackboard (See Figure 4.22). Then, the students filled the necessary blanks on the blackboard with knowledges and figures regarding the wind concept. Accordingly, she ensured the active participation of the students.

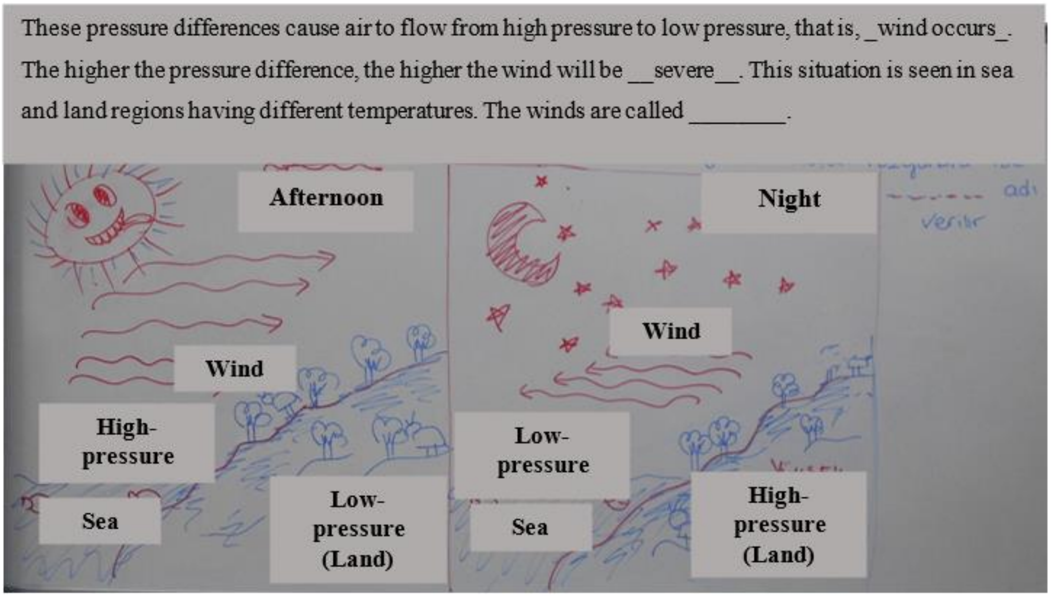


Figure 4.22 Students' Writing and Figure Regarding the Formation of Wind on the Blackboard

Lastly, after this topic was completed, she performed a poster activity, as an alternative assessment method, to assess students' understanding related to the seasons, weather, and climate topic. In the classroom, she formed five groups which contain approximately 4 or 5 students and each group was assigned to the content for which they will prepare their posters; the formation of seasons, the difference between weather events and climate, high pressure area and low-pressure area, weather events. Each group created their posters within the lesson time and moreover, students wrote necessary knowledge related to the content on their poster. After the groups completed their posters, students in each group presented them in the classroom respectively. She gave a "plus" to the students who performed their poster presentations. Each group's poster was shown below (See figure 4.23, 4.24, 4.25, 4.26 and 4.27).

Figure 4.23 Group 1's Poster: The Formation of Seasons

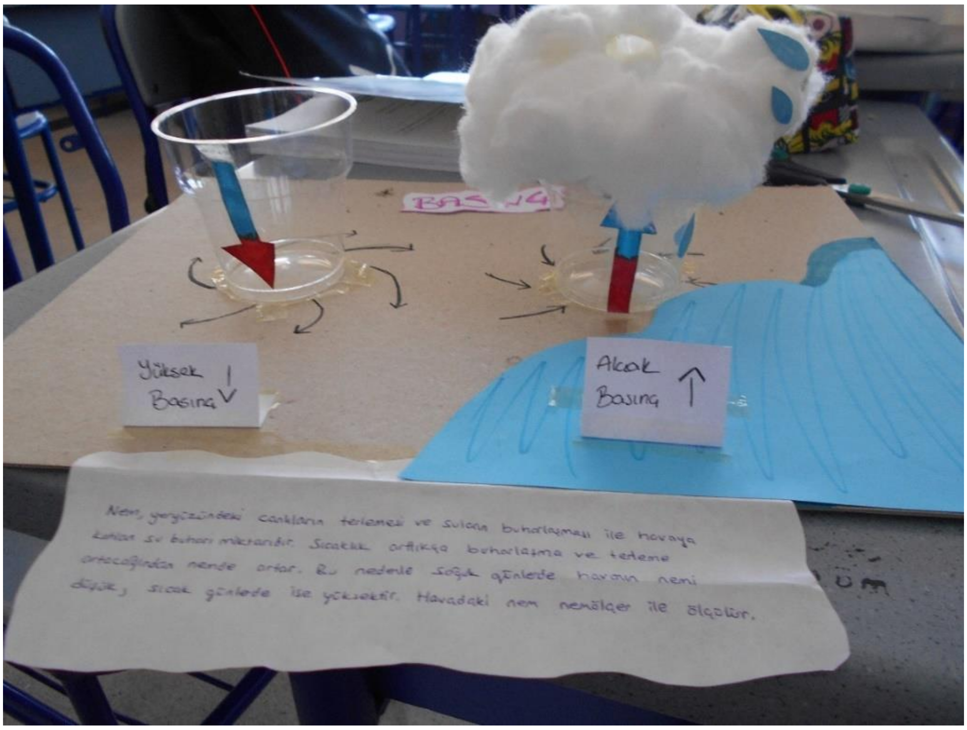


Figure 4.24 Group 2's Poster: High Pressure Area and Low Pressure Area

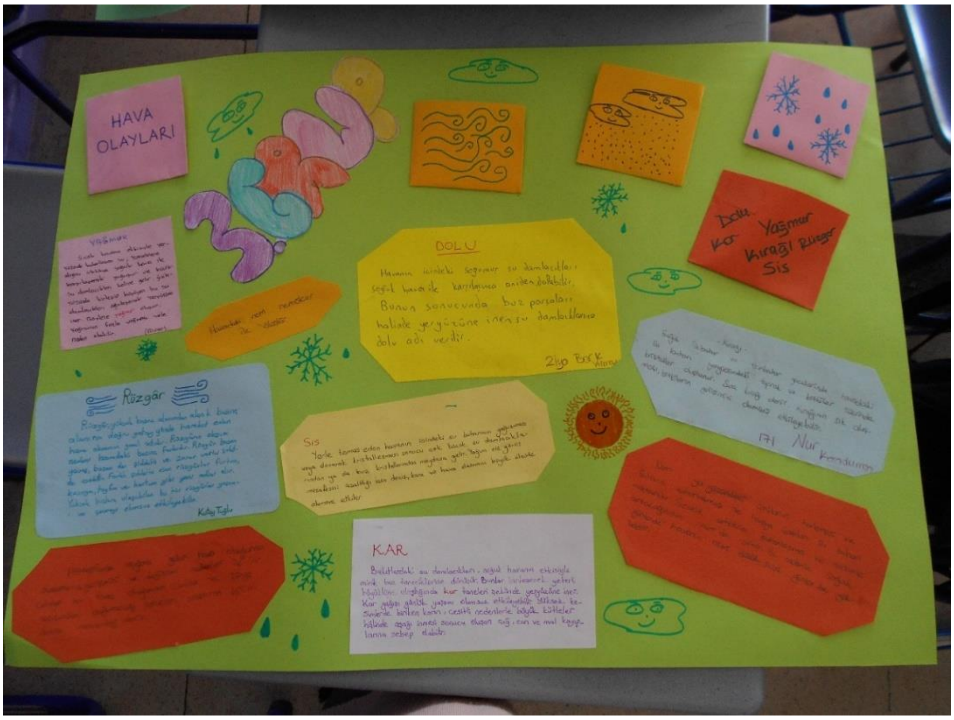


Figure 4.25 Group 3's Poster: Weather Events

Figure 4.26 Group 4's Poster: The Difference Between Weather Events and Climate

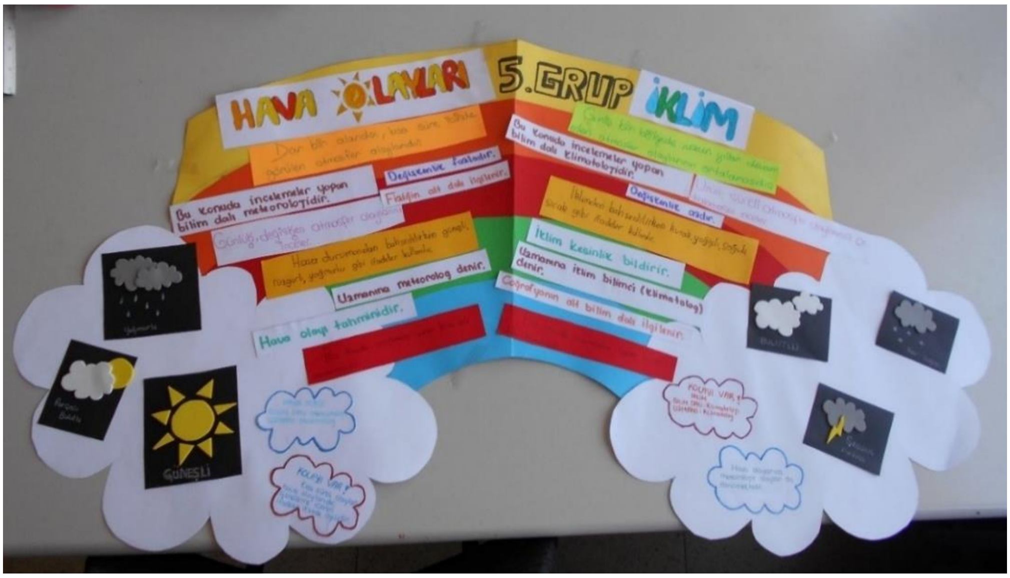


Figure 4.27 Group 5's Poster: The Difference Between Weather Events and Climate

At the end of the poster activity, she also utilized peer assessment which is another alternative assessment method. To make it clarify, after all posters were prepared, students asked questions regarding their own posters to their friends towards to the end of the lesson. For example, students in Group 5 who prepared poster regarding the difference between weather events and climate asked questions regarding their poster to their friends. Thus, she assessed the students' understanding regarding the seasons, weather, and climate topic by examining their answers to the questions. The following dialogues were occurred between the students and teacher as follows;

> Beyza: What are the common points between them [weather events and climate]?
>
> S_1: Weather events are observed in both [weather events and climate].
>
> Beyza: One of them [weather events] is determined daily and weekly. The other one [climate] is determined as a result of 30-40 years of research. Weather events is based on prediction, that is, the predictions may occur or may not occur.

Beyza: What is science discipline dealing with weather events?

S_2: Meteorology.

[Classroom Observation]

In the pre-interview, Beyza said that she will perform the general assessment with written exam after completing the seasons, weather, and climate topic. In the post-interview, the researcher asked when she will perform general assessment to confirm her response in the pre-interview. As she stated, in the post-interview, she expressed that she will perform the written exam in later times. The related excerpts from the interview were as follows;

> Researcher: During the pre-interview, you said that you will perform written exams and verbal exams as assessment methods to assess students' understanding related to the seasons, weather, and climate topic. During the lesson, you performed verbal exams by asking questions to the students. Are you going to do written exams later?
> Beyza: I will do them [written exams] in first week of January and the third week of November.

[PCK Post-Interview]

4.2.3.6 General Summary of Beyza's PCK

In this section, Beyza's PCK general summary related to teaching the seasons, weather, and climate topic was reported in Table 4.52.

Table 4.52 *Beyza's PCK in Teaching Regarding the Seasons, Weather and Climate Topic*

	Orientation Toward Science		**Knowledge of Curriculum**	**Knowledge of Students' Understanding**	**Knowledge of Intsructional Strategies**	**Knowledge of Assessment**
Beyza	**Central Goal** Subject matter goal Schooling goal	**Peripheral Goal** Schooling goal Affective goal	**Goal and Objectives** Expressed all objectives ***Vertical Relations*** The Earth's shape at 3rd grade The movements of the Earth, and the concept of volume at 4th grade The Sun, Earth, and Moon, and Change of state of matter at 5th grade The concept of density at 6th grade The pure substance and mixture at 7th grade ***Horizontal Relations*** Matter cycles and Environmental problems at 8th grade **Materials** Science Textbook Other textbooks published by different publishers EBA Globe Model	**Prerequisite Knowledge** (See Vertical Relations) **Students' Difficulties** Difficulty in making comment on the seasons, weather and climate Comprehending the Earth's tilted axis and its' impact on the seasons → Eliminating with drawing figure, scientific explanation, and an experiment **Misconceptions** Confusing the climate and seasons The relationship between the formation of seasons and distance of the Earth to the sun → Eliminating by scientific explanation.	**Subject-Specific Strategies** Direct Instruction Questioning **Topic-Specific Strategies** **Representations** Showing videos Showing figures from the science textbook Drawing figures Using a globe model Giving examples **Activities** Drama activity Experiment Poster activity	**Dimensions of Science Learning to Assess** Only assessing students' knowledge related to the seasons, weather and climate topic **Methods of Assessment** ***Formative assessment*** Questioning method ***Summative assessment*** Solving multiple-choice questions from other textbooks published by different publishers Performing unit evaluation questions and various practices in the smart board (e.g., true/false, matching) Creating fill in the blank activities on the blackboard Giving homeworks Poster activity Peer assessment

4.2.4 Beyza's Teaching in terms of Dual Perspective

In this section, Beyza's teaching was assessed in terms of dual perspective, by utilizing the whole data sets. Overall findings unveil her perception of individuals' tasks and responsibilities toward environment and environmental problems. According to her, the goals of science teaching *is to help students to become more conscious.".*

In SMK interview, to reveal Beyza's knowledge related to dual perspective, she was asked about actions to mitigate and prevent the effects of the climate change and global warming and the duties and responsibilities of individuals in preventing climate change. She was aware that there are actions to mitigate and prevent the adverse effects of climate change and global warming and she mentioned about both human- and government-based actions in addition to individual tasks and responsibilities to mitigate and prevent the effects of the climate change and global warming. For example, according to her, to prevent the adverse effects of the climate change and global warming, renewable energy sources (e.g., solar energy, wind energy) should be used, carbon footprint should be reducing, eco-friendly houses and factories should be built, and use of some energy sources such as petrol, gasoline, and coal should be avoided, thought that humans should clean the chimneys of their houses, install filters in chimney of their houses and change the filter in the exhausts of their cars regularly. She believed that chemicals that deplete the ozone layer (e.g., deodorant) should not be used, and the heaters which enhances the effects of global warming should not be used. Related to the government-based actions, she mentioned that the agreements are made among the countries such as Kyoto agreement to prevent the effects of global warming and climate change and to reduce the use of the fossil fuels. Examples of excerpts were provided below:

> Researcher: Do you think that is there anything to do to mitigate and combat with the effects of climate change and global warming?

Beyza: Yes, there are... [For example] to reduce air pollution, there should be some regulation for industrially advanced countries to follow while building factories. Even installing filters in the chimney may not be enough alone [to mitigate and tackle with the adverse effects of climate change and global warming] … Then, there are intergovernmental agreements… but not all countries contribute to those agreements, I guess.… there is an agreement called Kyoto. It [Kyoto agreement] is about the precautions that countries will take to prevent the climate change and global warming and to reduce the environmental pollution. It [Kyoto agreement] may be related to the reduction or avoiding the use of fossil fuels completely. There's a carbon footprint- a concept about how much human being pollutes nature. We [humans] all can do something [to reduce our carbon footprint]. … For example, Germany closed the coal mines and [the coal mines] have not function anymore. We [humans] can do something but how?... [For example], we [humans] should do it [closing the coal mines] … We [humans] depend more on electricity. For example, we [humans] may prefer not to use thermal power plants to obtain electricity…instead, build eco-friendly houses and factories. We [humans] can use renewable energy sources such as solar energy, wind energy, the potential energy of water…. We [humans] make a great difference… We [humans] are adopting them gradually …. But at the same time, [we are driving cars] working with gasoline.… In Turkey, electrical cars were recently introduced and very expensive.…cars working with both gasoline and electricity [hybrid]. So frankly, I don't know if I'll see it if we switch to the cars using electricity only…. For petrol and gasoline, we are constantly dependent on the outside countries and also, polluting the environment continuously [by driving such cars]. Coal is polluting the environment when compared to petrol…

Researcher: According to you, what do you think about the duties and responsibilities of individuals in preventing climate change?

Beyza: Hmmm… what can be done… For example, we, individually, can clean the chimney of our house. We [humans] can use filter [in the chimney of our house]. We [humans] can change the filters in the exhausts of our cars. … We [humans] may prefer not to use chemicals such as deodorant which depletes the ozone layer. The ozone layer cannot filter ultraviolet rays, which cause great harm to us and all living things. The sun, actually, is very beneficial, as well as very harmful... We [humans] need to know how to protect ourselves from the sun. [Excessive] use of heaters can be prevented. [For example], during wintertime, in restaurant or cafe, heaters were utilized excessively to keep people warm [especially who sit at the outside for smoking etc]. Heaters also contribute global warming etc....

When her teachings were examined, it was seen that she failed to mention about the vision, commitment, and action experience aspects in action competence, but mentioned about the knowledge aspect of action competence. To make it clear, she gave information about the environmental problems (i.e., greenhouse effect, global warming, climate change) and the reasons for these problems. As reported in SMK section, she mentioned about the impacts of the climate change and global warming on several areas such as biological diversity, agricultural area. Also, she drew a figure regarding the greenhouse effect (See Figure 4.16), and addressed how the greenhouse effect occurs saying that:

Beyza: Do you remember the greenhouse effect?... Nitrous oxide (N_2O), methane (CH_4) and ozone gases (O_3) are formed by the combustion of fossil fuels. As these gasses [N_2O, CH_4 and O_3] accumulate in the atmosphere, they prevent returning of the sun rays to the space. The sunlight strikes the Earth… and warms the Earth... The result of the greenhouse effect is global warming. Global warming results in climate change … The water level is rising… the water temperature is increasing… the floods occur... droughts occur… the biological diversity is decreasing…agriculture is affected …farmers harvest relatively small amount of product... There are a lot of adverse effects.

[Classroom Observation]

As a result of all data, it could be concluded that she addressed only knowledge dimension of action competence during her lesson. Unfortunately, Beyza’s one lesson was missed regarding the dual perspective. Therefore, during PCK post-interview, she was asked what she mentioned about the dual perspective in the lesson that researcher couldn't attend. She expressed that she mentioned about the tasks needs to be done and responsibilities to be taken against climate change both individually and on the basis of countries in her teaching. Summary of Beyza’s views regarding human-based and government-based actions to be taken to prevent the climate change and global warming based on interview and classroom observation data were shown in Table 4.53.

Table 4.53 *Beyza's views regarding Human-based and Government-based Actions to be taken to prevent the Climate change and Global warming*

	Interview Data	Classroom Observation Data
Human-based Actions	▪ Putting regulation for industrially advanced countries to follow while building factories ▪ Avoiding using petrol, gasoline and coal that pollute the environment ▪ Avoiding using chemicals that penetrate the ozone layer (e.g., deodorant) ▪ Avoiding using geothermal power plants to obtain electricity ▪ Changing the filters in the exhausts of our cars ▪ Building of eco-friendly houses and factories ▪ Installing a filter in the chimney of our house ▪ Cleaning the chimney of our house ▪ Reducing carbon footprint ▪ Using renewable energy sources ▪ Closing the coal mines ▪ Preventing the excessive use of heaters ▪ Becoming aware of the protecting ourselves from the sun.	*None.*
Government-based Actions	▪ Kyoto agreement is about the precautions that countries will take to prevent climate change, global warming and reduce the pollution of the environment.	

Summary of Beyza’s dual perspective based on interview and classroom observation data was shown in Table 4.54.

Table 4.54 *Summary of Beyza's Dual Perspective*

PCK Pre-Interview				Substantive Knowledge Interview	
				Types of Actions	
"The goals of science teaching are to help students to become more conscious." [Orientation Toward Science Teaching]				**Human-based Actions**	**Government-based Actions**
				Mentioned	Mentioned
Classroom Observation					
The Aspects of Action Competence				**Types of Actions**	
Knowledge /Insight	**Vision**	**Commitment**	**Action Experience**	**Human-based Actions**	**Government-based Actions**
Mentioned	Not Mentioned	Not Mentioned	Not Mentioned	Not Mentioned	Not mentioned

4.3 CASE 3: Esra's Subject Matter Knowledge and Pedagogical Content Knowledge Regarding the Seasons, Weather, and Climate: from the Dual Perspective

4.3.1 Esra's Background Knowledge and Her Classroom Environment

Esra is a thirty-six years old female teacher. She was graduated from science education program of faculty of education in one of the universities in Turkey. Overall, she has eleven years teaching experience and has been working for five years in the public school where current study was conducted. In the year of data collection [2018], she was teaching science to only 8th grade students. Classroom environment included smart board, three blackboards, several writings related to Atatürk on the boards, Turkey map and several posters including English words. The desks were arranged in rows. There were almost thirty students in her classroom. Although attended an in-service training program on project development and science consultancy training, first aid training, studies for special education students, she did not participate any in-service training related to the seasons, weather, and climate topic. She also stated that she has not any interest toward this topic.

4.3.2 Esra's Subject Matter Knowledge Regarding the Seasons, Weather, and Climate

Esra's SMK was reported under two subtitles which are substantive knowledge and syntactic knowledge. First, findings regarding Esra's substantive knowledge, which were collected through interview, classroom observation and teacher documents, were reported separately for seasons, weather, and climate respectively. Second, findings regarding Esra's syntactic knowledge, which were collected through interview and classroom observation, were reported.

4.3.2.1 Esra’s Substantive Knowledge Regarding the Seasons, Weather, and Climate

4.3.2.1.1 Esra’s Substantive Knowledge Regarding Seasons

Esra was asked several questions to reveal her knowledge regarding seasons concept:

> Researcher: How can you define seasons?
>
> Esra: Seasons… Seasons are the variation in temperature that occur as a result of fluctuation in sun’s angle reaching to the Earth during the year. This is my definition [for seasons] …
>
> Researcher: In your view, what are the reasons of the formation of seasons?
>
> Esra: One of the reasons for the formation of the seasons is the Earth’s revolution around the sun (at every 365 days 6 hours). Another reason is that the Earth’s tilted axis as 23.5° and the continual variation in sun’s angle caused by this tilt.

Similarly, during the teaching of the unit, she touched upon the causes of seasons and also, as a part of the science curriculum, causes of day and night, and said that;

> The Earth's tilted axis and the revolution of Earth around the Sun cause the seasons. Because of the [Earth’s] tilted axis, while the sun’s rays strike at a right angle to some parts of the Earth, they [sun’s rays] strike to some parts [of the Earth] at more oblique angle. Thus, different seasons are experienced in different places of the Earth. Its’ [Earth’s] rotation around itself causes day and night, not seasons…
>
> [Classroom Observation]

Similar to Burak, Esra drew a figure (See figure 4.28) showing the formation of seasons on the blackboard and indicated the solstices dates as December 21 (winter solstice), June 21 (summer solstice) and equinoxes dates as March 21 (spring equinox), September 23 (autumnal equinox). She also specified the seasons that experienced on solstices and equinoxes dates in each Hemisphere on the figure.

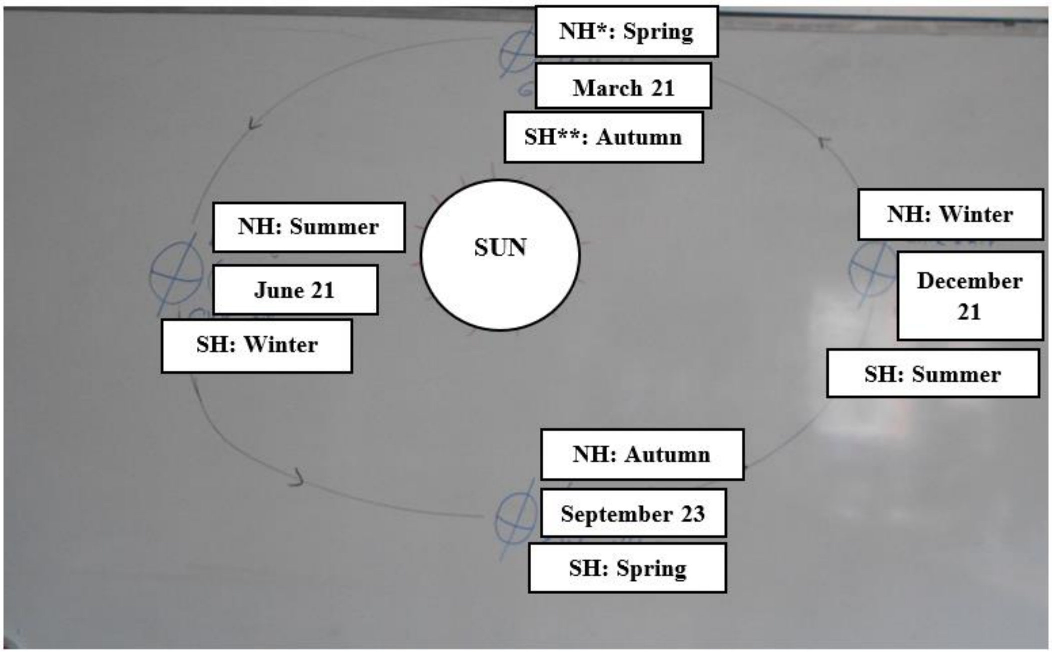


Figure 4.28 Esra's Drawing a Model Regarding the Formation of Seasons

[*: Northern Hemisphere, **: Southern Hemisphere]

In addition, she touched on the concepts of the Tropic of Cancer and the Tropic of Capricorn as a part of the science curriculum saying that;

> Esra: On Earth, above the equator line, that is, in the Northern Hemisphere, there is the Tropic of Cancer, and below this line, in the Southern Hemisphere, there is the Tropic of Capricorn. Since the sun's rays strike as perpendicular to the Tropic of Capricorn on December 21, the summer starts in the Southern Hemisphere. The longest night is lived on December 21 [in the Northern Hemisphere]. Turkey is located in the Northern Hemisphere. In the Northern Hemisphere, the summer starts when the sun's rays strike as perpendicular to the Tropic of Cancer. On June 21, the longest day is lived

[in the Northern Hemisphere]. March 21 and September 23 are equinoxes dates, and the length of days and night are equal on these dates.

[Classroom Observation]

Overall data showed her informed knowledge about seasons and related concepts found in the science curriculum (Table 4.55). For example, she correctly described the causes of the seasons by stating two factors which are Earth's tilted axis and the Earth's revolution around the Sun. She correctly expressed the Earth's tilted axis as 23.5° in accordance with scientific explanation. What is more, the classroom observation data confirmed her awareness related to the causes of the seasons along with related concepts such as solstices dates, equinox dates, the Tropic of Capricorn and the Tropic of Cancer.

Table 4.55 *Esra's Knowledge Regarding the Seasons*

The Concepts	**Response**
The Seasons	The reasons for the formation of the seasons are that; a) The Earth's revolution around the sun (at every 365 days 6 hours). b) The Earth's tilted axis as 23.5° c) The continual variation in sun's angle caused by this tilt.

In the following part, Esra's substantive knowledge regarding weather was presented.

4.3.2.1.2 Esra's Substantive Knowledge Regarding Weather

First question asked to clarify her knowledge on weather and weather events. Both the interview and classroom observation data showed that Esra possessed a good understanding of these concepts.

At first, Esra was asked her opinions regarding weather:

> Esra: Weather events change daily… They [weather events] are constantly changing and they [weather events] are predictable.
>
> Researcher: Well, what comes to your mind when saying weather and weather events? Can you explain?
>
> Esra: When saying the weather, the atmosphere comes to mind first… then, Earth... Apart from it [atmosphere], the gases in the air such as nitrogen, carbon dioxide, hydrogen, carbon monoxide, helium, water vapor, carbon…. and the oxygen that is most necessary one for us. It [oxygen] can also be considered as a source of life. Therefore, respiration, and photosynthesis come to my mind… Weather events change daily… For example, we can talk about weather condition… like rainy... snowy… sunny, cloudy… Rain…, hail, snow… rime…. are weather events occur in nature.
>
> [Interview]

She correctly expressed that weather/weather events are daily, predictable, and constantly change. Regarding weather related words, she expressed atmosphere, Earth, and gases found in the air (e.g., oxygen, carbon dioxide, helium, hydrogen). In line with the gases, she added the respiration and photosynthesis. Then, she expressed that weather events change daily, and she counted several weather events. Besides that, the classroom observation data confirmed that she was aware of the definition of weather/weather events. In her teaching, she stated that "Weather events are short-term weather conditions experienced in a particular place. Weather events can change instantaneously.". Her teaching of the unit included additional weather events such as hurricane, breeze, fog as well. The weather events that she mentioned in the pre-interview and classroom observation were reported together in Table 4.56.

To elaborate her understanding on weather events, Esra was asked about the nature of weather events. She considered that weather events can change, and there is no certainty in weather forecast. She attributed the change in weather events to the unpredictable movement of air current. Subsequently, she said that the factors that lead to changes in weather; variation in direction of wind, rapid heating, rapid cooling, angle of incoming sunlight. She believed the greenhouse effect as a factor causing changes in weather as well.

> Esra: Weather events show variation. They [weather events] even show variability during the day…interpretation [on weather events] can only be made based on predictions. Nevertheless, the predictions are not certain [it is difficult to make accurate predictions]. For example, we learn [weather events] from meteorology. Although we hear [from the meteorology] that "Today, weather will be rainy", it may not rain at all that day.
>
> Researcher: According to you, what can be the reasons for this variability in weather events?
>
> Esra: …Unpredictable movement of the air current. For example, a sudden change in the direction of wind, rapid heating, rapid cooling... I think weather events may change in an unpredictable way… The angle of incoming sunlight [to the Earth] … the greenhouse effect that occurs in many location… Even it [greenhouse effect] can affect weather events.

In addition to the temperature and wind factors she mentioned in the interview, she also added pressure and humidity as the factors causing the weather events to change during her teaching of the unit.

Her interview findings are partly consistent with her teaching (Table 4.56). Interview findings indicated that she was knowledgeable regarding weather and weather events, and also whether it is static or dynamic. She tended to attribute the causes of variation in weather events to wind, rapid heating and cooling, and the angle of incoming sunlight to the Earth, but she harbored some doubt about it because she also added greenhouse effect as a factor. On the other hand, in her teaching, she correctly attributed the causes of variation in weather events to the pressure, humidity, temperature and wind.

Table 4.56 *Weather Events that Esra Mentioned in Interview and Classroom Observation*

The Concepts	Interview	Classroom Observation
Weather	Weather events change daily… They are constantly changing and they are predictable.	Weather events are short-term weather conditions experienced in a particular place. Weather events can change instantaneously.
Types of Weather Events		
Rain	It [rain] is described as the formation of water droplets with condensation of water vapor in the air when it [water vapor] encounters cold air, and then, falling of these water droplets to the surface.	When it [bodies of water] warms up, it evaporates and moves into the sky. It encounters cooler air above [in the sky] and it condenses again. If it [bodies of water] transforms into liquid when it is condensed, rain occurs.
Snow	When it [water vapor] encounters cooler air current in the clouds in sky, water vapor freezes and falls to the Earth surface, and snow forms.	When it [bodies of water] warms up, it evaporates and moves into the sky. It encounters cooler air above and it condenses again. If it [bodies of water] transforms into solid when it is condensed, snow occurs.
Fog	Not mentioned.	When the mass of cold air encounters the mass of warm air, fog occurs.
Hail	I describe the hail as a rapid freezing. It [freezing] happens in the sky with a sudden change due to cold air…	In order to be formed hail, the water droplets in the clouds above [in the sky] need to drift a little. They [water droplets] will transform into raindrops. Water droplets will drift in the cloud before they turn into raindrops. They [water droplets] will freeze again and then, hail occurs.

Table 4.56 *(cont'd)*

Types of Weather Events	Interview	Classroom Observation
Rime	Rime forms with the freezing of water vapor in places near the Earth surface. For example, [rime forms] on a grass, on a car… on a cold surface.	When water vapor encounters cold air near the Earth surface and then, it [water vapor] transforms into ice, rime occurs.
Dew	Not mentioned.	Sometimes there's a raindrop on the plants and this is called dew.
Wind	It [wind] is the movement of air from an area of high air pressure to an area of lower air pressure. The faster this movement occurs, the faster the wind blows... The reason for this rapid movement is the pressure difference between the two [high-pressure and low-pressure] areas. The greater the pressure difference, the faster the wind will blow…	When air gets cold, the air that condensed will move down. The pressure of the atmosphere will increase. High pressure area will form. The air in the high-pressure area will try to fill the air's space in the low-pressure area. The air in the high-pressure area will move toward the low-pressure areas and the wind occurs.
Breeze	Not mentioned.	The wind blowing between the seas and the lands is called the breeze.
Hurricane	Not mentioned.	Hurricanes often occur along the coast of the ocean. It [hurricane] is caused by strong winds.

In the following section, Esra's substantive knowledge regarding the climate was presented.

4.3.2.1.3 Esra's Substantive Knowledge Regarding Climate

Esra's substantive knowledge, obtained from interview and classroom observation, regarding the climate was summarized under three subtitles: knowledge on climate, climate system and climate change, the global warming, and greenhouse effect, respectively.

At first, Esra was asked her opinions regarding the definition of the climate, and stated that;

> Esra: Climate, unlike weather, is a set of stable, long-lasting weather events that have emerged as a result of long research efforts.
>
> [Interview]
>
> Esra: Climate is the average of events such as wind, humidity, temperature and air pressure that are observed in a particular area of the Earth over long time periods.
>
> [Classroom Observation]

In the interview, her definition of the climate was deficient because she defined the climate as stable and long-lasting weather events. Contrary to the interview, while teaching of the weather and climate topic, she correctly defined the climate as long-term average of the events including wind, humidity, temperature, and air pressure. Furthermore, during her teaching of the unit, she addressed the types of the climate by asking that *"What are the climate types seen in our country [Turkey]?"*. Student 1 said *"Mediterranean [climate]"*, student 2 said *"Black Sea [climate]"* and student 3 said *"Terrestrial [climate]"*.

Esra, as an answer of next interview question, associated the climate with terrestrial climate, tropical climate, Mediterranean climate, climatology, climatologist, weather, atmosphere, global climate change and pollution. Then, she constructed a concept map by using these words. Esra’s concept map regarding the climate was shown in Figure 4.29.

R: Can you construct a concept map by using the concepts you mentioned above? Please explain your map briefly.

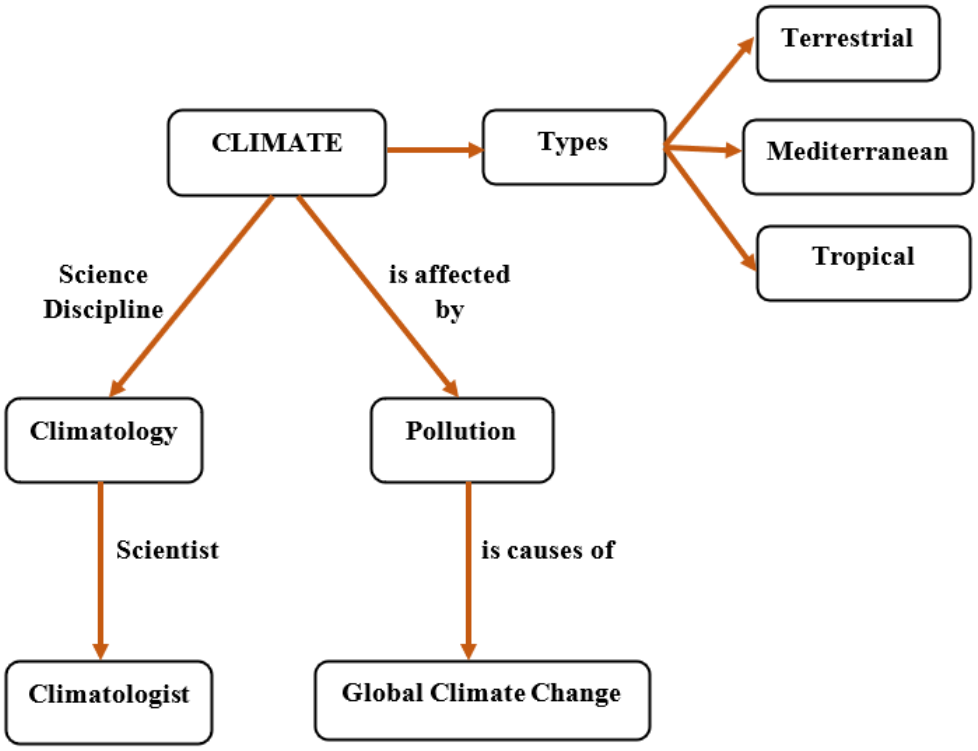


Figure 4.29 Esra's Concept Map Regarding Climate

As seen from Figure 4.29, she created ***a spoke structure*** (Kinchin, Hay, & Adams, 2000) by putting climate at the center. Other concepts were radiated from the central concept, which is climate. In other words, her map has a radial structure and all concepts related to the climate were directly connected only with the climate. There was no connection among other concepts. But she extended the concept of the climate with the example of the types of climates such as terrestrial, Mediterranean. She associated the concepts of climatology and climatologists with the climate.

Although she associated the climate with the weather in the interview, she, however, did not place the word “weather” on her concept map. Her concept map, also, revealed her misconception as to the relationship between pollution and the global climate change.

Since Esra associated climate with weather, she was asked to combine both concepts in a single concept map. However, instead of drawing a concept map, she preferred to explain the association between climate and weather verbally saying that *“We can associate the concept of climate with weather by saying that climates occur with air movements caused by temperature differences as a result of the effects of sunlight coming with different angles.”*

In the following question, Esra was asked her thoughts regarding whether the weather/weather events and climate are same concepts or different concepts.

> Researcher: In the previous question, you associated the weather with climate. Do you think that climate and weather events are the same concepts or different concepts? Why/Why not?
>
> Esra: The climate and weather events are not the same things… Hmmm… For example, let's give an example from the Mediterranean climate. In the Mediterranean climate, the summers are warm and relatively rainy, and the winters are mild. This does not change. But the weather is day-to-day condition. They [weather events] change continuously and they are predictable. Climates, on the other hand, are a set of events that depend on the result of research conducted over the years.

Likewise, while teaching of the unit, she mentioned the differences between the weather events and climate saying that;

> Esra: While the climate is determined by observations made in long-term, weather events are determined by observations made in over a short period of time. While the climate is long-term, weather events are short-term. Climate shows less variation. In the weather events, meteorologists make predictions based on available data. Meteorology makes research about

weather events. Meteorology examines daily changes [in the weather events]. Scientists dealing with weather events are called meteorologists. The science discipline trying to explain and explore the impact of climate is called climatology, climate science. Climatology examines long-term changes. Scientists dealing with the climate are called climatologists, climate scientist.

[Classroom Observation]

Furthermore, during her teaching, she drew a table on the blackboard comparing and contrasting weather events and climate (See Table 4.57). (The Esra's original table regarding the differences between weather events and climate was located in Appendix T, in Turkish.)

Table 4.57 *Esra's Table about the Difference Between Climate and Weather Events*

Climate	**Weather Events**
It is determined by observations made in long-term.	It is determined by observations made in short-term.
It is long-term.	It is short-term.
It occurs in a wide area.	It occurs in a particular place.
There is no prediction. It shows less variation.	The prediction is made based on the available data.
It is expressed by expressions such as dry, rainy, hot, and cold.	It is expressed by expressions such as sunny, windy, cloudy.
Climatology and climatologist concepts are related to climate.	Meteorology and meteorologist concepts are related to weather events.

Throughout the interview, Esra was asked the several questions regarding seasons, weather/weather events and climate concepts. However, the unit is consisted of all these concepts together, it is important to clarify participants' understanding of possible relationship among the seasons, climate, and weather events. Therefore, as a last question, she was asked to make connection among the seasons, climate, and weather events. She stated that seasons, climate, and weather events are related to each other, but indicated the climate as the most general concept compared to other concepts. The sample related excerpts from the interview were as follows:

> Esra: Of course, they are related. All of these [seasons, climate and weather events] occur as a result of uneven heating of the regions on Earth. They are the concepts related to heat and temperature. The most general concept is the climate...

Her teaching partly supported her interview findings, but there are some differences as well. Although she did not define the climate correctly in the interview, she correctly defined it in her teaching of the unit. Both in the interview and classroom observation, she correctly addressed the differences between weather and climate concepts. Also, she showed their differences through drawing a table. She tended to consider a relationship among the concepts of seasons, climate and weather, adding that the concept of climate is the most general concept. Esra's knowledge regarding climate based on interview and classroom observation data were presented in Table 4.58.

Table 4.58 *Esra's Knowledge of Climate*

The Concepts	**Esra's Responses**
Climate	Climate is the average of weather events such as wind, humidity, temperature and air pressure that are observed in a particular area of the Earth over long time periods.
The Differences Between Weather and Climate	**Weather;** Weather events are short-term. The weather is day-to-day condition. Weather events change continuously and they are predictable. It is determined by observations made in short-term. It occurs in a particular place. Meteorology examines daily changes in the weather events. Scientists dealing with weather events are called meteorologists. **Climate;** The climate is long-term. It occurs in a wide area. Climates are a set of events that depend on the result of research conducted over the years. The science discipline trying to explain and explore the impact of climate is called climatology, climate science. Scientists dealing with the climate are called climatologists, climate scientist.

Specifically, in this part, findings related to whether Esra perceived climate as a complex system or not were reported.

> Researcher: Up to now, we talk about climate. Do you think that climate is a system? Why/why not?
>
> Esra: Of course, it [climate] is systematic…
>
> Researcher: Well, what kinds of processes occur in climate system? Assume that, one of the components of the climate system has changed. What happened? How these change influence climate system? Can you give an example?
>
> Esra: There are components of the climate system. The things that form the

> climate system are certain... Heat and temperature… The sun... Then, the temperature differences on the Earth, the influence of the ocean, the effect of the sea… Because the ocean influences the air temperature [by absorbing sunlight]. While the land heats up and cools down rapidly, the ocean or sea heats up and cools down slowly. So, the sun and angle of incoming sunlight have greatest impacts on the climate. In the process of the climate system, the energy that the sun gives to each region is different and therefore, different climate characteristics occur in each region. Actually, the system is affected quickly by a change in one of the components in the climate system. But it is not possible for us to understand this effect immediately. There may be a rapid warming... As a result of heating, melting can occur in glaciers. As a result of this melting, the intensity of flood may increase gradually…

Esra’s knowledge of the climate system was shown in Table 4.59. Hence, she appears to be knowledgeable about the complex nature of climate. She perceived climate as a system, which included many components such as heat, temperature, sun, the ocean, the sea.

Regarding the processes in the climate system, she expressed the temperature differences on Earth, the impact of the heating and cooling rates of the land, ocean and sea on the climate, and the impact of the energy emitted from the Sun on the climate. She stated that the biggest effect on the climate system is from the Sun, giving an example the effect of the ocean on air temperature. Then, she addressed that the warming lead to melting of glaciers, which in turn the increases the severity of the flood. Based on the findings, she seems to be aware that a change in any component of the climate system affects this system.

Table 4.59 *Esra's Knowledge of Climate System*

Component	Description
Temperature	Temperature differences
Heat	Rapid warming on land. Influence ocean or sea temperature. Result in melting of glaciers, flood.
Ocean/Sea	Changes in temperature of ocean. Influences the air temperature [by absorbing sunlight].
Sun	Incoming sunlight Energy emitted from the Sun

Overall, data obtained from Esra can be summarized as a whole depending on categorization by Shepardson et al. (2014), and also, the interactions she established among the components of climate system were presented based on Shepardson et al. (2014) (See Table 4.60).

Table 4.60 *The Categorization of Esra's Knowledge of Climate System depending on Shepardson et al. (2014)*

Component	Description
Atmosphere	Air temperature Variation in air temperature Temperature Variation in temperature Heat
Glacial	Glaciers Melting of glaciers
Sun	Incoming sunlight Energy emitted from the Sun
Land	Flooding
Ocean	Changes in temperature of ocean
The Interactions among the components of climate system based on Shepardson et al. (2014)	
Ocean (ocean) → Sun (absorbing sunlight) → Atmosphere (influencing air temperature) Atmosphere (temperature) → Glacial (melting of glaciers) → Land (flood)	

In the following section, Esra's substantive knowledge regarding climate change, global warming and greenhouse effect was presented.

4.3.2.1.3.1 Esra's Substantive Knowledge Regarding Climate Change, Global Warming and Greenhouse Effect

When asked to explain the climate change and whether climates have changed, she stated that;

> Esra: Climate change... We scientifically say that the climate cannot change and the climate is certain such as a Mediterranean climate, a continental climate, a tropical climate... We normally predict that they [climates] will not

change. However, due to greenhouse gases, pollution and the excessive use of fossil fuels, gradual changes occur in the climate. These changes [in climate] are long term and very slow … A very slow change related to greenhouse effect. Changes in climate is not observable...

Researcher: Have you heard about the concept of global warming?

Esra: Yes, I heard the concept of global warming. I associate the global climate change with global warming.

Researcher: Well, do you think they are the same concepts?

Esra: Climate change is a more general concept as compared to global warming. Climate change may involve concepts such as heating and cooling. But global warming is a gradual increase in average temperature in the Earth during the year. Increasing number of living things and increasing the number of people is the factors that cause the increasing of temperature... increasing of the pollution. Decreasing the amount of oxygen gradually... I am talking about the increasing of the air pollution. In this case, I think that it [air pollution] causes the greenhouse effect and this [greenhouse effect] triggers global warming.

After mentioning about the greenhouse effect and greenhouse gases, Esra was asked more questions on those issues.

Researcher: Well, what is greenhouse effect?

Esra: Greenhouse effect… There are toxic gases releasing as a result of human activities…. humans abusing the nature. One of the toxic gases was nitrogen dioxide? Now, I couldn't really remember the names of the gases... Normally, the sun's rays come down to Earth and then, they [sun's rays] are reflected back [from the Earth]. These gases accumulate in one part of the atmosphere and prevent the reflecting of some sun’s rays [from the Earth]. Normally, these are gases [toxic gases], that I cannot remember their name, cause the sun's rays to stay in the Earth excessively. This [staying sun’s rays in Earth] causes overheating of the region or the Earth. This excessive heating can cause climate changes. We call it the greenhouse effect.

Researcher: In previous question, you said that the amount of greenhouse gases increases. Well, what are the factors that increase greenhouse gases?

Esra: Forest fires… Excessive use of fossil fuels, being relying less on the use of renewable energy sources such as solar energy, wind energy, geothermal energy. For example, the hydroelectrical energy related to the movement of water…. These can be called renewable energy sources. Day by day, use of non-renewable energy sources increases... Non-renewable energy sources are energy sources with high probability of depletion. Fossil fuels, nuclear energy… Petroleum, natural gas. These [petrol, natural gas] can be called fossil fuels. Also, the gases releasing from cars and factories that we use [increase] such as carbon dioxide, carbon monoxide, nitrogen dioxide, Sulphur dioxide… Along with these factors, the accumulation of these gases [toxic gases] are increasing gradually... These toxic gases are released mostly by a result of the industrialization. Apart from that, the destruction of forests, the increase in the rate of environmental pollution- the continuous increase in the air pollution caused by deforestation. What do forests and vegetation do?... They [forests and vegetation] make photosynthesis continuously to remove carbon dioxide and produce oxygen. However, what happens when we reduce forests and vegetation? The amount of carbon dioxide increases.

She believed the existence of climate change followed by stated the global warming, greenhouse gases, pollution, and excessive use of fossil fuel as factors causing the climate change. She stated the increasing of pollution (e.g., air pollution) and the number of the living things, and greenhouse effect as factors causing the global warming. She defined the greenhouse effect as the excessive warming of the Earth by keeping the sun's rays on the Earth due to the accumulation of toxic gases in the atmosphere (i.e., implying the greenhouse gases) released with human activities. She exemplified human activities that cause the increase in greenhouse gases such as the industrialization, destruction of forests, increasing of pollution (e.g., air pollution), gases releasing from cars and factories (e.g., carbon dioxide), the less use of renewable energy sources and the excessive use of non-renewable energy sources. However, she seems to have a lack of knowledge and misconceptions regarding the climate change, global warming, and greenhouse effect. For example, apart from correctly expressing carbon dioxide as a greenhouse gas, she had an incorrect idea that nitrogen dioxide, carbon monoxide and Sulphur dioxide are greenhouse gases. While explaining the greenhouse effect process, she used the concepts of sun's rays instead of sun's incoming short-wave radiation and earth's outgoing long-wave heat radiation. She incorrectly associated the greenhouse gases increase which cause the greenhouse effect, global warming and thus climate change with pollution, air pollutants or toxic gases. Her response also revealed a misconception with respect to the cause-effect relationship between the pollution and global warming, greenhouse effect and climate change.

Then, Esra was asked whether the presence of greenhouse gases is a natural phenomenon and what would happen if there were no greenhouse gases:

> Esra: In fact, it is natural [to exist greenhouse gases in nature], but we change their [greenhouse gases'] proportions. For example, nitrogen is an element, hydrogen is an element. It is normal for hydrogen, nitrogen, oxygen, and helium to exist in nature in certain proportions. However, when we increase their proportions, life is affected [adversely]…
>
> R: So, what would happen without greenhouse gases?
>
> Esra: What is the effect of greenhouse gases?... Climate changes… without greenhouse gases, there would be no changes in climate… the amount of oxygen would not decrease gradually. The amount of oxygen would not be affected. The amount of oxygen would remain constant in most places.

She harbored some doubt whether the existence of greenhouse gases in nature is natural. On one hand, she correctly indicated that it is natural for greenhouse gases to present in nature to some extent and the problem emerges when their amounts increase. On the other hand, she considered that if the greenhouse gases were not existed in nature, the climate change would not occur. As a result, she appeared to have difficulty in understanding the task of greenhouse gases is to provide the Earth become warm, and the average global temperature would be -17 ℃ in the absence of greenhouse gases (Dove, 1996). Moreover, her responses pointed out a misconception that she seemed to perceive the greenhouse effect as harmful environmental phenomena for the Earth, not a naturally occurring phenomena.

In the following question, Esra was asked her opinions regarding the consequences of climate change and its' impact on our daily life.

> Esra: There are many theories about global climate change... First, a rapid warming process … Of course, this will last for generations... and then, rapid cooling process will take place… I'm talking about great disasters and a high number of deaths... I think there may be floods and tsunamis caused by overheating or there may even be more severe earthquakes triggered by them [overheating]. The temperature of the air is constantly increasing due to climate changes. For example, in the Mediterranean climate, the average temperature increases from 24 degrees to 25 degrees… or in glaciers, [the average temperature] increases from minus 5 degrees to minus 4 degrees, which will gradually cause melting of glaciers in some regions. Melting of glaciers will lead to increase the amount of body of water on the Earth. These body of water will also start to move towards the land areas with rapid movement.
>
> Researcher: Does climate change have an impact on our daily lives?
>
> Esra: We can't talk about the short term [a few days] impact of climate change. It is very difficult to feel the effects [of climate change] in our daily lives because we're talking about a 1-degree change [in climate] … For example, we are talking about the average temperature changes because this [climate change] is an issue that has been going on for generations and for

long periods of time. Even a person's life may not be enough to feel such a small change in climate... Climate depends on lengthy research and change in climate occur in long-term processes.

R: What are the effects of global warming on environment and living things?

Esra: Global warming does not affect the environment and living things directly. We can't feel them [the effects of global warming]. We begin to feel effects of global warming, when glaciers start to melt, [for instance]. Individually, it is not possible to feel [the effects of global warming].

Briefly, she had confusion regarding the consequences of climate change although mentioned about its' several consequences. For example, on the one hand, she expressed the rapid cooling, rapid warming, occurrence of extreme weather events (e.g., flood), the increasing of average temperature, high number of deaths, and the melting of glaciers as consequences of climate change. Also, while addressing consequence of the climate change, she had an incorrect idea that "*there may even be more severe earthquakes triggered by overheating*". On the other hand, she added that it is difficult for people to feel the effects of climate change in their daily life because changes in climate are too small. Also, she did not mention about its' impact on humans' health, ecosystems, and the chemistry of ocean water. Regarding the consequences of global warming, she had also confusion since she considered that global warming does not directly affect the environment and living things. Contrary to her response, in fact, global warming has many impacts on the environment and living things.

As a last question, Esra was asked about a possible relationship between greenhouse gases and the matter cycles.

R: Do you think that whether the changes (e.g., decreases or increases) in amount of greenhouse gases affect the matter cycles?

Esra: Of course, it affects [matter cycles in nature]. It affects the oxygen cycle. This means decreasing of oxygen... What does it mean that level of a

> substance is increasing in nature? If the amount of one substance remains the same, it means that another substance will decrease. For example, rises of other toxic gases… For example, when the amount of the toxic gases increases, the clean ones decrease. This situation, of course, will affect the oxygen cycle. …. as well as the nitrogen cycle… Hmmm… result in lack of nitrogen, which in turn affect the nitrogen cycle how can I explain this phenomenon .... I do not know…

She seemed to be aware that the changes in the amount of greenhouse gases affect the matter cycles in nature by giving examples of nitrogen cycle and oxygen cycle. She had the idea that with the increase in the amount of greenhouse gases, which she defined as toxic or polluted gases, there could be a decrease in the amount of oxygen and nitrogen. However, she did not explain specifically how the oxygen cycle and nitrogen cycle are affected by the changes in the amount of greenhouse gases and what happens in these cycles detailly in her responses.

Up to this section, the interview findings were presented. Next section the findings were reported obtained from classroom observation.

4.3.2.1.3.1.1 Esra's Substantive Knowledge Regarding Climate Change, Global Warming and Greenhouse Effect: Classroom Observation Findings

Her responses to interview questions partly supported by classroom observation. For example, while teaching of the weather and climate topic, she addressed the climate change and global warming saying that;

> Esra: Does the climate never change?... It [climate] changes very slowly. Human life span may not be enough to observe these [changes in climate]. We define climate change as change seen in long time intervals. The factors such as greenhouse effect and ozone depletion bring about global warming, that is, climate change. What is the effect of global warming? We start to feel

> the changes in the climate gradually. Now, Earth's temperature is increasing slowly. The temperature in a certain place does not increase, but the average temperature is increasing. Weather events such as snow and freezing do not occur anymore [less occur compared to past].
>
> [Classroom Observation]

In her teaching, similar to her interview, she expressed the greenhouse effect, and global warming as the causes of climate change, and the greenhouse effect as the cause of the global warming. Unlike from the interview, she incorrectly attributed the causes of global warming and climate change to the ozone depletion. Although she did not mention about the impacts of global warming in the interview, she stated the changes in climate, rise in average temperature, and changes in weather (e.g., less occurring of snowing compared to past) as consequences of the global warming.

Besides the interview, she touched on the greenhouse gases during her teaching of the unit. Unlike from the interview, CFC, methane and nitrous oxide were correctly mentioned as greenhouse gases in her teaching. For instance, she asked that *"What are the greenhouse gases?"*. Student 1 responded that *"Carbon dioxide, methane"* and student 2 responded that *"the gases like nitrous oxide, CFC, Sulphur."*. Then, she explained the greenhouse gases saying that *"We're talking about gases containing carbon. These are gases in which carbon is more concentrated."*.

As well as in the interview, during her teaching of the unit, she defined the greenhouse effect as the warming of the atmosphere as a result of the majority of the sun's rays remaining in the atmosphere. However, unlike the interview, while explaining the greenhouse effect, she benefitted from *"greenhouse analogy".* The related excerpts from the classroom observation were as follows:

> Esra: The sun's rays reach the inside of the greenhouse. Inside of the greenhouse gets hotter. By this way, inside of the greenhouse remains always warm because its' [greenhouse's] surrounding is closed. The same phenomena happen with the greenhouse effect in the atmosphere. The sun's

rays are reflected from the atmosphere but most of the sun's rays remain in the atmosphere, which causes the atmosphere to warm.

[Classroom Observation]

As a result, above findings indicated that although she considered cause-effect relationship among climate change, global warming and greenhouse effect, she had difficulty in explaining these concepts. For example, she incorrectly associated the greenhouse gases with pollution. Since she associated with greenhouse gases, she had a misconception about associating climate change, global warming and greenhouse effect with pollution. Also, she had another misconception as to connection between the cause of global warming and climate change, and ozone depletion in her teaching. She appeared to be not aware of the function of greenhouse gases. On the other hand, in the interview, she mentioned about consequences of the climate change such as flood, melting of glaciers. Despite she stated that global warming does not directly affect the living things and environment in the interview, she addressed the consequences of global warming in her teaching such as changes in weather, changes in climate. Esra's knowledge of the climate change, global warming and greenhouse effect based on interview and classroom observation data were presented in Table 4.61.

Table 4.61 *Esra's Knowledge of Climate Change, Global Warming and Greenhouse Effect*

The Concepts	**Esra's Responses**
The Causes of Climate Change	Greenhouse effect Greenhouse gases Global warming Ozone depletion Pollution The excessive use of fossil fuels

Table 4.61 *(cont'd)*

The Consequences of Climate Change	The process of rapid warming and rapid cooling Constantly increasing of the air temperature Melting of glaciers Increasing in the amount of body of water Floods Tsunami More severe earthquakes High number of deaths
The Causes of Global Warming	Greenhouse effect Ozone depletion Increasing of the number of living things Increasing of the pollution (i.e., air pollution)
The Consequences of Global Warming	Global warming does not affect the environment and living things directly. Earth's average temperature is increasing slowly. Weather events such as snow and freezing do not occur anymore.
Greenhouse Effect	There are toxic gases releasing as a result of human activities. These gases accumulate in one part of the atmosphere and prevent the reflecting of some sun's rays from the Earth. Toxic gases cause the sun's rays to stay in the Earth excessively. Staying sun's rays in Earth causes overheating of the region or the Earth.
Greenhouse Gases	Carbon dioxide (CO_2) Carbon monoxide (CO) Nitrogen dioxide (NO_2) Sulphur dioxide (SO_2) Methane (CH_4) Chlorofluorocarbon (CFC) Nitrous oxide (N_2O)
The Function of Greenhouse Gases	There are toxic gases (i.e., implying greenhouse gases) releasing as a result of human activities. Toxic gases cause the sun's rays to stay in the Earth excessively. Staying sun's rays in Earth causes overheating of the region or the Earth. Without greenhouse gases, there would be no changes in climate. The amount of oxygen would not decrease gradually.

4.3.2.1.4 General Summary for Esra's Substantive Knowledge Regarding the Seasons, Weather, and Climate

Under this heading, general summary for Esra's substantive knowledge regarding the seasons, weather, and climate was presented.

Regarding the concepts included in seasons, Esra correctly expressed both two causes of seasons as Earth's tilted axis and Earth's revolution around the Sun both in the interview and classroom observation. She also explained the concept of weather correctly and expressed lots of the weather events both in the interview and classroom observation such as rain, snow, wind, hail, rime. She addressed most of the factors that lead to the change in weather events (e.g., wind, pressure, humidity, temperature). Besides, she was aware of the meteorology and meteorologist concepts. She tried to associate the weather with the climate. Despite she was not able to define the climate in the interview, she defined the climate correctly during her teaching of the unit. She was able to express the differences between the weather and climate. She was aware of the concepts of climatology and climatologist. She perceived the climate as a system by addressing some of the components of the climate system and interactions among the components. Regarding the causes of the climate change, she only mentioned about anthropogenic causes, neglected the natural causes of the climate change (e.g., solar variability). Associating the climate change with pollution in the interview and associating it with the ozone depletion in her teaching indicated that she had misconceptions (Table 4.62). She mentioned several consequences of the climate change such as flood, melting of glaciers. As in the climate change, associating the global warming with air pollution in the interview, and associating it with ozone depletion in her teaching indicated that she possessed misconceptions (Table 4.62). Although she considered that global warming does not directly affect the environment and living things in the interview, she expressed the changes in weather, changes in climate and rise in temperature as consequences of global warming in her teaching. As far as greenhouse effect was considered, data showed that she harbored some doubt about the greenhouse effect is natural phenomena because on the one hand, she stated that the existence of the greenhouse gases are natural. But on the other hand, she stated that climate change would not occur if greenhouse gases were not existed. Besides, she wrongly associated the greenhouse gases causing the greenhouse effect with pollution. So, she had a misconception as to the relation between greenhouse effect and pollution (See Table 4.62). On the other hand, she was able to express several factors causing the rise in the amount of the greenhouse gases such as excessive use of fossil fuel, destruction of forest, less use of renewable energy sources.

Table 4.62 *Esra's Misconceptions*

Esra's Misconceptions	**Supporting References**
Relating ozone depletion with global warming.	(Khalid, 2001)
Relating ozone depletion with climate change.	(Papadimitriou, 2004)
Relating global warming with pollution.	(Papadimitriou, 2004)
Relating pollution with cause of global climate change.	(Papadimitriou, 2004)
Relating the greenhouse effect with pollution.	(Papadimitriou, 2004)
Her perception of the greenhouse effect as harmful environmental phenomena for the Earth.	(Arslan, Cigdemoglu, & Moseley, 2012)

Overall, it was concluded that she seemed to be more knowledgeable about the basic concepts of seasons, weather and climate compared to climate change, global warming, and greenhouse effect (See Table 4.63).

Table 4.63 *Summary of Esra's Substantive Knowledge*

Concepts	Esra’s Substantive Knowledge
Seasons	Knowledgeable
Weather	Knowledgeable
Climate	Knowledgeable
Climate System	Knowledgeable
Climate Change	Lack of knowledge
Global Warming	Lack of knowledge
Greenhouse Effect	Lack of knowledge

4.3.2.2 Esra’s Syntactic Knowledge

In this section, Esra’s syntactic knowledge regarding the aspects of nature of science both separately and in the context of weather and climate was reported by using VNOS-C questionnaire (Lederman et al., 2002).

Firstly, Esra was asked her opinions regarding the science and what distinguishes science from other disciplines.

> Esra: Hmmm… Science… Any research that contributes to human development can be called science.
> Researcher: What makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines (e.g., philosophy)?
> Esra: Certainty… when compared to other disciplines, [level of] certainty is higher in science… certainty is higher at each step, such as conducting research, conducting experiments, collecting data, and reaching the results.
> Researcher: So, do scientists certain about global warming?
> Esra: I think they [scientists] are certain because the [scientific] measurements show that [global warming really occurs]. I never heard

anyone who says "I assume [that global warming occurs.].". Average temperature measurements show it [global warming occurs] ...

Researcher: In the question regarding certainty, you mentioned about some steps, such as conducting research, conducting experiments, collecting data, and reaching the results. Do you think that is there a sequence of steps (that scientists follow) in their research?

Esra: Not all scientists may work in the same way, of course... How does a scientist work? He/she [Scientist] works by doing experiments, by trial and error, and finally reaches a conclusion...

Researcher: Ok. Does the development of scientific knowledge require experiments? Why/ Why not?

Esra: Of course, yes… Experiment is necessary in order for scientific knowledge to develop. For example, you are working on a scientific knowledge which has been already produced. You come with new results when you do different experiments with different perspective. Scientific knowledge is produced in this way…

This question gave some clues about Esra's understanding of science, empirical, subjective and tentative NOS. She, overall, although defined the science as research that contributes to 'human development', she touched upon the features that distinguish science from other disciplines by emphasizing the existence of experiment, observation (i.e., temperature measurement) and data in science (i.e., empirical NOS). However, she also considered 'certainty' as one of the characteristics that distinguish science from other disciplines. She addressed the subjectivity and tentativeness by stating that every scientist may not work in the same way, and scientists can reach new findings (i.e., tentative NOS) by conducting different experiments (i.e., empirical-based) with having different perspectives (i.e., subjective NOS). Her responses also indicated her tendency to accept the existence of single scientific method by arguing that *Scientist works by doing experiments, by trial and error, and finally reaches a conclusion...*

Next question examines her knowledge on theory and law.

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

Esra: Sure…

Researcher: What are these differences [between scientific theory and scientific laws]?

Esra: For example, if it [scientific knowledge] becomes certain and there is no need to conduct further study about it [that scientific knowledge]; it is considered as a law. Scientific knowledge should be called theory, if the study on the subject goes on. So, that knowledge should be evaluated and repeated by future scientists.

Researcher: What about greenhouse effect? Is greenhouse effect a scientific law or a scientific theory?

Esra: Now, if we say that it [greenhouse effect] is a law, it could be a little assertive. It is more reasonable to say that it [greenhouse effect] is a theory.

Researcher: Why do you think it is a theory?

Esra: Hmmm… Because the studies on greenhouse gases still continues [not has been completed yet]. That's valid for all subdiscipline of science, isn't it?... assume that a scientist works on research in his/her field; similar research can also be conducted by other scientists. By this way new findings can be produced continuously…. that's why the greenhouse effect is not a very old concept... For me, it is more reasonable to called it [greenhouse effect] as a theory.

Responses of Esra gave some information about her understanding regarding the tentative NOS and the functions of and relationships between theory and law. She stated that when become certain, scientific knowledge becomes the law. Her response indicated a common misconception that there is a hierarchical relationship between law and theory, and that the theory as incomplete scientific knowledge. Following excerpts give further idea about her understanding of theory and law.

Researcher: In the questions above we talked about theory and law. Do scientific theories (e.g., a theory about climate change) change over time? Why/ Why not?

Esra: It [scientific theory] changes… Because technology and science progress side by side. Advances in technology increases production of a number of studies in science. A technological tool may facilitate the discovery of an unknown gases for example or anything else that has never known discussed before. By this way, related studies can take a different direction.

Researcher: What about the scientific laws?

Esra: Hmmm… In general, we say that the laws don't change. Still, many different scientific studies can be done on that subject again. Hmmm … The laws cannot change. For example, Newton's law of gravity... We consider this [Newton's law of gravity] to be unchanging... Laws cannot change, but theories can change more easily.

Besides her understanding of theory and law, this question gave some clues regarding Esra's understanding related to the tentative NOS as well. She considered that theories can change only with technological development. Also, in the embedded NOS question, despite she was aware of the greenhouse effect as a theory, her explanation did not represent the function of theory completely. Overall, her responses related to theory and law indicated that she was unaware that laws and theories are different kinds of knowledge.

Researcher: Scientists disagree about the causes of global warming. Some researchers say that the continues use of fossil fuels by humans causes our planet to warm up, while other scientists say that natural forces that have been determining weather conditions for millions of years have caused it [global warming]. From this example, how can scientists reach the different results using the same data? Can you explain?

Esra: … perspectives of scientists may be different… But I don't think that a scientist can tell the other scientists, "No. What you're saying [about global

> warming] is absolutely impossible.". Because each scientist continues research in a different way. I think that scientists should respect each other's ideas.

She attributed the reasons for reaching the different results using the same data to the subjective nature of science, by saying *perspectives of scientists may be different*. In this question, she should have addressed the impacts of inferences, tentativeness, creativity, social and cultural factors besides subjectivity.

> Researcher: Scientists conduct scientific experiments let’s say on renewable energy sources or climate change. Do scientists use their own imagination and creativity in their research?
>
> Esra: Creativity is important of course. Well, what is the contribution of imagination or creativity? It [creativity] gives direction to science. Therefore, scientists use their creativity as well as imagination.
>
> Researcher: Well, at what stages of their research do scientists use their imagination and creativity?
>
> Esra: I think [scientists use their creativity and imagination] in the beginning [of the research]..to decide research topics, or to determine data collection… Imagination is also important at this stage… After starting the experiment, scientists set aside their creativity and imagination and focus on the scientific data… [creativity and imagination replaced by the scientific data].
>
> Researcher: Why do scientists need to use their creativity and imagination in their research?
>
> Esra: Before starting anything, you have to imagine first… That is, if I'm going to investigate something that I don't know anything about it, I say “What do I need to do?”. At first, we need to be knowledgeable about that topic. Then, we can become curious about different things about the topic. This curiosity in turns lead our research to different directions.

She considered creativity as a crucial component of scientists’ research. According to her, scientists use their creativity and imagination at the beginning of their research and data collection, and then they do not need their creativity and imagination, instead they should focus on scientific data. Although she was aware of the importance of creativity and imagination in science, she was unaware that scientists use their creativity and imagination in all phases of the scientific investigation.

> Researcher: Some argue that science is influenced by the values of the society in which it is created such as religion, social, cultural values, philosophical assumptions and intellectual norms. For some, science is universal and independent from concepts such as social, cultural values, philosophical assumptions, and intellectual norms. What do you think about that? Do you think science is independent or influenced by the values of society? Why?
>
> Esra: For me, it [science] is independent. Scientists may not be able to stay independent. But in general, I do not think that science is affected greatly by the social dimension, the philosophy dimension and the religious dimension because it [science] is based on experiments and investigation. Moreover, it [scientific knowledge] has higher probability to be proven and it [scientific knowledge] can still remain open to other ideas after proved.

Although perceived science and scientist as independent, she harbors some doubt to decide whether *science is influenced by the values of the society*. For example, she believed that scientists may be affected by values of society, but at the same time, she said that science is universal and independent from values of the society (e.g., the social, the religious dimension). According to her, science depends on experiment and investigation (i.e., empirical NOS), as well as open to other ideas (i.e., tentative NOS). So, it is not affected by philosophy and religion.

In addition, Esra was asked a couple of questions to reveal her ideas related to scientist and scientists' work in the context of weather and climate.

> Researcher: What is the name of science discipline that do research on weather event? What is the name given to scientists investigating weather events?
>
> Esra: Meteorology and meteorologist.
>
> Researcher: Ok. How do meteorologists predict weather events?

Esra: I know that they [meteorologists] evaluate [weather events] by measuring the pressure difference since it [weather event] arises from pressure and pressure difference.

Researcher: What do you think about how meteorologists collect data?

Esra: Meteorologists evaluate air currents based on the air pressure measurements.

Researcher: How do meteorologists analyze data? How do meteorologists reach a conclusion? What kind of devices do meteorologists use?

Esra: I don't have much information about the devices they [meteorologists] use.

Researcher: Do you think the weather forecast made by meteorologist is accurate?

Esra: Weather events vary. It [weather event] even shows variability throughout the day and they [meteorologists] make inferences depending on the prediction. There is no certainty [in weather forecast]. Nevertheless, there occurs an unpredictable situation... [Therefore], they [meteorologists] can sometimes be mistaken in predictions [related to weather].

In the same way, Esra's teaching provided important clues about her understanding of how meteorologists determine weather events saying that:

Esra: Weather events are determined by observations made in a short period of time..… Meteorologists make prediction related to weather events based on existing data. There is no such thing that "It will definitely rain.". They [meteorologists] measure the amount of humidity in the air, the wind or the temperature differences. Sometimes, their [meteorologists'] predictions may be correct, sometimes not.

[Classroom Observation]

Both interview and classroom observation data enlightened Esra's understanding regarding certainty of science, empirical and inferential NOS. She thought that meteorologists collect data related to air pressure, wind, humidity and temperature differences, and then, predict the weather events based on their measurements. Although did not address in the interview, Esra highlighted role of observation in determining weather events in the classroom observation. She considered that meteorologists can be mistaken regarding weather forecast due to unpredictable situation, thus, the weather forecast made by meteorologists may not always occur. She also addressed the inferential NOS by stating that meteorologists make inferences based on their prediction related to weather events. This was the first time she talked about inference, though very briefly.

Following questions also revealed Esra's awareness of the climatology and climatologist. She adequately explained *climatology as a science discipline that tries to explain and explores the impact of climate,* and *climatologists as scientists who study on climate* both in the interview and her teaching.

> Researcher: What is the name of science discipline that do research on climate? What is the name given to scientists investigating climate?
>
> Esra: Climatology and climatologist.
>
> Researcher: Well, how do climatologists collect relevant data?
>
> Esra: I don't know much information about it… Climates are a set of events that depend on the result of research conducted over the years. But I assure that they [climatologists] should investigate the weather events on Earth. Apart from, they [climatologists] examine weather movements. They [climatologists] also investigate the causes of floods. In other words, they [climatologists] do different kinds of investigation about the weather at every point in the world. Like meteorologists, I think they [climatologists] use daily weather changes. They [climatologists] make inferences regarding temperature and are constantly measuring the average temperatures.…. are examining whether the average temperature changes or not.

Responses of Esra reflected her understanding of empirical as well as inferential nature of science. According to her, climatologists conduct various research on weather movements and weather events all over the world in the long-term, make use of data on daily weather changes, and make measurements regarding average temperature. She again briefly touched on the inferential nature of science stating that *Climatologists make inferences regarding temperature*.

In the following section, summary of Esra’s syntactic knowledge was reported.

4.3.2.2.1 Summary of Esra’s Syntactic Knowledge

Overall, Esra’s responses related to syntactic knowledge were evaluated based on the interview and classroom observation data together (See Table 4.64). According to the findings, it was found that she had deficiencies about some NOS aspects. For example, despite she believed that scientific knowledge including scientific theory could change with progression in technology and different perspectives, she had difficulty in transforming this view for the law because she had the idea that the law cannot change. Her perception of the law as certain knowledge as compared to the theory revealed a common misconception regarding hierarchical relationship between theory and law. Her failure to explain the greenhouse effect being a theory in accordance with the nature of the theory also reflected her incomplete understanding. She was not certain whether science is independent or influenced from the values of society. She had difficulty in explaining creative and imaginative NOS because she stated that scientists use their imagination and creativity only in the first phase of the investigation, not all phases. Her awareness that scientists have different perspectives, but not elaborating underlying reasons of her opinion, made her subjective NOS view deficient. Her understanding about empirical NOS showed inconsistency because, although she was aware of the experiment, observation and also prediction made based on available data, she had a common misconception that scientists follow general scientific method containing stepwise procedure. She was able to explain inferential NOS in the embedded NOS questions. In her teaching on the weather and climate, she briefly mentioned about the empirical NOS by emphasizing making observation and making predictions on the data, and also addressed that there is no certainty in science.

Table 4.64 *Esra's Responses Related to Syntactic Knowledge*

NOS Aspect	**Example from Esra's Responses**
Tentative NOS	➢ You are working on a scientific knowledge which has been already produced. You come with new results when you do different experiments with different perspective. ➢ Scientific knowledge can still remain open to other ideas after proved. ➢ Scientific theory changes… Because technology and science progress side by side. Advances in technology increases production of a number of studies in science. ➢ The laws cannot change. For example, Newton's law of gravity... We consider Newton's law of gravity to be unchanging...
Empirical NOS	➢ Any research that contributes to human development can be called science. ➢ Scientist works by doing experiments, by trial and error, and finally reaches a conclusion... ➢ Experiment is necessary in order for scientific knowledge to develop. ➢ Meteorologists evaluate air currents based on the air pressure measurements. ➢ Weather events are determined by observations made in a short period of time.…. Meteorologists make prediction related to weather events based on existing data. ➢ Climatologists use daily weather changes. Climatologists are constantly measuring the average temperatures…..are examining whether the average temperature changes or not.
Subjective NOS	➢ Perspectives of scientists may be different… ➢ Not all scientists may work in the same way. ➢ You come with new results when you do different experiments with different perspective.
Inferential NOS	➢ Meteorologists make inferences depending on the prediction. ➢ Climatologists make inferences regarding temperature.
Theory and Law	➢ If scientific knowledge becomes certain and there is no need to conduct further study about that scientific knowledge; it is considered as a law. ➢ Scientific knowledge should be called theory, if the study on the subject goes on. So, that knowledge should be evaluated and repeated by future scientists. ➢ It is more reasonable to say that greenhouse effect is a theory. Because the studies on greenhouse gases still continues.

Table 4.64 *(cont'd)*

Creative and Imaginative NOS	➢ Creativity gives direction to science. Therefore, scientists use their creativity as well as imagination. ➢ Scientists use their creativity and imagination in the beginning of the research…to decide research topics, or to determine data collection… ➢ After starting the experiment, scientists set aside their creativity and imagination and focus on the scientific data… creativity and imagination replaced by the scientific data.
Socio cultural NOS	➢ Scientists may not be able to stay independent. ➢ I do not think that science is affected greatly by the social dimension, the philosophy dimension and the religious dimension because science is based on experiments and investigation.

4.3.3 Esra's Pedagogical Content Knowledge Regarding the Seasons, Weather, and Climate

Esra's PCK was examined in terms of five components of Magnusson et al. (1999) Model of PCK. PCK pre-interviews, PCK post-interviews, classroom observation and teachers' documents were used to examine teachers' PCK.

Esra's responses to the PCK pre-interview questions regarding the seasons, weather and climate topic were summarized in Table 4.65.

Table 4.65 *Esra's PCK Summary on Seasons, Weather and Climate Topic (Adapted from Tıraş (2019))*

Pedagogical Questions (CoRe)	**Esra's PCK Summary**
What you intend the students to learn regarding this idea	Students will be able to understand the Earth's rotation axis around itself is 23.5 degrees and the seasons form due to falling sunlight to the different parts of the Earth with different angles, know weather events, which were already located in the curriculum, make comments on the [weather and climate] concepts and apply that knowledge to their daily life.
The importance for the students to know this	It is a fact that children are exposed to a series of examination, including LGS [High School Entrance Exam], a nationwide exam, is to be held again this year and the topics will be asked as questions in the exam. I think it will be effective to teach this topic [seasons, weather, and climate] as it is the information that children can use in their daily life apart from academic knowledge.
Difficulty connected with teaching of this idea	[For me] it [teaching of the seasons, weather, and climate topic] will be difficult because this topic was in the last units in previous curriculum [i.e., MoNE 2013] Therefore, we passed this unit superficially [in the past teachings] [that is, since the high school entrance exam will be held at the end of the year, there was limited time to teach this topic]. They [students' misconceptions and learning difficulties] affect [my teaching]. First, you have to overcome the students' misconception before starting the lesson, which makes it difficult to teach the topic… I think I have deficiencies regarding this topic, which are originated from my undergraduate education.
Knowledge regarding student thinking which influences teaching regarding this idea	They [students] can confuse the concepts of climate and weather, and they [students] may have difficulty in understanding the [Earth's] tilted axis. I think they [students] will come to school by holding the misconceptions regarding climate and weather events because they [climate and weather events] are used differently in daily life [not scientifically].

Table 4.65 *(cont'd)*

Other factor that influences your teaching regarding this idea	I cannot feel freedom myself when I teach any topic… We have to teach according to the curriculum. [Seasons, weather, and climate] topic is visual. It needs to be understood visually. I thought that it is necessary to use a visual material. I believe six thinking hat technique is very effective indeed but takes too much time. Therefore, I cannot use it. [I can understand the effective activities] with my teaching experiences. I love doing activity… I love doing my job. My communication with students is also strong. Therefore, I have not difficulty in finding and applying activity.
Teaching procedures (and particular reasons to use of these to engage with this idea)	We use the resources that the MoNE gives us as a textbook. I need to use different resources most of the time within the framework of questions coming from the students. At first, we start to the lesson with brainstorming. We will make drawings on the blackboard. Then, we will show videos, simulation about the topic to the students. In the content of the video, the Earth's rotation, the Earth's revolution around the Sun is showed in a visual way… Where and when more sunlight falls?... In the last stage, if we have time, we will perform a model building about the topic to show the Earth's rotation and its' [Earth's] rotation axis. I think that these methods might be effective for this topic [seasons, weather, and climate].
Ways of ascertaining student understanding or confusion regarding this idea	We want to assess whether the [students'] knowledge reached a sufficient level. In other words, we assess whether the students made their knowledge usable in daily life. We assess by doing the activities in our textbook [approved by MoNE]. Apart from that, I bring a lot of questions [to the classroom] and solve them… I examine the students' answers. At the end of a unit, I can do a small exam. Sometimes, we do small exam for two units together…. I use them because they [assessment techniques] are observable. I assess [students' understanding] with questions during the lesson. After the unit is completed, I also make general assessment because these times are appropriate to assess students' understanding.

4.3.3.1 Esra’s Orientation Towards Science

Esra’s orientation towards science, her belief about goals of science teaching were investigated through pre-interview, classroom observations and analyzed under two categories which are peripheral goals and central goals.

4.3.3.1.1 Esra’s Beliefs about Goals of Science Teaching

In this part, Esra’s responses regarding beliefs about goals of science teaching in the pre-interview were reported. The interview data were supported by classroom observation as well (See Table 4.66 and Table 4.67).

> Researcher: According to you, why do we teach science in middle school? What does “science teaching” mean to you?
>
> Esra: For academic achievement for the future… I think that science education creates changes in their daily lives that can make their lives easier… Teaching science for me is to teach life itself… Teaching science is to teach not to accept anything without questioning.
>
> Researcher: In your opinion, what are the goals of science teaching?
>
> Esra: To raise individuals who think scientifically. In other words, developing individuals who accept tentative nature of science, investigate, open-minded, inquiring, wonder, and do not believe everything they hear.
>
> Researcher: Well, how do you determine these goals?
>
> Esra: Well, we learned these goals in the university. Furthermore, they [goals for teaching science] were stated in the curriculum goals and objectives. So, we have that information. My observation on children, as a teacher taught me that child needs to be raised in that way. They [students] need to be open-minded… In this aspect, I agree with the Ministry of National Education [MoNE].
>
> [PCK Pre-Interview]

Table 4.66 *Esra's Beliefs about Goals of Science Teaching*

Questions	Esra's Response	Central Goals	Peripheral Goals
According to you, why do we teach science in middle school? What does "science teaching" mean to you?	Teaching science for me is to *teach life itself…*	Schooling goal	-
	For academic achievement for the future…	Subject matter goal	-
	Teaching science is to teach not to accept anything without questioning.	Affective goal	-
In your opinion, what are the goals of science teaching?	To raise individuals who *think scientifically*. In other words, develop individuals who *accept tentative nature of science, investigate, open-minded, inquirying, wonder,* and do not believe everything they hear.	Affective goal	-
As a science teacher, what is the meaning of teaching the seasons, weather, and climate topic for you? Why do you teach the seasons, weather, and climate topic as a science teacher?	I think it will be effective to teach seasons, weather, and climate topic as it is the information that children *can use in their daily life apart from academic knowledge.*	Subject matter goal	-
		Schooling goal	-

Her response to above questions revealed that she mostly put emphasis on affective goal. Primarily, she stated that she teaches science to provide the students succeed academically (i.e., subject matter goal as central goal), provide them to make connection with the daily life and facilitate their daily lives (i.e., schooling goal as central goal). According to her, science teaching means teaching not to admit knowledge without questioning (i.e., affective goal as central goal). Raising individuals who embrace tentative nature of science, consider scientifically, and make inquiry were expressed as aim of science teaching by her (i.e., affective goal as central goal). Lastly, she stated that she determined the goals for teaching science depending on her university education and goals and objectives presented in MoNE.

In the following question, Esra was asked about the role of the teacher and the student in science teaching.

> Researcher: How can you define the role of teacher in science teaching?
>
> Esra: The teacher's role is not to present information directly to the student yet encourage them to be curious.
>
> Researcher: Well, what about the role of the student in science teaching?
>
> Esra: The role of the student is to not accept the information without questioning and make research about it [information].
>
> [PCK Pre-Interview]

According to Esra, while the role of the teacher is to educate students as a curious person, the role of the student is to make inquiry and research before admitting the information.

Following question, Esra was asked what she does maximize student learning in the classroom.

> Researcher: How do you do to maximize student learning in your classroom?
>
> Esra: First, I try to make them curious [about the topic] in order to maximize their learning in the classroom when I get into my classroom. I ask question

to elicit their prior knowledge by brainstorming… I encourage them to make connection between concepts. Then, I try to enrich the lesson through visuals.

Researcher: Well, how do you know when your students understand?

Esra: Hmmm… They [students] ask questions about the topic. The most important point is asking questions… If the children start asking questions, I think they [children] have started to learn.

[PCK Pre-Interview]

To maximize students' learning, she primarily said that she will try to provide students become wonder regarding the topic, for example by brainstorming, and then, provide them to make connection between concepts. She added that she will support her teaching with showing visuals. Then, she claimed that the most important indicator of students' understanding the topic as their asking questions.

Esra, then was asked how she decides what to teach or not teach in the school setting. She argued that MoNE determine both what she teach and does not teach in the classroom, and when she moves on to a new topic. Moreover, she stated that she prefers to use resources as compatible with the objectives stated in the curriculum. Her responses pointed out that she obeys the curriculum program given by MoNE while teaching the topic. However, she added that in case most of the students do not understand the topic, she copes with this situation either by making review or returning to the topic again.

Researcher: Well, in the school setting, how do you decide what to teach and what not to teach?

Esra: MoNE decides what to teach and not to teach in the school setting. I cannot decide. I cannot feel freedom myself when I teach any topic… No colleague, including myself, do not feel free themselves because there is a curriculum... We have to teach according to the curriculum. I first examine the objectives and then, I find some resources (4 or 5) in the framework of those objectives. Finally, I select the ones [resource] and continue on my way.

Researcher: So, how do you decide when to move on to a new topic in your classroom?

Esra: Actually, MoNE decides when we will move on to the new topic. We have our annual plan. We are trying to follow it [MoNE] as much as we can. But if a topic is not understood by the majority of the [students in] class and we recognize that, we either return back or make brief review. Sometimes, we need to devote a few hours or even a week to summarizing the topic. We will pass to the new topic after we ensure that learning is really occurred. However, most of the time, we pass to the new topic when some students do not learn.

[PCK Pre-Interview]

Lastly, Esra was asked how students learn the science best. From her view, students learn the science best through visualizing the topic such as constructing models, performing experiment and she stated that teaching science by visualizing provide students to learn the topic rapid and permanent way. In addition, she mentioned that if the students did not understand the topic, she can review the topic again. The related excerpts from the interview were as follows;

Esra: They [students] learn [science] best if we visualize the topic. I'm not mentioning about watching video. I mean is that constructing models or performing experiment. When we transfer [topic] in this way, they [students] learn quickly and what they [students] learn is remain permanent [long retention]. But for some students, it is never like that [permanent]… This is the reality in fact. They [students] participate on the lesson to construct model, perform experiment. Yet when didn't learn [meaningfully], we return back and review the content once more.

[PCK Pre-Interview]

In addition to gather information regarding Esra's beliefs about goals of science teaching using pre-interviews, researcher also collected data using classroom observation to further understand her beliefs about goals of science teaching. Briefly, her pre-interview data showed that her subject matter goals, affective goals and schooling goals were appeared to be central goals, but no peripheral goals were identified in her responses. Esra's beliefs about goals of teaching in the context of seasons, weather and climate was unveiled.

> Researcher: As a science teacher, what is the meaning of teaching the seasons, weather, and climate topic for you? Why do you teach the seasons, weather, and climate topic as a science teacher?
>
> Esra: Well, I think it will be effective to teach this topic [seasons, weather, and climate] as it is the information that children can use in their daily life apart from academic knowledge.

[PCK Pre-Interview]

When asked what the seasons, weather, and climate topic mean for her, she associated this topic with daily life saying that students could benefit from that knowledge in their daily life (i.e., schooling goal as central goal). Moreover, she emphasized the subject matter goal as central goal with using expression of *"apart from academic knowledge"*.

While teaching the seasons, weather, and climate topic, in line with her belief stated above, she frequently underlined the subject matter knowledge and aimed to transmit the related curriculum objectives to the students. For this reason, it can be concluded that her subject matter goal was observed as central goal during her teaching. A related excerpt is shown below;

> Esra: When the sun's rays fall at approximately the right angle, summer is experienced. When the sun's rays fall with an oblique [angle], winter is experienced. While summer is experienced in the Northern Hemisphere, winter is experienced in the Southern Hemisphere. While summer is experienced in the Southern Hemisphere, winter is experienced in the Northern Hemisphere. While spring is experienced in the Northern

Hemisphere, autumn is experienced in the Southern Hemisphere. While autumn is experienced in the Northern Hemisphere, spring is experienced in the Southern Hemisphere.

[Classroom Observation]

Additionally, she addressed the importance of learning the seasons, weather, and climate topic for the scope of high school entrance exam. For example, she stated that;

"The starting dates of the seasons are important. Many questions about this topic will be asked in the exam [i.e., LGS: High school entrance exam].".

As clearly seen, in contrast to her reported PCK, her enacted PCK showed that her schooling goal regarding the preparing students to the High school entrance exam was central goal. She encouraged students to use the science textbook approved by MoNE arguing that the questions in the nation-wide exam were asked in the scope of the curriculum. Moreover, in her lessons, she provided students with different resources published by different publishers to prepare them for the High school entrance exam and so provided her students to see different types of questions on this topic. Therefore, it can be concluded that she primarily aims to draw students' attention to high school entrance exam.

Contrary to her reported PCK, her enacted PCK also showed that the relationship between the seasons, weather, and climate topic and daily life was observed as peripheral goal in her teaching (i.e., schooling goals). For example, she tried to relate this topic with daily life by mentioning about importance of being aware of weather forecast on daily life. A related excerpt is shown below;

Esra: What kind of difficulties did we have if there were no weather forecasts in our lives?

S_1: We experience some difficulties in deciding what to wear [clothes] …

Esra: Yes. We have difficulties in choosing clothes. For example, we know that the weather will be cold tomorrow. We know it [temperature] is going to drop 10 degrees starting from the Wednesday. If you wore thick clothes on Tuesday without comes Wednesday, you get warm really.

S_2: They [people] don't know about the weather forecast. They [people] know nothing.

Esra: Do you think that it is possible to continue life without knowing the weather forecast? But some professions especially need to know the weather forecast. For example, teachers need to know weather forecast not to feel cold while walking on the street. [Students and teachers], for example, need to get informed about weather forecast not to slip on the icy road. Meteorology warns [us] against icing. We obey those warnings.

S_3: Take a sailor... If he/she [sailor] sails without knowing the probability of a storm, he/she [sailor] may have difficulty.

Esra: Sea transportation sometimes is cancelled in Istanbul*. [Being informed about weather forecast is] very important for the sea [transportation].

S_4: You arrange a picnic with your friend, but it rained. [Because students don't know the weather, the picnic plan they set with their friends is badly affected by rainfall.]

S_5: [It is] important for the pilot and drivers as well because they [pilot and drivers] carry a lot of people. Planes may fall [due to the bad weather condition] …

Esra: Especially sometimes you hear those flights have been cancelled, right?

S_6: Yes.

> S_7: My father is a driver. Due to the probability of rain or icing, they [drivers] change their direction [route]. They [drivers] need to learn the weather forecast.
>
> S_8: [It is] important for farmers.
>
> [Classroom Observation]
>
> [***:** *a city located in Marmara region in Turkey*]

Researcher also observed the indication of affective goal as peripheral goal in the classroom observation. She attempted to raise awareness about the environmental problems by mentioning about these problems and precautions taken to prevent them, such as using renewable energy sources to avoid greenhouse gases emission, avoid using nonrenewable energy sources (detail information will be mentioned under Esra's dual perspective section). Overall, this affective goal revealed her effort to integrate *the concept of dual perspective* into the lesson and the importance she gave to raising her students as action competent citizens.

Table 4.67 indicates Esra's beliefs about goals of science teaching based on classroom observation during the seasons, weather, and climate topic.

Table 4.67 *Esra's Beliefs About Goals of Science Teaching Based on Classroom Observation*

Beliefs About Goals of Science Teaching	Central Goals	Peripheral Goals	Example
To convey the objectives stated in the curriculum	Subject matter goal	-	Teaching the seasons
To prepare students to high school entrance exam	Schooling goal	-	Emphasizing that the starting dates of seasons can be asked as a question in the high school entrance exam
To establish a relationship between seasons, weather, and climate topic and daily life	-	Schooling goal	Mentioning about the importance of knowing weather forecast on daily life
To raise the students' awareness toward the environmental problems	-	Affective goal	Emphasizing the encouraging people to use renewable energy sources through education

All in all, her pre-interview responses revealed that her subject matter goals, schooling goals and affective goals were central goals. In the classroom observation, her subject matter goals were revealed as same, but her schooling goals as central goals were revealed as different from the interview (i.e., equipping students toward high school entrance exam). Her affective goal and schooling goal (i.e., establishing a relationship between seasons, weather, and climate topic and daily life) were observed as peripheral goals because these goals were less emphasized in her lesson compared to other goals.

Following part, next component of PCK which is knowledge of curriculum is presented.

4.3.3.2 Esra's Knowledge of Curriculum

Esra's knowledge of curriculum, with collected data through pre-interview, post-interview, teacher documents and classroom observation, was reported under two sub-titles as knowledge of goals and objectives and knowledge of materials in this section. At first, Esra's knowledge of goals and objectives about the seasons, weather and climate topic was summarized.

4.3.3.2.1 Esra's Knowledge of Goals and Objectives about the Seasons, Weather, and Climate

All data sources revealed that experienced science teacher was found as knowledgeable about goals and objectives about the seasons, weather, and climate. To illustrate, she correctly expressed all objectives determined by the MoNE, identified the vertical and horizontal connections, in addition to preceding and following topics. However, she was not aware that there is no misconception regarding the seasons, weather, and climate topic stated in the curriculum. Also, she went beyond the curriculum by giving some advance knowledge such as Beaufort scale.

In the following question, Esra was asked questions about the place of the seasons, weather, and climate topic in the curriculum, its relation to other topics, units or classes in the curriculum. (i.e., vertical and horizontal curriculum).

> Researcher: Do you know the place of the seasons, weather, and climate in curriculum?
>
> Esra: It's in the 1st unit. It was located in 8th grade, as a first unit.
>
> Researcher: You stated that it is the first unit. What are the topics taught after this unit [seasons, weather, and climate]?
>
> Esra: The next unit is DNA.

Researcher: Is there any science topic taught in earlier grades related to the seasons, weather, and climate?

Esra: This topic [seasons, weather, and climate] is associated with the geography topic. In other words, it was linked to the geography lesson. It needs to be in fact… Because Turkey's geographical conditions are directly related to seasonal events.

Researcher: Is it associated with science topics?

Esra: Hmm… Frankly, I didn't check whether this topic [seasons, weather, and climate] was linked to other science topics.… It [seasons, weather, and climate topic] must be associated with the environmental topic. While talking, we mentioned about environmental topics. This topic needs to be associated with environmental pollution, global warming and climate change.

Researcher: Do you think that it should be?

Esra: We haven't received the science textbook from MoNE yet.

[PCK Pre-Interview]

In the interview, she expressed the environmental topic (e.g., environmental pollution) located in *Human and Environment Relationship* topic in 5th grade level as vertical relation. Similarly, during teaching, she established vertical relations of the seasons, weather, and climate topic with other science topics in previous grade level. For example, she addressed *the Earth's shape* (i.e., Geoid) taught in 3rd grade level and *the formation of day and night* and *the movements of the Earth* taught in 4th grade level. The dialogues occurred between the teacher and students were as follows;

Esra: How long does the Earth completes rotation around its' axis?

S_1: It [Earth] completes [rotation around its' axis] in one day.

Esra: Earth completes rotation around its' axis in one day, which in turn lead to form day and night. Is there any other movement of Earth?

> S_2: Earth revolves around the Sun…
>
> Esra: The Earth rotates around its' axis and revolves around the Sun in an elliptical orbit. How long does the Earth completes revolution around the Sun?
>
> S_3: It [Earth] completes [revolution around the Sun] in 365 days 6 hours.

[Classroom Observation]

During teaching, to explain the formation of high pressure and low-pressure areas, and so the formation of wind, she touched on *the concept of density* taught in 6th grade level (See her definition of wind in substantive knowledge section). Also, she mentioned about *the Pure substance and mixtures* unit in 7th grade level saying that;

> Esra: You have learned the components of the air from previous year. There are 78% nitrogen, 21% oxygen, 1% carbon dioxide and other gases including argon and water vapor [in the air].

[Classroom Observation]

As horizontal relation, during the interview, she associated this topic with global warming and climate change located in *Matter cycles and Environmental problems topic* which is 6th unit in 8th grade level. Similarly, during teaching, she mentioned about the climate change, global warming and greenhouse effect in *Matter cycles and Environmental problems* topic in same grade level (See more in substantive knowledge and dual perspective section). Moreover, her emphasis on these environmental problems and the precautions to be taken to prevent these problems pointed to her attempt to raise her students as action competent citizens, which indicated her tendency to integrate the dual perspective into her teaching.

She also addressed the specific heat concept which was included in *Interaction of matter with heat* topic in 8th grade level in the curriculum. The reason why she addressed this concept is that she explained the differences between the heating of land and seas through mentioning about the specific heat concept. While teaching the unit, she stated that;

> Esra: The factor that affects the formation of low-pressure and high-pressure area is temperature, even "specific heat". The main factor affecting the formation of sea breezes is specific heat. It [sea breeze] occurs caused by the difference between the specific heat of the land and sea.
>
> [Classroom Observation]

Overall data revealed her awareness about place of the topic, the horizontal, and vertical relations. While teaching the unit, she reminded the students that the DNA is the next unit after the seasons, weather, and climate topic saying that *"We'll move on to DNA in our next lesson. We will make a DNA model."*. During the interview, she expressed the environmental pollution located in *Human and Environment Relationship* topic in 5th grade level as vertical relation. Similarly, in her teaching, she addressed *the Earth's shape* in 3rd grade level, *the formation of day and night* and *the Earth's movements* in 4th grade level, and *the concept of density* in 6th grade level and *the Pure substance and mixtures* unit in 7th grade level. As horizontal relations, briefly, she correctly stated that seasons, weather, and climate topic should be connected with the environmental topics including global warming and climate change. As she stated, while teaching the unit, she addressed the concepts of *the climate change, global warming and greenhouse effect* in *Matter cycles and Environmental problems* topic in 8th grade level. She also addressed *the specific heat concept* in *Interaction of matter with heat* topic in 8th grade level. It can be concluded that her reported PCK and enacted PCK seem to be inconsistent in general (Table 4.68).

Table 4.68 *Summary of Esra's Knowledge of Vertical and Horizontal Relations of Seasons, Weather and Climate Topic in the Curriculum*

Esra	**Vertical Relations**	PCK Pre-Interview	Human and Environment Relationship (5th grade)
		Classroom Observation	The Earth's shape (3rd grade) The Movements of the Earth (4th grade) The concept of density (6th grade) The Pure Substance and Mixtures (7th grade)
	Horizontal Relations	PCK Pre-Interview	Matter cycles and Environmental problems (8th grade)
		Classroom Observation	Matter cycles and Environmental problems (8th grade) Interaction of matter with heat (8th grade)

Researcher: What are the objectives with respect to seasons, weather, and climate found in curriculum?

Esra: [Students] comprehend what the climate is, what the seasons are… what factors influence the occurrence of seasons. Then, they [students] explain how climate forms, what the climate science is and make comment on climate science [climatology] to realize that scientists who work on climate science are called climatologist.

[PCK Pre-Interview]

Among three objectives, Esra identified two of them in the interview. The objective, she did not address was about *"the difference between climate and weather events" (MoNE, 2018, p.47)*. In her teaching, however, she mentioned about the differences between weather events and climate by drawing a table (See Table 4.57). So, it was concluded that she was aware of all objectives related to the seasons, weather, and climate. Esra's understanding of objectives regarding the seasons, weather, and climate was depicted in the table 4.69. This table also indicated consistency as well as inconsistency between her reported PCK and enacted PCK.

Table 4.69 *Esra's Understanding of Objectives Regarding the Seasons, Weather, and Climate*

Objectives Stated in the Science Curriculum (MoNE 2018, p.47)	**Interviews**	**Does Esra's response meet the curriculum objectives? (Classroom Observations)**
"8.1.1.1. Make predictions about the formation of seasons."	Mentioned	Mentioned
"8.1.2.1. Explain the difference between climate and weather events."	Not mentioned	Mentioned
"8.1.2.2. State that climate science (climatology) is a branch of science and that experts working in this field are called climate scientist (climatologist)."	Mentioned	Mentioned

Researcher: Well, could you sort the objectives based on their importance?

Esra: The most important objectives, for me, are the seasons and formation of seasons.

Researcher: Is there any important points to be emphasized for you apart from existing objectives? For instance, you just said the objectives. Are there any extra important points that you see?

Esra: Definitely, I mention about the global warming [in the lesson].

Researcher: Why do you think global warming should be added?

> Esra: Because I believe that each student should develop environmental awareness and therefore, the unit should be designed around daily life application of the concept apart from science achievement only.

[PCK Pre-Interview]

She did not range all the objectives related to the unit in any order like from most important one to less important one, but only expressed the formation of seasons as most important objective. Apart from the existing objectives in the curriculum, she stated that she will address the global warming during her teaching because students should gain environmental awareness as well as use their knowledge in their daily lives. Specifically, her responses showed her tendency to *integrate the dual perspective into her lessons*, and that she attached importance to the growth of students as action competent citizens.

In the following question, Esra was asked whether there are limitations regarding the seasons, weather, and climate topic in the science curriculum.

> Researcher: Is there any limitations implied in curriculum regarding the seasons, weather, and climate?
>
> Esra: No, there is no limitations.

[PCK Pre-Interview]

Her degree of knowledge prescribed in the curriculum was examined through her classroom observation data. It was revealed that she mentioned some advance knowledge related to weather events in the worksheet she prepared by going beyond the curriculum. As an example, these advance knowledges that she mentioned are as follows;

> *The wind speed is indicated by the Beaufort scale.*

(taught in Grade 10 Geography curriculum).

Following, Esra was asked whether there is misconception about the seasons, weather, and climate topic in the science curriculum. She stated that the difference between weather and climate is a misconception stated in the curriculum. However, there are no misconceptions about the seasons, weather, and climate topic neither in the curriculum nor in the science textbook approved by MoNE. When her teachings were examined, it was revealed that she touched on misconceptions regarding the seasons. For example, she recognized from student's response that they incorrectly associated the formation of seasons with distance of the Earth from the Sun. Then, she tried to eliminate this misconception by stating that the idea of experiencing summer or winter when the Earth is close or further away from the Sun is incorrect. Another student expressed that the revolution of Earth around the Sun lead to form day and night. Then, she tried to eliminate this misconception by stating that Earth's tilted axis and Earth's revolution around the Sun lead to seasons to form (See more detail in Esra's knowledge of students' difficulties section).

> Researcher: In your view, why do seasons, weather, and climate topic place in curriculum?
>
> Esra: It is present in the curriculum because it is related to the daily life and daily life application. On the other side, it is a fact that children are exposed to a series of examination, including LGS [High School Entrance Exam], a nationwide exam, is to be held again this year and the topics will be asked as questions in the exam. Therefore, we will teach the topic [seasons, weather, and climate] both for students to use as academic knowledge and to use it in their daily life. [For me] it [teaching of the seasons, weather, and climate topic] will be difficult because this topic was in the last units in previous curriculum [i.e., MoNE 2013] Therefore, we passed this unit superficially [in the past teachings] [that is, since the high school entrance exam will be held at the end of the year, there was limited time to teach this topic]. We are going to teach in depth first time because this unit was located [as a first topic] in the 8th grade level in the current curriculum [MoNE 2018]. Also, I think I have deficiencies regarding this topic, which are originated from my undergraduate education. When we were studying in university, we did not give enough importance to learn this topic… We gave importance to

chemistry and biology topics, but in general I think that I have deficiency regarding topics such as the universe, sun, atmosphere, astronomy.

Researcher: So, what do you intend the students to learn about the seasons, weather, and climate unit?

Esra: Regarding the seasons topic, students will be able to understand the Earth's rotation axis around itself is 23.5 degrees and the seasons form due to falling sunlight to the different parts of the Earth with different angles. Hmmm… Now, assume that the objective is explanation of seasons. If this [explanation of seasons] is an objective, the fact that the students are able to explain [seasons] is what we expect from the students, what we want the student to do… and applying that knowledge to their daily life. Regarding the weather and climate, students will be able to know weather events, which were already located in the curriculum, make comments on the [weather and climate] concepts.

Researcher: Well, for you, what are the important ideas in this topic for students to grasp?

Esra: The most important concepts are the angle of sunlight, the angle of sunlight coming to the Earth followed by the starting dates of the seasons and equinox dates. These are the most important concepts about seasons…

[PCK Pre-Interview]

From her view, the seasons, weather, and climate topic are included in the curriculum since students will be asked questions about this topic in the nationwide exams (i.e., LGS: High School Entrance Exam) and they will use the knowledge they have learned within their daily lives. She pointed out that this topic was taught superficially since it was located at the end of the unit in the past years [i.e., MoNE 2013] and that she will teach in detail due to being taken to the first unit [in MoNE 2018]. She expects from students to understand the tilt of Earth's rotation axis around itself, the causes of seasons, the angle of incoming sunlight, the starting dates of the seasons, equinox dates, climate and weather events. Besides, she expects from them to make comment on these concepts and use their knowledge in their daily life. The concepts that she wants students to learn are compatible with the objectives regarding the seasons, weather, and climate topic stated in the science curriculum. Furthermore, she added that she has deficiencies related to the seasons, weather, and climate topic due to her undergraduate education.

In the following part, Esra's knowledge of materials as a sub-component of knowledge of curriculum is presented.

4.3.3.2.2 Esra's Knowledge of Materials

In this section, to reveal her knowledge of materials, Esra was asked which resources she uses in the lesson in the pre-interview.

> Researcher: What are the sources that you use in the seasons, weather, and climate topic?
>
> Esra: Now, this unit [seasons, weather, and climate] is new for us. That is, as a teacher, we have not taught it [seasons, weather, and climate] for a long period of time as a first unit. So, we don't have enough resources. Nevertheless, I determined three different resources up to now.
>
> Researcher: What are these resources?
>
> Esra: Yeah… I have examined three resources. I am going to use these three resources in different ways. However, students also can use any resources, different resources. Apart from these alternative resources, we have been already using the textbook approved by MoNE. However, our textbook [approved by MoNE] that hasn't arrived yet. We will find a chance to examine when it [textbook approved by MoNE] arrives.
>
> Researcher: Well, for what purpose do you use all resources?

Esra: Now, we use the resources that the MoNE gives us as a textbook. There are information, activities, and experiments in it [science textbook]. But apart from this [science textbook], I need to use different resources most of the time within the framework of questions coming from the students.

[PCK Pre-Interview]

She said that she will use science textbook approved by MoNE and also other textbooks published by different publishers. Similar to her reported PCK, her enacted PCK showed that she used science textbook approved by MoNE all the time. The students' science textbooks were always on their desks throughout the lesson. For example, she asked students to read related points from the science textbook and gave homework to the students from the science textbook. She, also, had students to do the unit evaluation questions included at the end of the seasons, weather and climate topic in the science textbook. Then, she used other textbooks published by different publishers, and also, wanted students to solve tests in these resources as a homework. Then, she solved the questions in these tests that students had difficulty in understanding within the lesson time. Moreover, she preferred to show videos related to the seasons, weather, and climate topic (e.g., the formation of seasons, the weather events, the climate change) *(showing video was mentioned in pre-interview questions of knowledge of instructional strategies section).* But in contrast to her reported PCK, her enacted PCK showed that she used a globe model to demonstrate the Earth's tilted axis, the Earth's rotation around itself and revolution around the Sun. Also, she prepared worksheets including knowledge regarding the concepts of seasons, weather and climate (See Table 4.70). Therefore, in the post-interview, she was asked why she used a globe model and prepared worksheets in her teaching.

Researcher: During pre-interview, you did not mention that you will prepare worksheets for the students. What are your reasons for preparing these worksheets?

Esra: I always prepare worksheet for each unit. But I definitely prepare the worksheet for each unit, especially for 8th grade students who are going to enter nationwide exam soon. By this way, I ensure that they [students] shouldn't miss important point [regarding the seasons, weather, and climate topic].

Researcher: During pre-interview, you didn't mention that you will use a globe model in the lesson. What makes change your mind?

Esra: I used it [a globe model] all the time on this unit [seasons, weather, and climate]. I used visual model to facilitate students' understanding. They see [visualize] the spinning of Earth on its' axis during that sun's ray strike.

[PCK Post-Interview]

In the post-interview, she explained that she used a globe model to enable students to visualize and easily understand the concepts in the seasons, weather, and climate topic. Then, she stated that she prepared worksheets to prevent students, particularly for 8th grade, from missing the essential points regarding the seasons, weather, and climate topic. For example, some information included in the worksheet she prepared were shown in below;

- Earth revolves around the sun every 365 days 6 hours.
- Earth rotates around itself every 24 hours.
- The day and night form in consequence of rotating of Earth around itself.
- The shape of Earth: Geoid
- The Earth's orbit is elliptical.

[Teacher Document_Worksheet Prepared by Teacher]

Table 4.70 *Esra's Knowledge of Materials*

Sources that teacher use	**Aim of using source (PCK Pre-Interview)**	**Classroom Observation**	**PCK Post-Interview (Reason)**
Science Textbook [MoNE, 2018]	Information, activities, and experiments are included in science textbook.	The science textbook approved by MoNE was used. From the textbook; ▪ homework was given, ▪ reading the related place were done.	-
Other textbooks published by different publishers	Different resources are needed to be used most of the time to meet the students' questions.	From other textbooks published by different publishers, she distributed tests to the students to solve questions as a homework.	-
Video	*(Showing video was mentioned in knowledge of instructional strategies section).*	Various videos regarding the seasons, weather, and climate were showed.	-
Worksheets	*(Esra did not mention in the PCK Pre-interview).*	Two worksheets prepared by her regarding the seasons, weather, and climate were distributed to the students.	Through these worksheets, she aimed to provide students to not miss important point regarding this topic.
Globe Model	*(Esra did not mention in the PCK Pre-interview).*	The Earth's tilted axis and its' movements were demonstrated through a globe model.	She used a globe model to provide students to visualize the concepts and facilitate their understanding.

In the next part, Esra's knowledge of students' understanding of science is presented.

4.3.3.3 Esra's Knowledge of Students' Understanding of Science

Esra's knowledge of students' understanding of science regarding the seasons, weather, and climate topic was reported under two sub-dimensions as knowledge of requirements for learning and knowledge of students' difficulties. The data regarding Esra's knowledge of students' understanding of science were collected through using pre-interview, and classroom observation.

4.3.3.3.1 Esra's Knowledge of Requirements for Learning regarding the Seasons, Weather, and Climate

In this section, Esra's knowledge of requirements for learning regarding the seasons, weather, and climate topic was reported.

> Researcher: What kind of prerequisite knowledge and skills do you think students need to learn the seasons, weather, and climate topic successfully?
> Esra: When we say seasons, something [knowledge regarding seasons] should come to the student's mind as prerequisite knowledge. When we ask what the seasons are, they [students] should be able to define this [the seasons]. Each student has different prerequisite knowledge. We try to combine this prerequisite knowledge. When I get into classroom, I start with the question that "What comes to your mind when I say seasons?". Many students say many things about it. I write them [words that students say about seasons] on the blackboard and expect them to make inference. We need to motivate students to talk.
>
> Researcher: Why is the important for students to know the seasons as prerequisite knowledge?

Esra: I mean, it's meaningless to teach how the seasons occur to the person who does not have any idea about the names of seasons. But it has meaning for me.

[PCK Pre-Interview]

She mentioned that students should know the seasons concept as a prerequisite knowledge, but did not mention about other prerequisite knowledge from the previous grade level related to the seasons, weather, and climate topic. She stated that she starts to teach the topic by eliciting students' prior knowledge through asking questions like *"What comes to your mind when I say seasons?"*.

Similarly, at the beginning of the lesson, she brainstormed about the topic by asking various questions to reveal what students know. For example, she said the name of the unit which is *''Seasons and Climate''* and then, asked the students that what they think about the seasons. She wrote all the answers coming from the students to the blackboard respectively. From the students' responses, it was observed that they have prerequisite knowledge about the names of the seasons, the Earth's tilted axis, the concept of the equator, the solstice, rotation, and heat energy. For example, related conversations occurred between the teacher and the students were as follows;

Esra: When we say seasons, what comes to your mind?

S_1: Spring, summer, autumn, winter…

S_2: [Earth's] tilted axis comes to my mind.

Esra. Yes. [Earth's] tilted axis.

S_3: What about equator?

Esra: Yes.

S_4: "The perpendicular rays coming to the Earth" come to my mind.

Esra: What else?

S_5: Snowfall comes to my mind.

S_6: Solstice comes to my mind.

S_7: June 21, September 23, March 21, December 21 come to my mind.

S_8: Rotation.

S_9: Heat energy comes to my mind.

S_{10}: Weather events come to my mind.

S_{11}: Meteorology comes to my mind.

S_{12}: Climate comes to my mind.

…. Continues.

[Classroom Observation]

Furthermore, while teaching the unit, she mentioned about other concepts that the students have learned at the previous grade levels such as *the Earth's shape* at 3rd grade level, *the movements of the Earth* at 4th grade level, *the concept of density* at 6th grade level, *Pure substance and mixtures* unit at 7th grade level (See detail in vertical relations in knowledge of curriculum section). Therefore, findings revealed her awareness regarding the students' prerequisite knowledge. Table 4.71 shows Esra's knowledge of requirements for learning about the seasons, weather, and climate topic. This table also indicated an inconsistency between her reported PCK and enacted PCK.

Table 4.71 *Esra's Knowledge of Requirements for Learning*

	PCK Pre-Interview	**Classroom Observation**
Esra's knowledge of requirements for learning	Not mentioned	The Earth's shape (3rd grade) The Movements of the Earth (4th grade) The concept of density (6th grade) The Pure Substance and Mixtures (7th grade)

Esra's knowledge of students' difficulties as a sub component of knowledge of students' understanding of science is presented in the following part.

4.3.3.3.2 Esra's Knowledge of Students' Difficulties regarding the Seasons, Weather, and Climate

Esra's knowledge of students' difficulties regarding the seasons, weather, and climate topic was reported.

> Researcher: Now I want to talk about the students' think about the seasons, weather, and climate topic. Can you tell me about which difficulties do students have while learning the seasons, weather, and climate topic?
>
> Esra: They [students] can confuse the concepts of climate and weather, and they [students] may have difficulty in understanding the [Earth's] tilted axis.
>
> Researcher: Do your students have misconceptions about the seasons, weather, and climate? If yes, what are the students' misconceptions regarding the seasons, weather, and climate?
>
> Esra: I think they [students] will come to school by holding the misconceptions regarding climate and weather events.
>
> Researcher: What are the sources of those misconceptions?
>
> Esra: Because they [climate and weather events] are used differently in daily life [not scientifically].
>
> Researcher: How do you identify students' misconceptions? Which methods do you use to identify misconceptions?
> Esra: Hmmm… First of all, I ask " What comes to your mind when I say seasons, weather, and climate". Then, I continue with brainstorming.
>
> Researcher: Do you use any other methods?

Esra: You encourage the students to talk. When students talk about topic, you can see whether they [students] have misconceptions or not.

Researcher: Well, do you eliminate students' misconceptions?

Esra: Of course.

Researcher: How do you eliminate students' misconceptions regarding the seasons, weather, and climate?

Esra: In this aspect, I perceived myself as traditional teacher… Excessive review worked well. For example, student comes with a lot of misconceptions about the heat and temperature, and we repeat constantly by giving examples from daily life. In this topic [weather and climate], [we give examples like] "it will be rainy today… this is [example of] weather event… Antalya*'s climate is the Mediterranean climate...". By this way, we repeat the weather and climate topic frequently [by giving examples]. I can try to direct the student to the right one [concept] by asking questions…. By asking questions in different ways. If this method is not beneficial, we may correct them [students' misconceptions with different methods]. It is also very easy to access the internet in the classroom environment, although we sometimes have difficulty in connecting to smart board. When they [students] ask anything, I can find visual and [scientific] explanation on the Internet immediately.

Researcher: Well, why are you choosing this method to eliminate misconceptions?

Esra: Because I have already noticed that the method is effective before [from my past teaching].

Researcher: Do you think that those methods are enough to eliminate misconceptions?

Esra: Sometimes it may not be enough. Because even if you repeat the topic, you may not be attracted by some students' attention.

Researcher: How do learners' difficulties and misconceptions in the seasons, weather, and climate topic influence your teaching?

Esra: Of course, they [students' misconceptions and learning difficulties] affect [my teaching]. First, we have to overcome the students' misconception before starting the lesson, which makes it difficult to teach the topic…

Researcher: I mean how do you use the learners' difficulties and misconceptions during planning the lesson?

Esra: Firstly, I consider that what the misconceptions of the students can be and then, I focus on the students' misconceptions during the lesson.

[*: The city is located in Mediterranean region in Turkey]

[PCK Pre-Interview]

During the interview, she considered that students could confuse the weather and climate and have difficulty in comprehending the Earth's tilted axis. She stated that they may have misconception about the climate and weather events which can be originated from using these concepts differently in daily life. She added that she identifies students' misconceptions using brainstorming, dialogue with students, and that she eliminates those misconceptions through excessive review, giving daily life examples, directing students to right concept with asking questions, and also, finding visuals and scientific explanation from internet. She stated that she prefers these methods because she experienced that they were effective in her previous teachings but added that the methods she used might not be enough because of might not attract the attention of some students. She argued that students' misconceptions and learning difficulties affect her teaching and for this reason, she primarily eliminates their misconceptions prior to starting her teaching.

Similarly, while teaching of the topic, she asked the students what they know about the Earth's tilted axis and then, noticed from students' responses that they had difficulty in understanding the Earth's tilted axis and its' effects on the formation of seasons. Therefore, to eliminate their learning difficulties, she explained these concepts in the classroom by the help of drawing, giving scientific explanation and showing video. First, she drew the Earth figure on the blackboard (See Figure 4.30) and specified the equator and Earth's tilted axis on this figure to show visually.

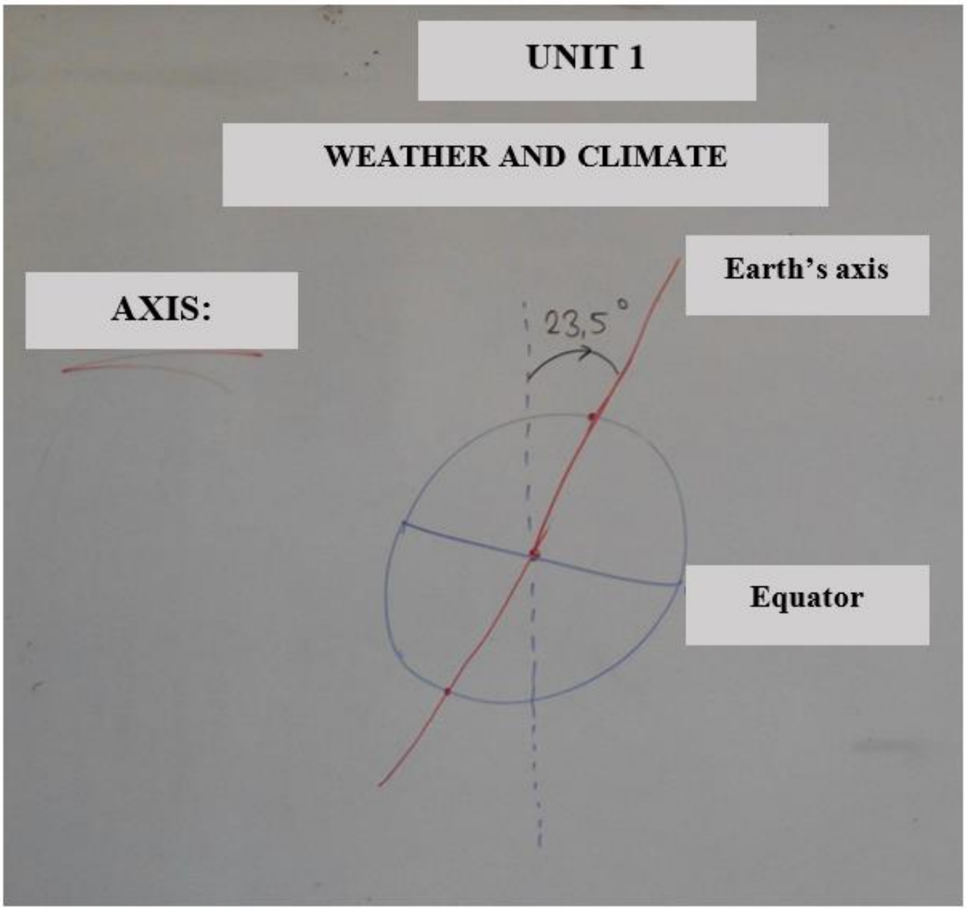


Figure 4.30 Esra's Drawing About the Earth's Tilted Axis

After she drew the figure 4.30 on the blackboard, the following dialogues were occurred between the teacher and the students in the classroom as follows;

Esra: What comes to your mind about the term “axis”?

S_1: Is it the area where the Earth revolves around the sun?

Esra: No. What else can be?

S_2: Angle.

S_3: Orbit of an object.

Esra: We're talking about Earth’s axis. It [Earth’s axis] is an imaginary line connecting the North and South poles with the center of the Earth. The Earth completes its’ spin on its’ axis in 24 hours which corresponds to 1 day, right?

S_4: Yes.

Esra: In fact, we define the non-existent line as the Earth’s axis. This line [Earth’s axis] is not a straight line… slightly oblique. How much its’ degree?

S_5: 23.5°.

Esra: The Earth rotates as oblique, not as perpendicular. This [Earth’s rotation as oblique] have an effect on the lengths of the seasons and day and night. [Earth’s] tilted axis is used as 23.5°. It is normally 23.27°. But it is accepted as 23.5°.

[Classroom Observation]

Then, in her teaching, she briefly asked *“What would happen, if the Earth’s tilted axis were not exist?”*, and then, she showed the related video from smart board. In this video, the situations in which the Earth’s tilted axis were not exist were mentioned. Then, she made scientific explanation as follows;

Esra: If it [Earth] rotated in a straight orbit, it [Earth] would stay perpendicular and the sun rays would always fall as perpendicular to the equator. It [sun rays] would fall to other pole regions with the tilted angle… the equator would always be warm… the poles would always be cold. While the summer season would be always experienced in the equator, the winter season would be always experienced in poles. It would be only one season everywhere in the Earth. Let's give examples from the equator to be more understandable. A person living a place near to equator would always live in summer seasons.

[Classroom Observation]

As she stated, in her teaching, she continued her lecture with questioning method frequently to identify students' misconceptions. Through students' responses, she recognized a students' misconception as to relating the formation of the seasons with the Earth's distance from the Sun (e.g., Tsai, & Chang, 2005). Then, she tried to remediate students' misconception through showing a video regarding seasons on the smart board, drawing a figure on the blackboard, and giving a scientific explanation (See Figure 4.31).

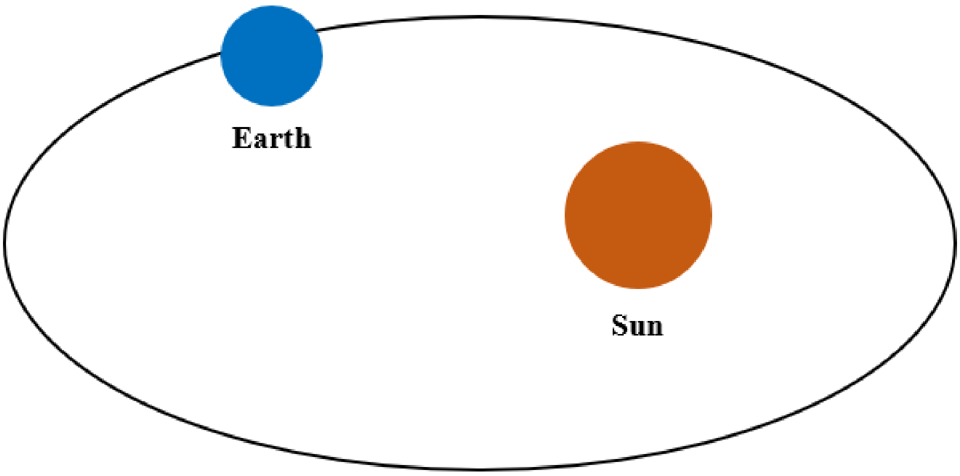


Figure 4.31 Symbolic Representation of Esra's Drawing About the Formation of Seasons on the Blackboard

After drawing the Figure 4.31 on the blackboard, she gave a scientific explanation that;

Esra: In general, there is a misconception… Since Earth revolves around the Sun in an elliptical orbit, it seems to be far away from the sun [she refers to the Figure 4.31]. This is an incorrect idea that “If the Earth is near to the sun, the summer is experienced. If the Earth is farther away from the sun, the winter is experienced.”.

[Classroom Observation]

In her teaching, she distributed tests including multiple-choice questions and then, noticed from students’ responses that students had misconception with regard to express the Earth’s revolution around the sun as the causes of day and night (Atwood, & Atwood, 1997). Then, she tried to eliminate their misconception by only making a scientific explanation, but she did not use any topic-specific strategies. The dialogues occurred between student and teacher were as follows:

S_1: Earth's revolution around the sun leads to form the seasons and night and day.

Esra: Earth's tilted axis and Earth's revolution around the Sun cause seasons to form. The rotation of the Earth around itself causes the formation of day and night, not seasons.

[Classroom Observation]

Furthermore, during the dialogues with the students on the climate change, global warming and greenhouse effect, their misconceptions regarding these concepts were emerged. These misconceptions identified in the classroom observation were reported below;

- Relating the cause of global warming with depletion of ozone layer (Daniel, Stanisstreet, & Boyes, 2004)
- Relating the use of deodorants and perfumes with the depletion of ozone layer (Khalid, 2003).

Esra, however, failed to notice these misconceptions and therefore, she did not eliminate them. The dialogues occurred between teacher and students in which these misconceptions were detected were shown below;

Esra: What do you think about greenhouse gases?

S_1: These gases exist in the air. These gases accumulate in the atmosphere.

Esra: The more those gases accumulate, the more sun rays reflected from the atmosphere stay in the atmosphere and thus cause [global] warming. What is the reason of global warming?

S_2: Ozone layer [depletion].

S_3: Global warming causes the ozone layer to deplete.

Esra: What do you mean?

S_3: Polluted air [greenhouse gases] and deodorants cause the ozone layer to deplete.

S_4: The ozone layer is depleted with the use of deodorants and perfumes.

[Classroom Observation]

Overall findings revealed that as she stated in the pre-interview, she noticed in her teaching that students had difficulty in understanding the Earth's tilted axis and its' impact on the seasons. She tried to eliminate students' learning difficulty through showing videos, drawing a figure, and making scientific explanation. She identified two misconceptions that students had regarding the seasons concept using questioning method and tried to eliminate them through making scientific explanation, showing videos or drawing a figure. However, she failed to realize other misconceptions regarding the global warming and ozone layer depletion. Lastly, her teaching showed that as she stated, students' learning difficulties and misconceptions related to the seasons, weather and climate topic influenced her teaching which led to her to repeat the concepts. Esra's knowledge of students' difficulties was shown in Table 4.72, which indicated consistent and inconsistent points between her reported PCK and enacted PCK.

Table 4.72 *Esra's Knowledge of Students' Difficulties*

Esra's Knowledge of Students' Difficulties			
PCK Pre-Interview		**Classroom Observation**	
Learning Difficulties	**Methods for Elimination**	**Learning Difficulties**	**Methods for Elimination**
Confusing the concepts of weather and climate Difficulty in understanding the Earth's tilted axis	Not mentioned	The Earth's tilted axis and its' impact on the formation of seasons	Drawing figure Scientific explanation Showing video
Misconceptions	**Methods for Elimination**	**Misconceptions**	**Methods for Elimination**
Confusing the weather events and climate	Excessive review Giving examples from daily life Directing the student to the right concept by asking questions Finding visual and scientific explanation through internet	Relating the formation of the seasons with the Earth's distance from the Sun (e.g., Tsai, & Chang, 2005).	Showing video Drawing figure Scientific explanation
		Expressing the Earth's revolution around the sun as the causes of day and night (Atwood, & Atwood, 1997).	Scientific explanation
		Relating the cause of global warming with depletion of ozone layer (Daniel, Stanisstreet, & Boyes, 2004) **Relating the use of deodorants and perfumes with the depletion of ozone layer (Khalid, 2003).**	**She neither detected nor eliminated these misconceptions**

In the following part, Esra’s knowledge of instructional strategies is presented.

4.3.3.4 Esra’s Knowledge of Instructional Strategies

Esra’s knowledge of instructional strategies was reported under two parts which are *knowledge of subject specific strategies* and *knowledge of topic specific strategies*. The knowledge of representation and knowledge of activities were reported under the knowledge of topic-specific strategies. Related data were collected through pre-interview, post-interview, teacher documents and classroom observation.

4.3.3.4.1 Esra’s Knowledge of Subject Specific Strategies

When asked her knowledge with regard to subject-specific strategies, she generally addressed general strategies in addition to topic-specific one. Table 4.73 depicted her all responses regardless whether topic specific or not.

Table 4.73 *Esra's Knowledge of Strategies*

Dimensions	**Science Topics**	**Seasons, Weather, and Climate**
Subject Specific Strategies	Simulation* Experiment* Brainstorming Six thinking hat technique	Direct instruction Questioning Brainstorming Videos* Simulation* Drawings* Model Building*
The Reasons of Selecting the Strategies	These methods are useful They can be used in short period of time	Effectiveness for seasons, weather, and climate topic.
The Sources of Learning Strategies	Undergraduate Education (Teaching method course)	Undergraduate Education (Teaching method course)

***Indicate topic-specific strategies**

Researcher: Which teaching method/strategy do you prefer to use while teaching science?

Esra: We use many techniques. They [the techniques we use] change from unit to unit. So, before I start the unit, I ask myself which methods and techniques are appropriate to teach this unit and to what extent this method is suitable to my student [their knowledge level]. I try to use different methods and techniques.

Researcher: Well, is there a method you can say to teach science topics?

Esra: We do experiments. After that, we show simulations…. Besides, we do brainstorm. I know that there is a technique called six thinking hat. I believe six thinking hat technique is very effective indeed but takes too much time. Therefore, I cannot use it [six thinking hat technique].

Researcher: What is the six-thinking hat technique?

Esra: It [six thinking hat technique] is a method that provides looking to the case from different perspectives. Instead of this technique [six thinking hat], we use mostly simulations, experiments and brainstorming.

Researcher: Why do you prefer to use these methods?

Esra: Their [teaching methods'] usefulness... Because they are the methods that can be used in short period of time [not take too much time].

Researcher: How did you learn to use this teaching strategy?

Esra: I have learned [teaching strategies] from teaching methods course in university.

Researcher: What about the teaching of seasons, weather, and climate topic? Which methods do you use to teach the seasons, weather, and climate topic?

Esra: At first, we start to the lesson with brainstorming. I ask question to elicit their prior knowledge by brainstorming… Then, we try to provide the students to wonder [about the topic]. We will little mention about topic [that is, we will use direct instruction]. We will make drawings on the blackboard. Then, we will show videos, simulation about the topic to the students. In the last stage, if we have time, we will perform a model building about the topic to show the Earth's rotation and its' [Earth's] rotation axis. Model that is created will show the revolution of Earth around the Sun every 365-day and 23.5° tilt of the Earth's axis. That is, it [model] shows how it [Earth] rotates.

Researcher: Do you have particular reasons for using those teaching methods?

Esra: Hmmm… I think that these methods might be effective for this topic [seasons, weather, and climate]. But teaching methods change from unit to unit. For example, we may need to do experiment in different topic…

[PCK Pre-Interview]

She primarily pointed out that the teaching methods can be used based on specific to topic, and she tended to prefer methods that can be used in limited time in teaching science topic. For example, she stated that she prefers to perform brainstorming to attract students' attention to the topic, show video or simulation and perform experiments. For teaching the seasons, weather, and climate, she tended to use direct instruction and questioning methods which are teacher-centered methods. Specifically, she added that she uses the methods that can be effective such as performing a model-building activity showing the formation of seasons and making drawing about the topic. Lastly, she expressed the teaching method course she took in her undergraduate education as the source of learning these teaching methods. However, she mentioned about topic-specific strategies in general, and she did not address subject-specific strategies such as conceptual change approach, 5E learning cycle.

Her reported PCK and enacted PCK seem to be consistent in general. Classroom observation data confirmed that her teaching practices were mostly teacher-centered;

she frequently used direct instruction and questioning. As she stated, in her teaching, she showed videos and simulation, and drew figures related to the seasons, weather, and climate topic *(explained in knowledge of representation section).* Contrary to her reported PCK, her enacted PCK showed that she did not perform model building activity due to time limitation.

Lastly, Esra was asked about the link between the goals and the methods she selected for teaching the seasons, weather, and climate topic. She stated that the visual material should be used due to visual nature of this topic and added that the methods she selected to teach this topic are congruent with her goals.

> Researcher: What is the connection between your goals in teaching and the methods you choose? If any.
>
> Esra: [Seasons, weather, and climate] topic is visual. It needs to be understood visually. I thought that it is necessary to use a visual material.
>
> Researcher: To what extent do you think it reflects your goals?
>
> Esra: I think they [teaching methods] are compatible [with my goals].
>
> [PCK Pre-Interview]

In the following part, Esra's knowledge of topic-specific strategies as a sub-component of knowledge of instructional strategies is presented.

4.3.3.4.2 Esra's Knowledge of Topic Specific Strategies

Findings were reported under the two parts which are knowledge of representations and activities.

4.3.3.4.2.1 Esra's Knowledge of Representations

In the pre-interview, she highlighted that she will make drawings, show videos and simulations regarding the seasons, weather, and climate topic. As she stated, in her teaching, she used all of them. Furthermore, she gave examples related to the weather and climate, used a globe model to show the Earth's movements and Earth's tilted axis. She used a simple analogy regarding the greenhouse effect to facilitate students' understanding. Esra's knowledge of representations was shown in Table 4.74.

Table 4.74 *Esra's Knowledge of Representations*

Types of Representations		
PCK Pre-Interview	**Classroom Observation**	**Examples used in the Classroom Observation**
Illustrations		
Visuals		
Videos	*Videos*	The formation of the seasons and the Earth's tilted axis The greenhouse gases and its' effects The formation of day and night The ozone layer The types of weather events The effects of weather events on landforms The climate change and global warming and precautions taken toward these problems
Simulations	*Simulations*	The formation of sea breeze and land breeze
Drawing Figures	Drawing Figures	The formation of seasons The Earth's tilted axis The formation of wind
-	Model *Globe Model*	She benefitted from a globe model in order to show the Earth's movements.
-	Analogy	The greenhouse analogy Compared greenhouse effect with greenhouse
-	Examples	Types of climates Types of climates seen in Turkey Types of weather events Greenhouse gases Places where humidity is high

Researcher: Do you use illustrations, examples, models, drawings, and analogies to assist students' learning in the seasons, weather, and climate topics and concepts?

Esra: There are the videos I downloaded from the internet. [We] show those videos. After that, I will make my own drawings on the blackboard, and I will want students to draw these drawings in their notebook. In the content of the video, the Earth's rotation, the Earth's revolution around the Sun is showed in a visual way… Where and when more sunlight falls?... [We use] simulation that shows these concepts.

Researcher: … And you said you draw on the blackboard.

Esra: Yes. …and then, we draw on the blackboard. First, we draw on the blackboard actually because the student may not watch the simulation carefully.

[PCK Pre-Interview]

She stated that she will show videos and simulation (e.g., about the Earth's revolution around the Sun) and draw figures on the blackboard to enrich her teaching on the seasons, weather, and climate topic. Similar to her reported PCK, her enacted PCK showed that she showed videos, simulations and drew several figures. In addition to her reported PCK, she used a globe model, and then gave several examples with respect to the seasons, weather, and climate topic in her teaching. Also, she used a simple analogy to enable students to understand how the greenhouse effect occurs.

In her teaching, she opened the simulation program on the smart board regarding the types of wind and then, she showed how the sea breeze and land breeze occur visually to her students. Then, she also showed a variety of videos from the smart board regarding the seasons, weather, and climate topic. The contents of the videos were as follows;

- The formation of the seasons and the Earth's tilted axis
- The greenhouse gases and its' effects

- The formation of day and night
- The ozone layer
- The types of weather events (e.g., dew, rime, rain, breeze)
- The effects of weather events on landforms
- The climate change and global warming and precautions taken toward these problems (e.g., Kyoto protocol)

Especially, it is important to note that Esra's showing video on the climate change and global warming as well as the precautions to be taken to reduce or prevent the adverse effects of these environmental problems indicated her tendency to integrate the dual perspective into her teaching.

She benefitted from greenhouse analogy to explain the concept of greenhouse effect. In this analogy, while the target concept is atmosphere, familiar concept is greenhouse. While another target concept is the formation of the greenhouse effect by keeping most of the sun's rays in the atmosphere, the familiar concept is the heating of the greenhouse by the sun's rays reaching it. However, she did not emphasize the breaking points between analog and target concept in her analogy (See detail regarding the greenhouse analogy in Esra’s substantive knowledge section).

She showed how seasons occur to her students by drawing various figures on the blackboard such as the formation of seasons (See figure 4.28), the Earth’s tilted axis (See figure 4.30). Also, since the formation of wind related to the concept of climate, she showed how wind occurs by drawing figure on the blackboard (See figure 4.32). She specified the high-pressure area and low-pressure area on this figure that she drew (See her explanation of wind in substantive knowledge section).

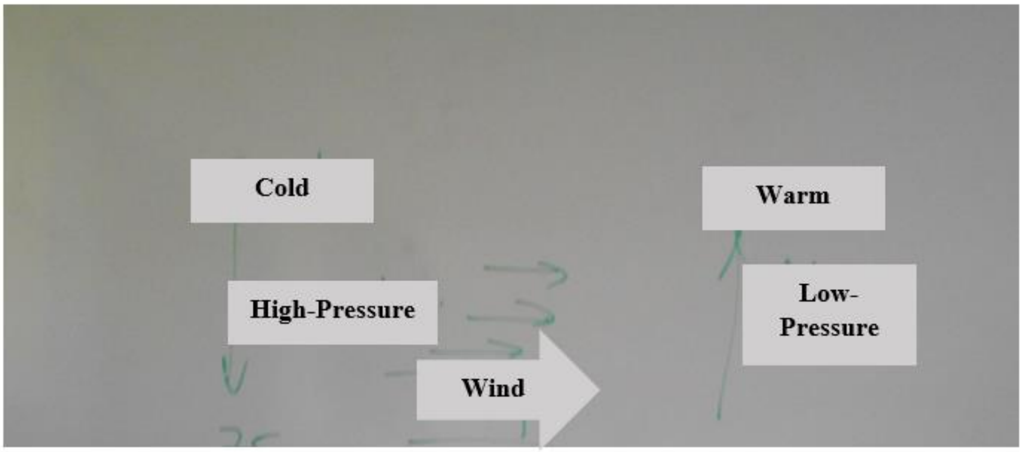


Figure 4.32 Esra's Drawing About the Formation of the Wind

For enriching her teaching, she gave several examples regarding the concepts in the seasons, weather, and climate topic (See Table 4.75).

Table 4.75 *Esra's Examples Regarding the Seasons, Weather and Climate Topic*

Topic	**Esra's Example**
Types of climates	Tropical, Black Sea, Mediterranean, terrestrial, monsoon, Desert, Steppe, Tundra, oceanic, equatorial.
Types of climates seen in our country [Turkey]	Black Sea, Mediterranean, Terrestrial.
Types of weather events	Rain, wind, snow, hail, hurricane, fog, rime.
Greenhouse gases	Nitrous oxide, CFC, Carbon dioxide, Methane.
Places where humidity is high	Adana*, Manisa**, Mersin***, Istanbul, Izmir****

[***:** *The city is located in Mediterranean region in Turkey,* ****:** *The city is located in Aegean region in Turkey,* *****:** *The city is located in Mediterranean region in Turkey,* ******:** *The city is located in Aegean region in Turkey*].

Moreover, in her teaching, she used a globe model with the aim of showing the Earth's tilted axis, the Earth's rotation around itself and revolution around the Sun to her students. While using the globe model, the following dialogues between the teacher and students were occurred as follows;

> Esra: Do you think that people living in different place of world experience same seasons at the same time?
>
> S_1: No.
>
> S_2: It changes depend on the position of the Earth to the Sun.
>
> Esra: For example, same seasons are not experienced at the same time in everywhere due to the angle between the Earth's rotation axis and its' [Earth's] position [around the Sun].
>
> In this moment, she used a globe model that brought to the classroom, and she showed the Earth's tilted axis on the model to the students.
>
> Esra: Because the Earth stands in a tilted position, it [Earth] rotates according to its' tilt that is 23.5°.
>
> [Classroom Observation]

In the following part, Esra's knowledge of activities as a sub-component of knowledge of instructional strategies is presented.

4.3.3.4.2.2 Esra's Knowledge of Activities

In this section, Esra's knowledge of activities regarding the seasons, weather, and climate topic was reported. In the pre-interview, she stated that she will perform model building activity in the classroom. Despite she mentioned in the pre-interview, she did not perform model building activity in her teaching. Esra's knowledge of activities was summarized in the Table 4.76.

Table 4.76 *Esra's Knowledge of Activities*

Pre-Interview	**Classroom Observation**	**Post-Interview (Reason)**
Model building Activity	*Not Observed.*	She did not perform model building activity because she found explanatory visuals and videos regarding the seasons, weather, and climate topic and there was limited time.

In the following question, Esra was asked about whether she conducts activities related to the seasons, weather, and climate topic.

> Researcher: Do you conduct activities in the class regarding the seasons, weather, and climate?
>
> Esra: Yes. We will do.
>
> Researcher: Well, what are you going to do? What kind of activities do you perform?
>
> Esra: We can construct a model building [activity] at the end [of the seasons, weather, and climate topic]. Together with the students, we can construct a sun and Earth models, and then, we can show how the Earth revolves around the sun.
>
> [PCK Pre-Interview]

She stated that she will perform model building activity where students actively participate to demonstrate the revolution of the Earth around the Sun in the classroom. Contrary to her reported PCK, her enacted PCK showed that she did not perform model building activity in her lesson. Also, in her teaching, she did not perform some activities related to this topic found in the science textbook. In the post-interview, therefore, she was asked why she did not perform model building activity in her teaching. The related excerpts from the post-interview were as follows;

> Researcher: During the pre-interview, you stated that you can do a model building activity. However, you did not perform model building activity in your classroom. What changed your mind?
>
> Esra: Because I found nice visuals from the internet and the videos I showed were very explanatory related to the seasons, weather, and climate topic. Applying model building activity takes a long time in the classroom. Therefore, I didn't want to spend my time to perform this activity on this unit [seasons, weather, and climate] … That's why, I had students construct a DNA model in the second unit [DNA and Genetic Code]. We've completed it [a DNA model].
>
> [PCK Post-Interview]

Lastly, Esra was asked about how she understood the effectiveness of the activities she has planned. She noticed the activities that she used in the lesson are effective thanks to her teaching experience. Also, she believes herself successful about finding effective activity based on the students' assessment results. The related excerpts from the interview were as follows;

> Researcher: Well, there are activities you plan to do. How do you come to realize that they will work?
>
> Esra: I think I can find effective activity… [I can understand the effective activities] with my teaching experiences. I love doing activity… I love doing my job. My communication with students is also strong. Therefore, I have not difficulty in finding and applying activity. I find myself successful [about finding effective activity]. We can recognize this while assessing students at the end of the unit…. [For example], if most of the students were able to learn the topic in the classroom, we can say that the teacher was able to provide a successful teaching environment.

[PCK Pre-Interview]

In the following part, Esra's knowledge of assessment is presented.

4.3.3.5 Esra's Knowledge of Assessment

Esra's knowledge of assessment was reported under two sub-dimensions as knowledge of dimensions of science learning to assess and knowledge of methods of assessment. Related data were collected through pre-interview, post-interview, teacher documents and classroom observation.

4.3.3.5.1 Esra's Knowledge of Dimensions of Science Learning to Assess

In this section, Esra's knowledge of dimensions of science learning to assess regarding the seasons, weather, and climate topic was reported (See Table 4.77).

Table 4.77 *Esra's Knowledge of Dimensions of Science Learning to Assess*

Knowledge of Dimensions of Science Learning to Assess	PCK Pre-Interview	Classroom Observation
Knowledge on the seasons, weather and climate	Mentioned	Assessed
NOS Understanding	Not Mentioned	Not Assessed
Science Process Skills	Not Mentioned	Not Assessed
Knowledge of Dual Perspective	Not Mentioned	Assessed

> Researcher: What do you want to assess in depth when you assess your students' knowledge in terms of seasons, weather, and climate?

Esra: We want to assess whether their [students'] knowledge reached a sufficient level. In other words, we assess whether the students made their knowledge usable in daily life. For example, the explanation of seasons is an objective and the student's explanation of this objective is what we expect from the students.

[PCK Pre-Interview]

Consistently, while teaching the unit, she frequently used questioning method to understand whether the students learned the seasons, weather, and climate topic. For example, through questioning, she repeated the differences between weather events and climate with students. The dialogues were occurred between the teacher and the students as follows;

Esra: Let's repeat the differences between climate and weather events. Weather events are the weather conditions occur in the short term. Climate is the average of weather conditions can be seen in the long-term. What are the differences between weather events and climate?

(Students said the differences between weather events and climate.)

S_1: Climate involves prediction.

S_2: There are predictions in weather events.

Esra: Yes. There are predictions in weather events.

S_3: While climatology examines the climate, meteorology examines the weather events.

S_4: The climate is long term and covers large region.

S_5: Weather events occur in a short period of time.

S_6: The terms such as hot, cold refer to climate. The terms such as sunny, rainy refer to weather events.

[Classroom Observation]

As seen, these questions were consistent with the objectives relevant to the seasons, weather, and climate topic in the curriculum. Similar to her reported PCK, her enacted PCK showed that she assessed students' knowledge related to the seasons, weather, and climate and did not assess students' knowledge on science process skills or NOS understandings. Also, she distributed the tests including multiple-choice questions from different textbooks published by different publishers to the students and these questions aimed to assess students' knowledge related to the seasons, weather, and climate topic. Contrary to her reported PCK, her enacted PCK showed her tendency to assess students' knowledge of dual perspective through few multiple-choice questions. For instance, one question assessed students' knowledge related to the consequences of the global warming, and another one assessed students' knowledge about precautions and mitigation strategies to be taken to prevent the global climate change. While answering the latter question, the following dialogues were occurred between the teacher and the student as follows;

> S_1: The wrong answer is C which state that *Using fossil fuels instead of renewable energy sources* … Because fossil fuels harm the nature…
> Esra: People need to do something to protect the environment against [effects of] global climate change. However, using the non-renewable energy source stated in the "C" option is harmful for the environment …
>
> [Classroom Observation]

In the following part, Esra's knowledge of methods of assessment as a sub component of knowledge of assessment is presented.

4.3.3.5.2 Esra's Knowledge of Methods of Assessment

In this section, Esra's knowledge of methods of assessment regarding the seasons, weather, and climate was reported (See Table 4.78). Esra focused on only traditional assessment methods in her pre-interview, and used traditional assessment methods in her teaching (e.g., questioning method, multiple choice questions). She assessed students' understanding with questioning method during the lesson (i.e., formative assessment), and with different type of questions such as fill in the blank, multiple-choice questions at the end of the unit (i.e., summative assessment). Moreover, although she did not mention in the pre-interview, she had students to do research about the concepts as a homework. In the post-interview, she stated that she will perform general assessment later.

Table 4.78 *Esra's Knowledge of Methods of Assessment*

Dimensions	**PCK Pre-Interview**	**Classroom Observation**
How to assess?	Doing the activities in science textbook approved by MoNE Solving a lot of multiple-choice questions Questioning Performing a small exam Written exam	Questioning Unit evaluation questions (e.g., fill in the blank, multiple choice) Other textbooks published by different publishers including multiple-choice questions Giving homework Illustrating seasons through drawing Having students do research about the concepts
The reasons of selecting assessment strategies	Assessment techniques she used are observable.	Assessing students' knowledge of seasons, weather and climate, and knowledge of dual perspective
When to assess?		
Formative assessment (During the lesson)	Mentioned	Applied
Summative assessment (At the end of the unit)	Mentioned	Applied

Researcher: Which assessment techniques do you use to assess their understanding in seasons, weather, and climate topic?

Esra: We have enough data in our textbook [approved by MoNE] to assess [the students' understandings]. We assess by doing the activities in our textbook [approved by MoNE]. Apart from that, I bring a lot of questions [to the classroom] and solve them… I examine the students' answers. At the end of a unit, I can do a small exam. Sometimes, we do small exam for two units together….

Researcher: Well, what are the particular reasons for using them to assess students' understanding?

Esra: Because they [assessment techniques] are observable.

Researcher: Well. You said they are observable… To see how well your students understand.

Esra: Yeah. Now in recent times, especially the test questions, or the written exams are criticized too much. [For example], it is said that "They [test questions or written exams] should not be used as an assessment.". But I don't agree with this idea. There are 30 different students in a classroom. We can't keep in mind how much they [students] learned [knowledge regarding the topic] … These tests give clear information about how much students learn [regarding the topic], where they [students] have difficulty. Therefore, I believe they [test questions or written exams] should be used.

Researcher: Well, when do you assess your students regarding seasons, weather, and climate?

Esra: Hmmm… I assess [students' understanding] with questions during the lesson. After the unit is completed, I also make general assessment because these times are appropriate to assess students' understanding.

Researcher: How do you use the assessment results? What do the results tell you?

Esra: These results inform us about whether children understand the topic as much as I aimed… If it [seasons, weather, and climate topic] is not understood, we can return to the beginning [of the topic]. If it is well understood, we can continue to teach the topic.

[PCK Pre-Interview]

From Esra's responses, it can be said that she tends to use traditional assessment methods such as multiple-choice questions, written exams, questioning method. She stated that she uses questioning method throughout the lesson as formative assessment, and uses summative assessment at the end of the unit. She added that she can recognize whether the students understood the topic through their assessment results.

Following, Esra was asked how she feels in finding assessment ways to evaluate her teaching. She expressed that she has learned lots of assessment methods which are applicable while studying at the university. However, she stated that she could not prefer to use these assessment methods due to several obstacles such as time limitation, curriculum, high number of students. Therefore, she tended to choose traditional assessment methods to assess students' understandings instead of alternative assessment methods. The related excerpts from the interview were as follows;

Researcher: How do you see yourself in finding assessment ways to evaluate your teaching?

Esra: I think that I can be better about finding ways to evaluate my teaching. We have learned many assessment methods at university. For example, portfolios… There are lots of assessment techniques. But after I started working as a teacher, I understood that these assessment techniques take too much time. I have lots of obstacles such as curriculum, high number of students, school disciplines… We may not set a clear criterion for assessment because there are individual differences and therefore, assessment can be misleading. That's why, I usually prefer to use traditional methods. But I think that if I overcome these obstacles, I could be much better about finding ways to evaluate my teaching.

Researcher: How did you come to this opinion?

Esra: While studying at university, I believed that these methods were applicable. We applied these methods in university times. But when we start working at school as a teacher, we don't have enough time to apply these methods because the number of students is too much or our classroom environment, school environment may not be appropriate. I know and believe that these methods are very good and applicable. But I still think I will use these methods if appropriate environment will be provided or if I can provide appropriate environment to apply these methods.

[PCK Pre-Interview]

Her enacted PCK generally confirmed her reported PCK because she used both summative (e.g., matching type, open-ended, true/false, fill in the blank, and multiple-choice questions, giving homework) and formative (e.g., questioning method) assessments. But, in addition to her reported PCK, she also had students do make research about some concepts as a homework (i.e., summative assessment).

As formative assessment, during her teaching, she frequently used questioning method. For instance, she repeated the seasons topic by asking many questions to the students. The dialogues were occurred between teacher and students as follows;

Esra: Last week, we have learned the formation of the seasons. Now let's repeat it [the formation of seasons] again. How the seasons occur? In what order do they [seasons] follow each other?

S_1: Autumn, spring, summer, winter.

Esra: Is spring coming after autumn?

S_2: Spring, summer, autumn, winter.

Esra: Yes. The seasons are followed as spring, summer, autumn and winter. How the seasons occur?

S_3: Mam…. It is due to 23.5° tilted axis [of Earth].

Esra: Due to the [Earth's] tilted axis, the seasons occur. Which degrees did you say?

S_4: 27°.

S_5: 23.5°.

Esra: It is 23.27°, but we accept it as 23.5°. Earth's tilted axis is 23.5° and the seasons occur as a result of [Earth's] tilted axis. When does the winter begin in Northern Hemisphere?

S_6: On December 21.

Esra: It [winter] starts on December 21st [in Northern Hemisphere]. In line with this idea, when does the summer begin in Southern Hemisphere?

S_7: On June 21.

Esra: No. I'm asking about the Southern Hemisphere.

S_8: On December 21.

Esra: Yes, it is on December 21st. When it is summer in Southern Hemisphere, it is winter in Northern Hemisphere.

[Classroom Observation]

In her teaching, as summative assessments, she used several types of questions to assess students' understanding related to the seasons, weather, and climate. For example;

- She asked students to complete the unit evaluation questions regarding the seasons, weather and climate found in the science textbook approved by the MoNE as a homework. In the unit evaluation questions, there are different types of questions including matching type, open-ended, true/false, fill in the blank, multiple-choice questions. Then, in the next lesson, she checked students' responses, and asked questions found in the science textbook to the students.
- She drew the figure related to the formation of seasons on the blackboard, and then, as a homework, she asked the students to draw the formation of seasons in their notebooks without looking at any book or source. Then, she checked the students' drawing to understand whether they learned the formation of seasons.
- At the end of the lesson, she distributed tests from other textbook published by different publishers to the students and asked them to solve the multiple-choice questions. After students completed solving these questions, she explained the questions that they had difficulty in understanding.
- Students were requested to do research about the types and features of climate (e.g., Mediterranean, black sea, terrestrial, tropical, oceanic, monsoon), ozone layer, greenhouse gases, and global warming concepts, and to write their reports in their notebooks. In the next lesson, she invited students who completed their homework to the blackboard and each student read their reports related to ozone layer, greenhouse gases and global warming concepts.

Although Esra did not mention in the pre-interview, she gave homework regarding the seasons, weather, and climate topic to the students in the lesson. In the post-interview, when asked her reasons, she highlighted that she aimed to provide students to do research by themselves by giving homework. The related excerpts from the post-interview were as follows;

> Researcher: During the pre-interview, you did not mention that you give homework about the seasons, weather, and climate topic to the students. But

in your teaching, you gave several homework such as research homework, tests to your students. Can you explain the reason why you give homework?

Esra: Besides what they [students] have learned in classroom, I give research homework to show that they [students] should do research.

[PCK Post-Interview]

Moreover, in the pre-interview, she said that she will perform the general assessment after the seasons, weather, and climate topic is completed. In the post-interview, she was asked when she will perform general assessment to confirm her response in the pre-interview. As she said, in the post-interview, she stated that she will perform the general assessment exam in later times. She added that through monthly exams, teacher receives information regarding level of students' achievement depending on schools, districts, province as well as country. The related excerpts from the post-interview were as follows;

Researcher: At the end of the pre-interview, you mentioned that you will also assess the students' understanding with a general assessment after the seasons, weather, and climate topic is completed. Will you make the general assessment at later times?

Esra: Yes. I will do it [the general assessment] later. Also, we have common exams that are administered as monthly. These exams include questions from mathematics, Turkish, science and social studies. These exams give various data related to students' [achievement] level. For example, I only teach 8th grade students in this year. These exams inform us about whether the 8th grade students' [achievement] level above or below the school average and also, these exams give information about students' [achievement] level based on districts, province and country.

[PCK Post-Interview]

4.3.3.6 General Summary of Esra's PCK

In this section, Esra's PCK general summary related to teaching the seasons, weather, and climate topic was reported in Table 4.79.

Table 4.79 *Esra's PCK in Teaching Regarding the Seasons, Weather and Climate Topic*

	Orientation Toward Science		Knowledge of Curriculum	Knowledge of Students' Understanding	Knowledge of Intsructional Strategies	Knowledge of Assessment
Esra	**Central Goal** Subject matter goal Schooling goal	**Peripheral Goal** Schooling goal Affective goal	**Goal and Objectives** Expressed all objectives ***Vertical Relations*** -The Earth's shape at 3rd grade -The movements of the Earth at 4th grade -The Sun, Earth, and Moon, Change of state of matter, and Human and Environment Relationship at 5th grade -The concept of density at 6th grade -The pure substance and mixture at 7th grade ***Horizontal Relations*** -Matter cycles and Environmental problems, and Interaction of matter with heat at 8th grade **Materials** Science Textbook Other textbooks published by different publishers Worksheets prepared by her Globe Model Videos	**Prerequisite Knowledge** (See Vertical Relations) **Students' Difficulties** -Confusing the concepts of weather and climate -Understanding the Earth's tilted axis and its' impact on the seasons → Eliminating by drawing figure, scientific explanation, and video **Misconceptions** -Confusing the concepts of weather and climate - The relationship between the formation of day and night and revolution of Earth around the sun - The relationship between the formation of seasons and distance of the Earth to the sun → Eliminating through drawing figure, video, and scientific explanation - Failed to recognize students' misconceptions as to global warming and ozone layer depletion concepts	**Subject-Specific Strategies** Direct Instruction Questioning **Topic-Specific Strategies** **Representations** Showing simulation Showing videos Drawing figures Giving examples Using a globe model Analogy **Activities** Model building activity was stated, yet not performed in teaching	**Dimensions of Science Learning to Assess** Assessing students' knowledge related to the seasons, weather and climate topic Assessing students' knowledge regarding dual perspective **Methods of Assessment** ***Formative assessment*** Questioning method ***Summative assessment*** -Completing the unit evaluation questions (e.g., matching type, fill in the blank) - Having students do research about the concepts as a homework -Solving multiple-choice questions from other textbooks published by different publishers -Illustrating seasons through drawing

4.3.4 Esra's Teaching in terms of Dual Perspective

In this section, Esra's teaching was assessed in terms of dual perspective, by utilizing the whole data used for PCK and SMK. Analyses of all data set revealed the extent to which she was aware of the importance of growing students who are conscious regarding tasks and responsibilities toward environment and environmental problems, but she emphasized the collective actions or government-based actions rather than students' own actions.

During interview sessions (i.e., PCK pre-interview and SMK interview), for example, when asked whether there are important points to be emphasized apart from existing objectives, she emphasized the dual perspective stating that *"Definitely, I mention about the global warming in the lesson. Because I believe that each student should develop environmental awareness and therefore, the unit should be designed around daily life application of the concept apart from science achievement only."*

[PCK Pre-interview-Knowledge of Curriculum Section]

Similarly, she pointed out the both human- and government-based actions to prevent and mitigate the adverse effects of the climate change and global warming. She addressed the importance of growing environmentally aware children and significance of raising environmentally conscious people related to environmental pollution (e.g., air pollution, water pollution, soil pollution). When asked the precautions taken by the world's countries to prevent global climate change, she mentioned about government-based actions by stating that climate change should be taken into consideration in agreements signed by countries and that these agreements should be implemented by all countries. Lastly, she addressed Greenpeace environmental organization, most famous organization, studying on the climate change. Examples of excerpts were provided below:

> Researcher: Do you think that is there anything to do to mitigate and combat with the effects of climate change and global warming?

Esra: First of all, people need to be convinced that climate change is really occurring. … For me, primarily, people should accept that the earth is a habitat [shared by many organisms] and [it is] not a place belonging to people only …. that climate change is really happening and that this [climate change] will lead to disaster for all societies living in the world. After that, I think that more comprehensive studies [on mitigating and preventing the effects of climate change] can be carried out properly. First, humans may think that "It [climate change] doesn't affect me or I don't need to do anything [to reduce the effect of climate change]". Therefore, at the first place, societies need to be made aware of this issue [climate change] … on the other side, it is wrong to expect actions on this issue [climate change] from the society only... This issue [climate change] needs to be considered in agreements among countries [as well] … all countries should be involved in implementing the rules [presented in] agreements [regarding the climate change] …. not only certain countries…. For example, the most famous organization that study on this issue [climate change] is the Greenpeace Environmental Organization.

Researcher: Well, what do you think about the duties and responsibilities of individuals in preventing climate change?

Esra: I believe that I can change somethings, if I raise environmentally aware students or children… It bothers me, if I see a person throwing trash on the ground. This [feeling] shows that I have some degree of awareness. Protecting the environment is not just about avoiding throwing waste in environment… [but] environmental pollution can [also] occur in many areas such as air pollution, water pollution, soil pollution and people need to become conscious about environmental pollution.

As it was seen in the interview, she mentioned about knowledge aspect of action competence concept and tasks and responsibilities to be taken toward environmental issues.

Likewise, while teaching the seasons, weather, and climate topic, Esra addressed the knowledge, vision and commitment aspects of action competence (See Esra's knowledge aspect of action competence more in Esra's substantive knowledge section related to the seasons, weather, and climate in detail).

In her teaching, she addressed environmental problems and tasks and responsibilities of individuals to prevent environmental problems (i.e., knowledge). For example, as reported in SMK section, she mentioned about the impact of global warming on several areas such as climate, weather (i.e., knowledge). Then, she expressed solutions and her opinions to prevent the climate change and global warming including encouraging people to use renewable energy sources and mentioned about government-based actions like Kyoto protocol (i.e., commitment). She addressed the renewable and nonrenewable energy sources in line with the precautions to be taken to the prevent the environmental problems (i.e., knowledge) as well. For example, she drew attention that the renewable energy sources should be used in order to prevent the spread of greenhouse gases (i.e., vision). She proceeded her lesson through questioning-answering sessions, in attempt to develop her students' action competences. In this way, she encouraged her students to express their knowledge, visions and commitment for the future related to environmental problems. For instance, after she asked *"What can be done to encourage people to use renewable energy sources?"* (i.e., commitment), one student said that *"The governments can purchase or use the electrical car."* (i.e., commitment) and another student said that *"To create awareness, the videos or simulations about environmental problems can be shown to politicians and people in the countries."* (i.e., vision). She enriched her lesson by showing several videos through smart board related to precautions taken to prevent the environmental problems. For example, she showed a video related to actions that harm the ozone layer (e.g., use of chlorofluorocarbon (CFC), use of insecticides such as methyl bromide and industrial pollution) and addressed the ways of protection from harmful effects of rays coming to Earth as a result of damages in ozone layer (e.g., using sunscreen, using sunglasses, CFC degassing of refrigerators). She also showed additional video about the precautions to be taken to prevent the effects of the global warming and climate change (e.g., Kyoto Protocol). At the end of the lesson, she assessed her students' knowledge related to environmental problems and precautions that are taken to prevent the environmental problems by using the multiple-choice questions found in other textbooks published by different publishers (See PCK – Knowledge of Assessment).

In attempt to raise environmental awareness, she mentioned about the renewable and non-renewable energy sources. For example, she pointed out that renewable energy sources should be used while emphasizing that non-renewable energy sources should not be used. She initiated a question-answer session to allow students expressing their ideas:

> Esra: What are the renewable energy sources?
>
> S_1: Solar energy.
>
> Esra: Solar energy is a renewable energy source. But, at first let's explain what does renewable energy source mean?
>
> S_2: [Renewable energy sources are] never depleted…. never run out …resources that do not harm the nature.
>
> Esra: Yes. Energy sources that never run out and do not harm nature are called renewable energy sources. On the contrary, the nonrenewable energy sources, which are harmful and limited in supply. What other examples can you give for renewable energy sources?
>
> S_3: Wind.
>
> S_4: Hydroelectrical [energy].
>
> Esra: Hydroelectrical energy [hydropower] can also have environmental impacts. It [hydroelectrical energy] needs water movements [flowing water] [to produce energy]. Therefore, it [hydroelectric energy] can cause depletion of the water sources of the villagers who live nearby [near those dams]. ...Next example for renewable energy sources?

S_5: Geothermal energy.

Esra: What is geothermal energy?

S_6: The water beneath the ground warms up and then reach to the surface.

Esra: Coming out of hot water from deep within earth to the surface. I know an example... Sandıklı region, a city famous with its' baths. People living in that region [Sandıklı] don't depend on natural gas or coal for heating. They use hot water [subterraneous] for heating.

S_7: Biomass.

Esra: What is this [Biomass]?

S_8: It is the waste of the living things…

Esra: The waste of living things is converted [to produce fuel], it is called [bio] mass energy. Non-renewable energy sources are tended to be limited in supply and cause pollution.

S_9: Petroleum.

S_{10}: Coal.

S_{11}: Natural gas.

S_{12}: Fossil Fuels.

[Classroom Observation]

Then, she began to talk about the government-based actions related to the prevention of the climate change and global warming, such as Kyoto Protocol. Then, she created a learning environment, using questioning method, which allowed her students to discuss their ideas. During the lesson, the following dialogues were occurred between teacher and students as follows;

Esra: All of fossil fuels cause pollution and therefore results in global warming... 191 countries and the European Union signed the Kyoto protocol to provide renewable energy transformation. Did the countries follow these protocols?

S_1: No.

Esra: Countries do not follow the protocols they signed; they just signed… never obey the regulations… What can be done to encourage countries to follow these protocols? …People don't follow these protocols as well… What can be done to encourage people to use renewable energy sources?

S_2: To create awareness, the videos or simulations [about environmental problems] can be shown to politicians and [people living in] countries...

Esra: You mean that education is the solution.

S_3: The governments can purchase or use the electrical car.

Esra: Use of electric cars should be supported. Well, what will happen if the electric used in those cars generated from [geo]thermal power plant?

S_4: [dilemma] …. difficult to decide!......

Esra: Yes, difficult choice to be made... People are ignoring the warning about environmental problems. In this country [Turkey], first of all, government should implement practices that encourage people to take precautions against environmental problems.

S_5: [For example], every individual should give money [donation], for example, to launch satellites to the atmosphere to filter the gases.

Esra: Yes, you are right… [Moreover], to prevent the spread of greenhouse gases to the nature, renewable energy sources should be used. We [humans] should give up using nonrenewable energy sources.

[Classroom Observation]

Toward the end of the lesson, she asked students writing a report on ozone layer, greenhouse gases and global warming as a homework. In the next lesson, she checked students' homework and asked to read their reports. Moreover, she distributed the tests including multiple choice questions two of which assessed the students' knowledge related to environmental problems and precautions taken to prevent the environmental problems (i.e., dual perspective). (See more detail in PCK-Knowledge of Assessment).

As a result of all data, it could be concluded that she, though, addressed the knowledge dimension as well as the students' development of action competence throughout her lesson, the students' own responsibilities or pro-environmental behavior was not mentioned. Rather she focused on collective action or government-based actions regarding the prevention of the global warming and climate change. Summary of Esra's views regarding human-based and government-based actions to be taken to prevent the climate change and global warming based on interview and classroom observation data were shown in Table 4.80.

Table 4.80 *Esra's views regarding Human-based and Government-based Actions to be taken to prevent the Climate change and Global warming*

	Interview Data	**Classroom Observation Data**
Human-based Actions	▪ Convincing existence of climate change ▪ Raising environmentally awareness children ▪ Becoming aware of the climate change ▪ Becoming conscious about environmental pollution (e.g., air pollution, water pollution, soil pollution)	▪ Using renewable energy sources to avoid greenhouse gases emission ▪ Avoiding using nonrenewable energy sources ▪ Encouraging people to use renewable energy sources through education ○ Showing documentaries or simulations related to the environmental problems to create awareness among politicians and people living in countries
Government-based Actions	▪ Signing agreements	▪ Signing the Kyoto protocol among 191 countries and the European Union to provide renewable energy transformation ▪ Purchasing or using the electrical car ▪ Sending the satellite to the atmosphere to clean the gases with a filter in atmosphere ▪ Implementing practices that encourage people to take precautions against environmental problems

Overall, summary of Esra’s dual perspective based on interview and classroom observation data was shown in Table 4.81.

Table 4.81 *Summary of Esra's Dual Perspective*

PCK Pre-Interview				Substantive Knowledge Interview	
				Types of Actions	
"I mention about the global warming in the lesson. Because I believe that each student should develop environmental awareness and therefore, the unit should be designed around daily life application of the concept apart from science achievement only." [Knowledge of Curriculum]				**Human-based Actions**	**Government-based Actions**
				Mentioned	Mentioned
Classroom Observation					
The Aspects of Action Competence				**Types of Actions**	
Knowledge /Insight	**Vision**	**Commitment**	**Action Experience**	**Human-based Actions**	**Government-based Actions**
Mentioned	Mentioned	Mentioned	Not Mentioned	Mentioned	Mentioned

CHAPTER 5

DISCUSSION, CONCLUSION AND IMPLICATIONS

In this study, three in-service science teachers' SMK and PCK on the seasons, weather and climate topic were investigated using Magnusson and his colleagues (1999) Model of PCK. In this chapter, the findings of the study regarding in-service science teachers' SMK (i.e., substantive knowledge, syntactic knowledge), PCK related to the seasons, weather and climate were discussed in detail by taking their dual perspective into consideration, and interpreted in the light of contextual factors.

Overall data showed that science teachers' SMK appears to have an effect on their PCK. For example, science teachers' lack of substantive and syntactic knowledge (i.e., NOS knowledge) regarding the concepts of climate change, global warming and greenhouse effect may have negatively affected their confidence and so, directed them to teacher-centered orientation followed by teacher-centered teaching methods. Their SMK were also found to be effective upon their knowledge of students' understanding (i.e., students' misconceptions and learning difficulties). To make it clear, their deficient knowledge and misconceptions regarding the concepts of the climate change, greenhouse effect and global warming may have caused them inadequate about knowledge of students' learning difficulties and misconceptions about these concepts.

Also, at first glance, there seems to some interactions among PCK components. For example, science teachers' teacher-centered orientations were appeared to direct them to use teacher-centered teaching methods in general. Their knowledge of instructional strategies were seemed to be affected by their knowledge of curriculum because they did not implement some activities in the science textbook. There seems to be a relationship between their knowledge of instructional strategies and knowledge of students' understanding because they were able to identify some students' learning difficulties and misconceptions through questioning method. However, they generally applied teacher-centered methods to eliminate them, which indicates that their knowledge of students' understanding was affected by their teacher-centered orientation. Their knowledge of assessment was appeared to be impacted by their knowledge of students' understanding. To illustrate, their misconceptions especially regarding climate change, greenhouse effect and global warming may have restricted them to assess students' knowledge regarding these concepts. Related literature shows that several research aimed to find out interactions among PCK components (e.g., Aydin, & Boz, 2013; Henze et al., 2008; Kaya, 2009; Mavhunga, 2018; Park, & Chen, 2012; Soysal, 2018; Şen, Demirdöğen, & Öztekin, 2022). For instance, Şen et al. (2022) found that interactions among components of PCK vary upon content knowledge. Teacher who is content novice possessed PCK map with the least interaction, while teacher who is dependent on the curriculum had PCK map with richer interactions than content-expert one. Şen et al. (2022) stated that content knowledge may be necessary factor to have an integrated PCK.

Figure 5.1 shows the concept map that representing the interactions among the science teachers' SMK, PCK and contextual factors in the context of the seasons, weather, and climate topic. The arrows in the concept map show the interaction between the concepts.

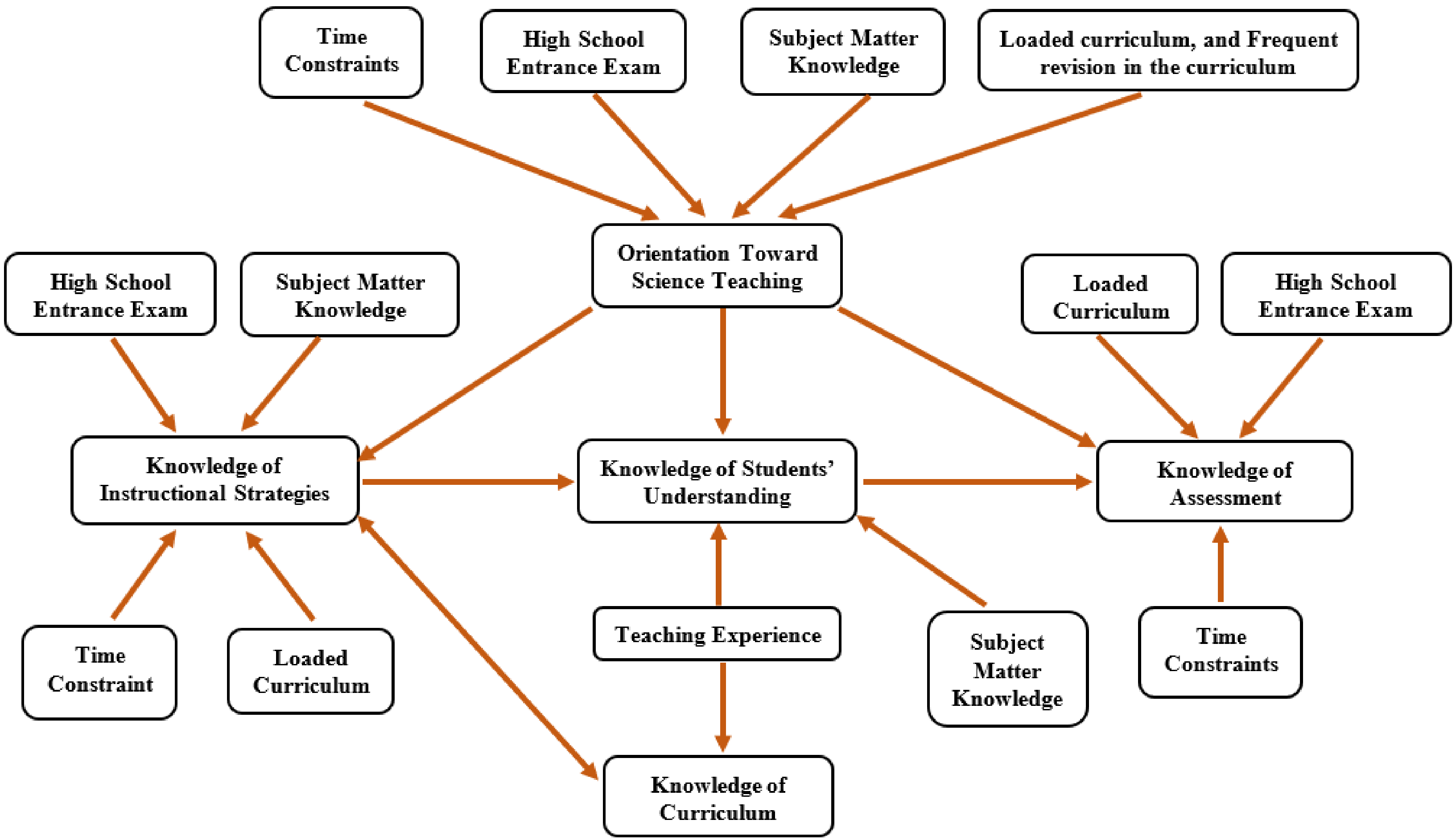


Figure 5.1 The Concept Map Showing the Interactions among Science Teachers' SMK, PCK and Contextual Factors Regarding the Seasons, Weather, and Climate Topic

First, findings about science teachers' substantive knowledge regarding seasons, weather and climate topic followed by syntactic knowledge (i.e., NOS understanding) were discussed. Second, findings about science teachers' PCK regarding seasons, weather and climate topic were discussed. Lastly, the implications and recommendations of this study were reported.

5.1 Discussion on In-service Science Teachers' Subject Matter Knowledge

In this section, science teachers' substantive knowledge (i.e., seasons, weather and climate) in relation to syntactic knowledge (i.e., NOS understanding) were interpreted and compared and contrasted with the available literature.

As far as SMK taking into consideration, in this study, all science teachers appeared to be more knowledgeable about concepts of the seasons, weather and climate compared to other concepts: climate change, global warming and greenhouse effect. For example, they were able to describe the causes of the seasons as the Earth's revolution around the Sun and Earth's tilted axis, which was compatible with the scientific explanation. Their interview findings were also supported by classroom observation findings. During their teaching, they mentioned about the seasons and causes of seasons correctly; they pointed out the equinox and solstices dates. Besides, all of them drew figures/models related to the causes of seasons on the blackboard correctly. By this way, they tried to enrich their teachings on the seasons to facilitate their students' understanding. In addition, they addressed the formation of day and night in their teaching by stating that the Earth's rotations around itself leads to the formation of day and night. Any misconception was detected regarding seasons and the formation of day and night neither in their interviews nor teachings.

As a result, it can be concluded that all science teachers were found to be knowledgeable about the seasons. This finding, in fact, is not surprising because the seasons are not a new topic in the science curriculum. It has been located in the curriculum for years (see MoNE 2005, 2013, 2018), and also due to the spiral nature of the science curriculum, students were taught the concepts related to the seasons starting from 3rd grade to 8th grade. Since the participated science teachers have more than ten years of experiences, they have taught the seasons for a long time. Considering the related literature, it can be seen that the studies conducted with experienced teachers and in-service teachers are rather limited. While some partly supported the findings of the current study (e.g., Kikas, 2004; Mant, & Summers, 1993; Parker, & Heywood, 1998), others (e.g., Bulunuz, & Jarrett, 2010) produced opposite results. For example, similar to the findings of this study, in UK context, Mant and Summers's (1993) study about seasons, [also phases of the moon, day-night, solar system and the universe) indicated that majority of the primary school teachers have sound understanding of the formation of day and night. Fewer teachers expressed the scientific concepts responsible for seasons such as "Earth tilted", "Tilt causes changes in intensity, i.e. heat, light more 'spread out", "Yearly orbit", "Summer towards Sun, winter away from Sun" (Mant, & Summers, 1993, p.113). Unlike from the current study, their study also reported teachers' misconceptions related to the association between the formation of seasons and the alteration in the distance between the Sun and Earth. For instance, teachers stated that "In the summer the Earth was tilted towards the Sun and part of the Earth was therefore physically nearer"; "the Earth moved in an annual cycle relative to the Sun and was not tilted. In the summer the Earth was nearer to the Sun in its yearly motion." (Mant, & Summers, 1993, p.113). Mant and Summers (1993) concluded that the mental models that teachers make about the universe are incompatible with scientific explanations, causing them to use false expressions with respect to the seasons, phases of the moon and day-night. We agree with the idea of Mant and Summers (1993) who stated that teachers' lack of experiences and direct observations which are the necessary for teaching these concepts, as another reason for their deficient knowledge. In UK context, Parker and Heywood (1998) found that proportionally more teachers compared to graduate and undergraduate students defined day and night scientifically, and students had misconceptions. Contrary to this study, very few participants were able to define the seasons scientifically, but the number of teachers were proportionally higher here. All of them had misconceptions, especially in the students. For example, they thought that while axis of the earth tends to oscillate towards the sun in summer season, it tends to oscillate distant to the sun in winter season. Researchers implied that teachers have relatively few misconceptions compared to students because they have experience in teaching concepts. Current study supports the findings of Kikas (2004) in which she found that majority of teachers with varying degrees of teaching experience (range from 1 to 16 years) were able to make scientific explanations for seasonal changes compared to pre-service teachers. However, contrary to current study findings, Kikas (2004) found that both of them had also misconceptions, for example, they stated that “the only possibility *not* to have temperature changes between summer and winter is to live near the equator.” (Kikas, 2004, p.442). Similarly, Bulunuz and Jarnett (2010) found that most of the elementary teachers having teaching experience between one and three years had misconceptions regarding the seasons such as the associating the formation of seasons with the distance of the Earth to the Sun.

The studies conducted with pre-service teachers (e.g., Atwood, & Atwood, 1996; Atwood, & Atwood, 1997; Kücüközer, 2007; Sebastià, & Torregrosa, 2005; Starakis, & Halkia, 2013) and students (e.g., Hsu, 2008; Starakis, & Halkia, 2013), on the other, generally reported the misconceptions that participants have. For example, studying with pre-service elementary teachers in USA, Atwood and Atwood (1996) indicated, as opposed to the findings of this study, that teacher candidates had misconceptions as to the causes of seasons such as “the rotation of the earth on its axis”, “the distance of the earth from the sun”, “the way the earth is positioned on its axis; the part facing the sun is having summer”, “the closeness of part of the earth due to the earth’s tilt” (Atwood, & Atwood, 1996, p.557). According to Atwood and Atwood (1996), the misconceptions of pre-service teachers might be attributed to the lack of adequate education and highlighted the need of a short-term training program that focus on eliminating misconceptions. A similar finding was reported by Sebastià and Torregrosa (2005) in Spanish pre-service elementary teachers (“days are longer in the summer and shorter in winter, with intermediate values in spring and autumn" (Sebastià, & Torregrosa, 2005, p.123)). Starakis and Halkia's (2013) study with Greek pre-service teachers and primary school students indicated that they generally attributed the reason of seasonal change to the change in the distance between the Earth and Sun and change in the Sun-Earth relative orientation, and researchers stated that this notion can be related to the everyday experience (Starakis, & Halkia, 2013).

Overall, those findings tended to support our claim that being familiar with the concepts of seasons, experienced teachers were knowledgeable. Participants also tended to use their knowledge to teach the concept effectively in the class (See following in PCK discussion part).

Similar to seasons concepts, all science teachers were found to be knowledgeable about the concepts of weather, climate (See Table 4.2, 4.4, 4.29, 4.31, 4.56, 4.58), and differences between the weather and climate (See Figure 4.3, 4.30, 4.57).

Those findings are not surprising considering that participated science teachers have more than ten years of experience, and taught these basic concepts for a long time. They were able to define these basic concepts since the weather and climate related concepts were taught within various topics from 3rd grade to 8th grade in the curriculum for years (See MoNE 2005, 2013, 2018). They also, may have awareness regarding the concepts of weather and climate due to the relevance to daily life. As a matter of fact, in their teachings, they mentioned about the daily weather events or climate types experienced in a particular region or city of Turkey, or weather forecast made by meteorologists and the importance of weather forecasts in people's daily life. To our best knowledge, there are limited studies conducted with experienced teachers, and pre-service teachers. While few study partly support the findings of the current study (e.g., Lambert et al., 2012), others generally reported opposite results (e.g., Bostrom, Morgan, Fischoff, & Read, 1994; Lane, 2015b; Mandrikas et al., 2017). For example, in USA context, Lambert et al. (2012) conducted a study with experienced in-service and pre-service teachers, and found that few participants were able to express the differences between the climate and weather, and some participants had partial understanding. Contrary to the findings of this study, some of them were not able to express them. Mandrikas et al. (2017) found that preservice elementary teachers confused the concepts of climate and weather. For example, one of them stated that "Pindos is the largest mountain range of Greece. So, in the mountainous regions of Pindos the weather is continental" (Mandrikas et al., 2017, p.244). Also, they expressed the wind as an only factor that lead to change occurred in weather. Similar findings were reported by Bostrom et al.'s early study (1994) in USA public, including well-educated participants in a university, they stated that "climate is the weather conditions that are on the earth", "Climate is the weather" (Bostrom et al., 1994, p.964).

Among the studies carried out with students of different grade levels, however, generally reported students having lack of knowledge and misconceptions (e.g., Cepni, 2014; Henriques, 2002; Yılar, 2007). For example, Yılar (2007) attributed the fifth grade students' lack of knowledge about the concept of climate to the teacher, and insufficient teaching methods, and based on these results, he emphasized that the teachers need to have teaching experience and knowledge in order to provide an effective teaching. Cepni (2014) attributed the inconsistency of students' metaphors about weather event with its' definition in the literature to students' deficient knowledge about weather event, which might be originated from the teachers' incompetence, and so underlined that teachers should possess sufficient experience and knowledge regarding geography. These explanations tended to confirm our claim that experienced science teachers were knowledgeable regarding the weather and climate, although current study did not intend to investigate students' knowledge on weather and climate concepts.

When asked climate as a system, all science teachers had a common idea that climate is a system. Overall findings showed that the interactions between the components in the climate system are based on cause-effect relationships, their ideas generally seem to tend to have a linear mindset and they frequently mentioned about atmosphere component while establishing interactions between the components. All of them were aware that any change in the component affects another component, and explained by giving examples. Current study findings are similar to the findings of Shepardson et al.'s (2014) study with seventh grade students. For example, Shepardson et al. (2014) found that the students established interactions based on linear and unidirectional cause-effect relationships between the components of the climate system and often mentioned the atmosphere as a component. Shepardson et al. (2014) stated that students' educational experience obtained about natural systems (e.g., ecosystem) in their schools away from the systems approach may have affected their systems thinking. Shepardson et al. (2014) emphasized the importance of the support of climate and science educators in order to advance teachers' knowledge regarding the Earth's climate system as well as the pedagogical approaches necessary for educating students about this system and the process of change in it.

Besides basic climate concepts, the concept of climate change was placed in the "seasons and climate" unit at the eighth-grade level in the curriculum and therefore, science teachers' knowledge regarding climate change were assessed. Considering the relevant literature, climate change is defined as a complex (Ratinen, Viiri, & Lehesvouri, 2013) and critical (Papadimitriou, 2004) global environmental problem. However, in order to comprehend the climate change that occurs in consequence of global warming (Papadimitriou, 2004), it is necessary to have knowledge about the greenhouse effect (Ratinen et al., 2013). Accordingly, the global warming and greenhouse effect concepts with cause-effect relationship regarding the concept of climate change were also included in the current study.

Considering all findings of this study, it can be concluded that although science teachers considered a cause-effect relationship among climate change, global warming and greenhouse effect, they seemed to have difficulty in explaining them since they had lack of knowledge and several misconceptions. Since the concepts of climate change, global warming and greenhouse effect are in a cause-effect relationship with each other, their deficiencies in one concept may have caused them to be deficient in the other concept as well. The fact that they were knowledgeable about basic concepts such as seasons, weather and climate and have important deficiencies in these concepts may be related to the fact that they include more complex and abstract concepts. As some of the participants mentioned (See SMK and PCK interview), it can be concluded that the knowledge obtained from the media (e.g., news) and the deficient education in undergraduate years may have caused science teachers to have incomplete knowledge and misconceptions about these issues. So, we support Akerson (2005) who stated that elementary teachers might have lacking knowledge regarding the science conceptions and for developing their knowledge in science, the lesson they take at the university might not be sufficient. Also, they tended to teach the topic by following the curriculum (See PCK pre-interview) and so climate change, global warming and greenhouse effect were not mentioned in detail in the science textbook may have caused their knowledge to be limited. In this context, Arzi and White (2008) conducted a longitudinal study lasting 17 year examining the alterations in teachers' knowledge regarding topics they taught, and we support their conclusion that the school curriculum is the source and organizer of knowledge and has a strong impact on content knowledge of teacher.

Participating science teachers' misconceptions regarding the climate change, global warming and greenhouse effect in this study were similar to the misconceptions of in-service teachers in the literature (e.g., Daskolia et al., 2006; Herman et al., 2017; Michail et al., 2007). Similar to the current study, in Greece context, Daskolia et al. (2006) found that kindergarten teachers had misconceptions, for example, they associated the global warming and climate change with depletion of ozone layer. Different from the current study, they had also another misconception as to the relation between greenhouse effect and hole in ozone layer. We agree with Daskolia et al. (2006) who stated that their views regarding environmental problems like greenhouse effect and ozone layer depletion may be affected from the abstract, uncertain and complex nature of concepts, media and their own experience. Michail et al. (2007) found that Greek primary school teachers had misconceptions about the greenhouse effect and ozone layer depletion. For example, they stated that the rise in global warming triggers the depletion of the ozone layer, and they had difficulty in understanding the natural greenhouse effect. In addition, unlike this study, they associated the greenhouse effect with the depletion of the ozone layer. We agree with Michail et al. (2007) who attributed the reason for teachers' misconceptions to the fact that the knowledge in the environmental media may be incomplete, misleading or erroneous. In USA context, Herman et al. (2017) found that secondary science teachers had misconceptions regarding the climate change like; for example, they believed the primary cause of climate change as depletion of ozone layer. Unlike the current study, they associated the climate change with using of pesticides and aerosol. We support Herman et al. (2017) who attributed their lack of knowledge regarding climate change and teaching the climate change science to the inadequacy of the undergraduate education and the inaccurate and superficial knowledge they received from media sources (e.g., television, internet). As Herman et al. (2017) claimed, multi-disciplinary science courses in which research-based pedagogical views are used that are intended for climate change should be involved in science teacher preparation programs.

In addition, participating science teachers' misconceptions were similar to pre-service teachers (e.g., Arslan et al., 2012; Boyes, & Stanisstreet, 1992; Dove, 1996; Khalid, 2001; Ocal et al., 2011; Papadimitriou, 2004; Ratinen, Viiri, & Lehesvuori, 2013) and even students (e.g., Daniel et al., 2004; Gowda et al., 1997; Rye et al., 1997). For example, similar to the current study, Papadimitriou (2004) found that prospective primary teachers possessed misconceptions regarding climate change, greenhouse effect and global warming. For example, they associated climate change with pollution (e.g., air pollution, environmental pollution) and ozone depletion. They related the global warming and greenhouse effect with pollution. They thought that heat is trapped by the layer formed by pollutants (i.e., greenhouse gases) surrounding the Earth while defining greenhouse effect, and as Papadimitriou (2004) stated, this may be a metaphor related to the greenhouse that formed by plastic or glass walls utilized in agricultural area. Similar misconceptions were found by Ratinen et al. (2013) with primary school student teachers in Finland context. We support Papadimitriou (2004) and Ratinen et al. (2013) who stated that there are abstract concepts and process (e.g. wavelength, IR rays, greenhouse effect, electromagnetic spectrum, gases and its' properties, absorption of electromagnetic energy) in the science of climate change, and therefore, participants have difficulties in comprehending climate change. As Ocal et al. (2011) reported, we can attribute the causes of Turkish prospective teachers' misconceptions regarding global warming to use of informal knowledge sources like media and the lack of environmental education provided in teacher training program of universities. As Ocal et al. (2011) suggested, in universities, environment related courses and activities such as conference are needed to be increased.

Overall, those findings tended to support our claim that the complex and abstract nature of concepts, the role of media, and the deficient education in undergraduate years may have led to experienced science teachers to have more misconceptions regarding the climate change, global warming, and greenhouse effect. It was an expected finding that participants tended to use teacher-centered teaching methods (e.g., direct instruction, questioning) in teaching these concepts, and also did not notice students' misconceptions emerged in the lesson (See following in PCK discussion part).

Regarding syntactic knowledge, as a part of SMK, in this study, all science teachers were found to have lack of knowledge regarding NOS and especially embedded NOS. In the context of weather, climate and related concepts, they addressed mainly empirical, tentative, subjective, and inferential NOS, and theory and law, but did not address sociocultural and creative NOS. For example, they had an idea that greenhouse effect could be a theory since studies on it are still going on. Burak also considered that it could be a law in case of the acceptance by the world. So, their responses indicated a common misconception about hierarchical relationship between theory and law. Also, it can be said that their incomplete understanding about the nature of theory and law limited their tentative NOS view. On the other hand, two of them were able to express subjective NOS by attributing the reason why scientists can reach different results using the same data regarding causes of the global warming to their different perspectives, but other teacher was not able to expree any idea. Also, all of them were able to state that climatologists determine the climate based on the past data, and one of them stated that meteorologists make inference depending on the prediction (i.e., inferential NOS). But, their responses on empirical NOS varied depending on context. For example, on one hand, while two of them erroneously stated that scientists are certain about the occurrence of the global warming based on measurements or evidences, Burak was in dilemma about it. On the other hand, they correctly stated that meteorologists make measurements and then, predictions about weather based on the obtained data. In their teachings, they briefly mentioned about empirical NOS saying that weather events are based on prediction, but did not mention about other NOS aspects.

Based on all findings, it can be concluded that their views on NOS aspects are related to each other because they may be affected from each other. Compared to the concepts of weather and climate, their limited knowledge of climate change, global warming and the greenhouse effect may have caused their embedded NOS knowledge of these concepts to be limited. Therefore, it is not surprising that they did not adequately integrate NOS aspects in their lessons. To our best knowledge, studies especially investigating teachers' understanding of embedded NOS are very limited. Science teachers' deficiency about embedded NOS understanding were partly compatible with previous research conducted with in-service teachers (e.g., Yılmaz Yendi, 2019), pre-service teachers (e.g., Bell, Matkins, & Gansneder, 2011; Matkins, & Bell, 2007; Matkins, Bell, Irving, & McNall, 2002), and also students (e.g., Khishfe and Lederman, 2006). Also, similar findings about science teachers' deficiency regarding NOS teaching were reported in previous research (e.g., Hanuscin et al., 2011; Wahbeh, & Abd-El Khalick, 2014). Depending on the related literature, four factors could enlighten why science teachers possessed deficient knowledge regarding NOS, especially embedded NOS and did not able to integrate many NOS aspects into their teachings; lack of undergraduate education, deficiency of subject matter knowledge and NOS knowledge, deficiency of PCK for NOS, and curricular priorities.

At first, a possible lack of undergraduate education may explain their lack of NOS knowledge and teaching. In Turkey, NOS courses are new to the curriculum of undergraduate education, and by means of these courses, pre-service science teachers can learn NOS conceptions, historical development of scientific knowledge, and how they translate their NOS understandings into classroom practice. However, it should be noted that participated science teachers have more than ten years of experiences, and therefore, it is likely that they have not taken NOS courses while studying at university. As a matter of fact, to integrate embedded NOS knowledge into their lessons, they need to be able to associate their NOS knowledge with specific science topics. So, their deficiency in embedded NOS knowledge and not adequately integrating it into teachings may be related to the fact that science topics were taught without NOS emphasis in undergraduate education. Similar finding was reported in previous research conducted with pre-service teachers (e.g., Bilican 2014; Matkins et al., 2002; Matkins, & Bell, 2007) and experienced teachers (e.g., Şen, 2014; Yılmaz Yendi, 2019). Similar to the current study, Matkins et al. (2002) found that most of the pre-service elementary teachers used incorrect bases (i.e. proven or unproven) to define the greenhouse effect as law or theory, that did not consider it as a beneficial event for nature, and that they stated that scientists had a common consensus on the occurrence of global warming. Matkins et al. (2002) attributed their lack of NOS understanding to the fact that NOS is not sufficiently mentioned in the science courses in teacher preparation programs, and also that NOS is handled without contextualized manner. Researchers also emphasized that this situation could cause teachers' very limited mentioning explicitly about NOS in their science lessons. Matkins and her colleagues (Matkins, & Bell, 2007; Matkins et al., 2002) concluded that participants’ NOS views seemed to be impacted positively through explicit contextualized NOS instruction. In this context, the explanations of Matkins and her colleagues also make us think the necessity of contextual and explicit NOS instruction in undergraduate education. Therefore, as Bektaş et al. (2013) suggested, for promoting pre-service teachers’ integration of aspects of NOS into their lessons, instruction on embedded NOS for specific science topic need to be involved in the courses of teacher education programs.

Secondly, science teachers' NOS teaching is impacted by depth of subject matter knowledge and NOS knowledge (Demirdöğen et al., 2016; Schwartz, & Lederman, 2002), and for teaching NOS, it is prerequisite to have NOS knowledge (Demirdöğen et al., 2016). Subject matter knowledge includes syntactic knowledge that implies to NOS understanding (Abd-El-Khalick, & BouJaoude, 1997) and substantive knowledge. Considering SMK findings in this study, science teachers' substantive knowledge and embedded NOS knowledge especially in the context of climate change, greenhouse effect, global warming were found to be incomplete. Also, their lack of substantive knowledge may have caused their embedded NOS knowledge to be limited. For instance, they explained neither the process of the greenhouse effect nor why the greenhouse effect is theory correctly. They did neither define the global warming correctly nor were aware that scientists have different views on the existence of global warming. Therefore, it is not surprising that they did not adequately integrate NOS knowledge into their teachings due to their deficiency of SMK. These findings were consistent with previous research (e.g., Bektaş et al., 2013; Schwartz, & Lederman, 2002; Wahbeh, & Abd-El-Khalick, 2014). For example, Bektaş et al. (2013) found that some pre-service chemistry teachers had deficient knowledge regarding NOS aspects (e.g., tentative NOS, the nature of theory and law), and so had difficulty in explaining the way of integrating their NOS knowledge into the particle nature of matter topic. Some participants, on the other hand, could not translate NOS knowledge into their teaching of particle nature of matter topic, even if they had sufficient NOS knowledge. The researchers attributed the reason for this situation to their lack of knowledge on the topic. Wahbeh and Abd-El-Khalick (2014) found that one of the experienced science teachers, who is an expert on biology, integrated inferential, creative, subjective, empirical, and socio-cultural NOS, and the nature of theory and law into the teaching of heredity and genetics, but she had difficulty in integrating inferential and empirical NOS into teaching of chemical reactions. Researchers attributed her lack of integrating NOS aspects into her teaching to her lack of knowledge regarding mole concept. So, current study findings support Wahbeh and Abd-El-Khalick (2014) who claimed that the fact that science teachers possess a superficial content knowledge regarding science is an obstacle toward their efforts to integrate understandings of NOS into their lessons.

Third factor affecting integration of teachers' NOS understanding into their teachings can be their PCK for NOS. It is necessary for science teachers both to learn NOS and possess knowledge about the way of teaching NOS toward a specific students' group (Faikhamta, 2013). To integrate NOS understanding into teaching, teachers need to have beliefs and intentions toward NOS teaching, have PCK for NOS, and deal with students' ability for learning NOS (Schwartz, & Lederman, 2002). In the science curriculum, it is intended to grow students as science literate individuals (MoNE, 2018), and a crucial element of scientific literacy is NOS (Bell et al., 2011; Faikhamta, 2013). This situation thinks us the necessity of integrating NOS into teaching in order for students to be science literate individuals. In this study, considering their orientations, in their teachings, science teachers' central goals were found to convey objectives and prepare their students for the high school entrance exam, which showed that they had no intention toward teaching NOS. They did not use any teaching methods for NOS teaching. Also, they did not attempt to assess their students' knowledge of NOS, which prevented them to obtain any information about the students' understanding of NOS. Hence, it is reasonable to think that science teachers' PCK for NOS did not develop. These findings are consistent with previous some research (e.g., Abd-El-Khalick et al., 1998; Şen, 2014), partly consistent with other research (e.g., Bektaş et al., 2013; Hanuscin et al., 2011; Wahbeh, & Abd-El-Khalick, 2014). For instance, current study findings while support Hanuscin et al. (2011) who found that teachers did not assess students' NOS understanding, did not support their finding that teachers applied explicit and reflective instructional methods to their NOS teaching. Researchers attributed this to their lack of knowledge regarding the assessment methods for NOS and what to assess about students' knowledge of NOS. We support Hanuscin et al. (2011) who claimed that teachers' inability to assess students' knowledge on NOS may be an obstacle to develop their knowledge of students' understanding and learning difficulties about NOS. Based on current study findings, as Şen (2014) suggested, a professional development program is required for science teachers in order to advance their substantive knowledge, their NOS understandings and their PCK for NOS.

Fourthly, curricular priorities could be another reason affecting teachers’ integration of NOS into their classroom practice (Wahbeh, & Abd-El-Khalick, 2014). Recently [in 2018] in Turkey, a new revision was applied to the curriculum. Looking at the revised curriculum, there are subject matter knowledge objectives specific to the seasons, weather, and climate topic, but there is deficiency of objective with respect to NOS in the context of the seasons, weather, and climate topic. When the science textbook approved by MoNE was examined, it was revealed that NOS was rarely mentioned in the seasons, weather and climate topic, for example, making predictions on the formation of seasons, meteorologists’ studies about the weather and then making predictions. However, there is no emphasis regarding NOS in the context of climate change, global warming, and greenhouse effect. Besides, in the study of Abd-El-Khalick et al. (1998), it was found that pre-service science teachers specified the deficiency of activities and resources to integrate NOS into their teachings. In the same way, Hanuscin et al. (2011) highlighted the deficiency of specific curriculum programs and materials as a factor that restraining teachers’ teaching of NOS. Accordingly, it can be concluded that the lack of curriculum objectives, the lack of emphasis on NOS aspects in science textbook, the deficiency of resources and activities may have prevented science teachers to adequately integrate NOS into their lessons. As Bektaş et al. (2013) proposed, it needs to be covered NOS aspects when curriculum and science textbooks are being reconstructed. Thus, science teachers can be encouraged to integrate their NOS understandings to their teachings by revised curriculum requirements.

As mentioned in the discussion on SMK, science teachers' SMK seem to influence their PCK. Therefore, in the next section, how SMK affects PCK will be explained.

5.2 Discussion on In-service Science Teachers' PCK

Overall, in the context of seasons, weather, and climate topic, it can be concluded that compared to their knowledge of curriculum, experienced science teachers' knowledge of instructional strategies, students' understandings, and assessment appeared to be deficit. Besides, their orientations toward science teaching were found as teacher-centered.

For teaching science, beliefs and knowledge of teachers related to the goals and purposes in specific grade level are described as orientation toward science teaching (Magnusson et al., 1999). Regarding teachers' knowledge and beliefs about the purposes and goals for science teaching, an inconsistency was emerged between what they said in the pre-PCK interview and what they did in their teaching practice. Specifically, pre-PCK interview findings showed that all science teachers' central goals were subject matter goals (i.e., teaching subject matter knowledge) and schooling goals (i.e., establishing a relationship between science education and daily life). In addition, two of the science teachers' central goals were affective goals (e.g. encouraging students to like the science lesson or raising individuals who open-minded). However, in their teaching practice, while their central goals regarding subject matter goals were found to be same, schooling goals tended to be focus on equipping students to high school entrance exam instead of relating this topic with daily life. Hence, it can be said that science teachers of the current study mainly adopted a teacher-centered orientation. In fact, this inconsistency in the schooling goal could be stemmed from a wide range of contextual factors among them are presence of nationwide exams, their level of subject matter knowledge, and finally, the nature of science curriculum which is loaded and subject to frequent revision as also mentioned by the participants. All these factors, except frequent revision in the curriculum, seemed to have a potential to affect teachers' orientation toward science teaching negatively.

For example, in Turkey, Grade 8^{th} is the last grade of middle school, and students are expected to enter high school entrance exam, abbreviated as LGS, at the end of the year. In order for their students to be successful in this exam, teachers prefer to teach the topics strictly by following the curriculum. Accordingly, teachers tend to teach basic knowledge and convey related objectives in the curriculum to the students in their lessons. As far as the location of the seasons, weather and climate topic are considered, science teachers' central goals were found as teaching the objectives in the curriculum and equipping students toward high school entrance exam. In line with the classroom observations, it can be inferred that the presence of the high school entrance exam has an effect on determining the central goals of science teachers in their lessons. Similar findings were reported in previous PCK research conducted on different science topics in both national (Aydın, 2012; Aydın, Friedrichsen, Boz, & Hanuscin, 2014; Ekiz Kıran, 2016; Tıraş, 2019) and international (e.g., Nargund-Joshi, Rogers, & Akerson, 2011; Zhang, Krajcik, Sutherland, Wang, Wu, & Qian, 2003). For example, studied with two Turkish experienced science teachers in the context of ecosystem, Tıraş (2019) reported that the aim of teachers is to provide students with information about the ecosystem in their lessons (i.e., subject matter goal). She stated that teachers' orientation could be affected by the loaded curriculum and the presence of the high school entrance exam. Likewise, working with two Turkish experienced chemistry teachers in the context of nuclear reactions and electrochemical cells, Aydın et al. (2014) found that teachers aimed to teach the topic to students and equip them toward the other nation-wide examination called university entrance exam. Authors attributed to the differences between their goals in their interview and teaching to existence of the university entrance exam and the intensive curriculum.

Similar to the situation in Turkey, India and China's educational system also dependent on nationwide exams and studies conducted in these countries demonstrated that these exams also have an influence on teachers' orientation toward science teaching (e.g., Nargund-Joshi et al., 2011; Zhang et al., 2003). For instance, Nargund-Joshi et al. (2011) found that although the orientations of Indian teachers were revealed to be directed towards inquiry-based teaching, it was observed that they tended to prepare their students for board exams based on traditional teaching in their lessons. Nargund-Joshi et al. (2011) concluded that lots of factors that Indian teachers' feel on themselves such as highlighting board exam-based teaching, big classrooms, time limitation, might explain the differences between their teaching and science teaching orientations. For this reason, instead of implementing reform-minded inquiry-based manner (i.e., constructivist approach), teachers perceived that it was necessary to practice their teaching in the form of too didactic manner (Nargund-Joshi et al., 2011). Zhang et al. (2003) expressed that ideas regarding constructivist practices and theories (e.g., inquiry-based education) have been supported by Chinese science educators, yet this form of teaching was implemented by too few science educators. Zhang et al. (2003) identified college entrance exams as being the greatest factor in the form of science teaching and learning. Also, factors such as crowded classrooms, deficient preparation of teachers to implement inquiry-based teaching, the absence of inquiry-based teaching in China's science curriculum, students' concerns towards this teaching, and the lack of resources for this teaching were identified by Zhang et al. (2003) as barriers to inquiry-based teaching. Therefore, this finding is not surprising and well- parallel with those reported in the literature, generally common across different culture.

As previous studies mentioned, teachers' orientation toward science teaching was also found to be influenced by the nature of science curriculum. In this study, all science teachers emphasized that the location of the seasons, weather, and climate topic in the curriculum at grade 8 has recently changed; it was moved from last units (MoNE 2013) to first unit (MoNE 2018). This change, however, was found to be positive by all participants. They stated that in previous years, due to its' location, the seasons, weather, and climate topic was taught superficially. Besides, existence of the high school entrance exam [LGS in Turkey], which held at the end of the year, was exerted an additional pressure on teacher. As a result, limited time left for the teachers to teach this topic in detail. Combination of these factors may also explain why science teachers adopt teacher-centered orientation rather than student-centered one. On the other hand, it can be inferred that the loaded curriculum may have also led the science teachers to teacher-centered orientation. For example, Beyza stated in the pre-PCK interview that she gives homework to help students learn the concepts due to the loaded curriculum. Therefore, it can be said that the loaded curriculum may have led them to teach the seasons, weather, and climate topic in the limited time by proceeding more teacher-centered rather than student-centered. The findings were compatible with the studies in the literature (Atwood and Sheline, 1989; Aydın, 2012; Aydın, Boz, & Boz, 2010; Ekiz Kıran, 2016; Friedrichsen, & Dana, 2005; Samuelowicz, & Bain, 1992). For example, in Aydın's (2012) study, two experienced chemistry teachers' science teaching orientations were revealed as didactic in the topic of radioactivity and electrochemistry. Aydın (2012) found that due to the loaded curriculum, the limited time required to teach the topics caused teachers not to do the implementations they wanted to do in the classroom (e.g., increasing the students' activeness, performing more experiments). Another study found that experienced chemistry teachers performed only traditional didactic teaching method in their teachings on mixtures topic (Ekiz Kıran, 2016). The researcher explained the reason behind teachers' choice in terms of contextual factors, such as loaded curriculum, existence of nationwide exams and limited time for teaching. Atwood and Sheline (1989) expressed that the fact that most teachers do not contain nuclear chemistry in their lessons may be due to being the nuclear chemistry located in last topics in the textbook. Their study show that the location of the nuclear chemistry topic has an effect on the teaching of the topic, as found in this study.

Another factor influencing the teachers' orientation toward science teaching is regarded as their subject matter knowledge (Avraamidou, 2013; Friedrichsen et al., 2011). In the current study, science teachers' lack of subject matter knowledge regarding climate change, global warming and greenhouse effect topic found to influence their beliefs and confidence about their ability to teach these concepts negatively. Consequently, they preferred to teach this topic by using teacher-centered methods that are compatible with their science teaching orientations. By this way, they kept control of their lesson in their own hands. In this regard, it is not a surprising why participating science teachers have adopted a teacher-centered orientation. Similar to the findings of this study, Yılmaz Yendi (2019) explained that experienced science teachers selected to teach biogeochemical cycles through didactic way (i.e., teacher-centered orientations) due to their lack of subject matter knowledge regarding biogeochemical cycles. Appleton (2002) reported that in Australia, lots of primary school teachers' lack of science background knowledge and their lack of confidence toward science explain their tendency of unwillingness for science teaching to some extent. For example, one of the teachers chose to behave more controlled by showing the hands on activity to the students and then having them this activity (Appleton, 2002), and it can be inferred that the teacher has a tendency to teach the lesson based on teacher-centered approach.

In fact, data regarding knowledge of instructional strategies clearly demonstrated science teachers’ tendency to apply teacher-centered teaching methods. According to available data, this tendency can be explained by a) their science teaching orientation, b) the existence of high school entrance exam (i.e., LGS), c) deficiency of their knowledge on subject-specific strategies, d) lack of their subject matter knowledge, and e) deficiency of their knowledge on topic-specific activity.

At first, as mentioned previously, participants adopted teacher-centered orientation. For example, science teachers’ central goals were determined as to teach the objectives in the curriculum and equip students with knowledge necessary to be successful in high school entrance exam in which questions are asked within the framework of the objectives. According to them, this can be achieved through use of direct instruction. Actually, the existence of high school entrance exam can be associated with loaded curriculum and create time constraints which force science teachers to use teacher-centered teaching methods. As frequently mentioned in the pre-PCK interview, teachers teach the topics strictly following the curriculum which is heavily-loaded. This situation, in turns, restricted the time to be taught through student-centered approaches. All of these factors appeared to force teachers employ teacher-centered approaches in their classes, even if not preferred (see inconsistency between interviews and teaching practice), implying an intention-behavior gap. Similar finding was also found by Aydın et al. (2014), Barendsen and Henze (2019), Brown, Friedrichsen and Abell (2013), Nargund-Joshi et al. (2011) and Zhang et al. (2003). For example, studied with a Dutch experienced chemistry teacher, Barendsen and Henze (2019) reported that although the teacher indicated his intention to use constructivist approach in interviews, he proceeded his teachings, however, through lectures method. According to Barendsen and Henze (2019), the reasons for this discrepancy probably stem from the limited time for teaching, excessive workload, the students' lack of participation in the lesson, his orientations and beliefs (i.e., teaching theoretical chemistry concepts), and his fear about losing control in the classroom. In USA context, Brown et al. (2013) studied with four secondary school biology teacher candidates, and one of them tended to perform teacher-centered teaching methods in his lesson (e.g., explaining function and structure of DNA with lectures), as opposed to his intention of applying the 5E instructional model. Brown et al. (2013) concluded that teachers candidates' orientation towards science teaching (i.e., conveying knowledge by teacher-centered discussion, learning knowledge by discovering) can affect their knowledge of instructional strategies.

Second, science teachers' preference of use of teacher-centered instructions over the student-centered one might be associated with their lack of knowledge about subject-specific strategies (Brown et al., 2013; Tıraş 2019), and their deficiency regarding the knowledge about applying the subject-specific strategies (Aydemir, 2014; Brown et al., 2013; Settlage, 2000). To make it clear, participating science teachers' pre-PCK interview findings indicated that although they stated that the source of their knowledge on subject-specific teaching strategies was their undergraduate education or teaching experiences, they little or no mentioned about subject-specific instructional strategies for teaching the seasons, weather, and climate topic. This situation makes us think about science teachers' lack of knowledge about subject-specific strategies. In addition, as Flick (1996) stated that, the fact that they did not prefer to apply these strategies in their teachings may indicate their deficit experience with respect to the performing of the subject-specific strategies.

Third, science teachers' tendency to apply teacher-centered teaching methods can be attributed partly to their lack of subject matter knowledge (see Aydın, Boz, & Boz, 2010; Boz, & Boz, 2008; Childs, & McNicholl, 2007; Hanuscin et al., 2011; Hashweh, 1987; Kaya, 2009; Rollnick, 2016; van Driel, Verloop, & de Vos, 1998), and partly to their lack of knowledge regarding topic-specific activities (Brown et al., 2013; Veal, & Kubasko, 2003; Yılmaz Yendi, 2019). Participants of this study had relatively higher level of knowledge regarding seasons, weather and climate compared to climate change, global warming and greenhouse effect, and therefore employed topic-specific activities mostly while teaching the concept of seasons, weather and climate. Beyza for example, had her students do a poster activity about the concepts of seasons, weather and climate, and performed two experiments both to eliminate students' learning difficulties regarding the Earth's tilted axis and its' impact on the seasons and to concretize these concepts, but without involving students' science process skills. Burak, although used analogy to overcome students' learning difficulties regarding the Earth's tilted axis as the one of the causes of the seasons, failed to emphasize the breaking points between analog and target concept. Burak and Beyza while performed two drama activities with the aim of showing the Earth's movements and how the seasons occur in a visual way, performed one drama activity to animate how the types of wind or tornado occur, but the students played their roles by taking directions from the teachers. Burak created a concept map to explain the types of weather events, yet students were passive in this process. Although mentioned in the interview, Burak did not perform poster activity and demonstration thinking that this topic was easier than he expected, and Esra did not perform model building activity to show the formation of seasons, believing that such activity takes a lot of time. On the other hand, participating science teachers' substantive and syntactic knowledge in the context of climate change, global warming and greenhouse effect were found as inadequate. While teaching of these concepts, they frequently applied questioning and direct instruction, rather than subject-specific strategies. They used fewer topic-specific representations (e.g., analogy, showing video, drawing figure, daily life examples) as compared to the seasons, weather and climate and did not apply topic-specific activities. What is more, science teachers' lack of SMK may have also influenced their self-efficacy and confidence negatively towards teaching of the concepts of climate change, global warming and greenhouse effect. As a matter of fact, Esra stated that she had deficiencies in topics such as the universe, sun, atmosphere and astronomy which are stemmed from her undergraduate education. Therefore, as Şen et al. (2018) reported, science teachers' self-efficacy regarding SMK may affect their PCK. In turn, their low sense of confidence about teaching of the concepts may lead them employing teacher-centered approaches. Consistent with the current explanations, Kind (2009) reported that having a good subject matter knowledge that promotes the teacher at the point of planning convenient PCK gives them feel of security, and teachers incline to prefer more passive teaching strategies in case they have deficient subject matter knowledge. Similar finding was also reported by Coetzee, Rollnick, and Gaigher (2020), Rollnick et al. (2008) in the South African context and Teed and Franco (2014) in USA context. For example, Teed and Franco (2014) found that when teachers' content knowledge regarding the climate change, weather and climate developed, their confidence toward their ability for science teaching developed and in turn, they became keen to implement various pedagogical approaches (e.g., inquiry learning and cooperative learning methods).

Furthermore, it was seen that while one of the science teachers did not perform any topic-specific activity, other teachers generally performed activities with little or passive involvement of their students in the process (i.e., teacher-centered), and they had deficiencies at the point of implementation of some activities. Accordingly, the traces of their teacher-centered methods were also seen in their implementation of topic-specific activities and therefore, it can be inferred that their deficiency regarding knowledge of applying topic-specific activity may directed them to apply teacher-centered methods. Similarly, Yılmaz Yendi (2019) stated that teachers' tendency towards teacher-centered teaching methods can be attributed to their deficiency regarding knowledge of the implementation of topic-specific strategies such as not applying topic-specific strategy regarding sustainable development in the context of biogeochemical cycles. In USA context, Veal and Kubasko (2003) revealed that prospective geology and biology teachers’ lessons were directed towards traditional teaching methods, and it was concluded that the source of this situation could be their deficient knowledge regarding topic-specific activity and backgrounds of students.

Aligned with their orientations, participating science teachers emphasized dual perspective in their teachings in various degrees. For example, they preferred to use teacher-centered teaching methods and very few representations (i.e., videos, drawing figure) while emphasizing raising their students as action competent citizens. To some extent, science teachers' deficient knowledge regarding the climate change, global warming and greenhouse effect reflected in their integration of the dual perspective in their teachings. Similarly, Clausen (2016) found in his study that teachers expressed that in order to enable students to develop as action competent citizens, teachers should be knowledgeable about physical and human geography and address vision, action experiences and commitment throughout their lessons. In attempt to raise action competent students (i.e., dual perspective), however, Clausen (2017) found that Danish geography teachers benefitted from student-centered activities in their teaching on climate change and weather formation. For example, one of the experienced teachers directed questions to the students about decreasing the consumption of electricity. He also created a group work in the classroom in which the students were asked to order a certain number of activities that lead to effect on environment according to their degree of effect, and then, he formed a discussion environment. In addition, in this study, it was observed that the students did not participate enough in the lessons to express their ideas toward the preventing the climate change and global warming. The reason for this situation may be that science teachers usually mentioned about collective actions or government-based actions and less or no mentioned about students' pro-environmental behavior that can be taken to prevent the adverse effects of climate change and global warming. Therefore, students may not associate these actions with their daily life. Similar to current study findings, Clausen (2017) found that the students could not show enough participation to express their ideas regarding actions toward preventing the climate change. We support Clausen (2017) who stated that this situation may be related to the fact that the issues mentioned in the lesson about climate change were not related to the students' daily lives.

Finally, science teachers’ tendency to apply teacher-centered teaching methods can be related to their knowledge of curriculum. According to Hanuscin, Lee and Akerson (2011), there can be a relationship between science teachers' knowledge of instructional strategies and knowledge of curriculum. For example, participating science teachers, in their lessons, did not perform a few of the activities related to the seasons, weather, and climate topic found in the science textbook approved by MoNE. This situation may indicate that they have deficiencies in terms of their knowledge of instructional strategies. The fact that science teachers did not implement activities in the curriculum can be partially explained by the presence of the high school entrance exam, the loaded curriculum and the limited time. Similar findings have been reached in other PCK studies (e.g., Mıhladız, & Timur, 2011; Şen, 2014; Tıraş, 2019).

Unlike other components of PCK, their knowledge of curriculum appears to be adequate. All of them were aware of the concepts required by curriculum (i.e., objectives, vertical relations, the location of the topic, horizontal relations) within the topic of seasons, weather, and climate (See PCK knowledge of curriculum section). All of them were knowledgeable not only about all objectives with respect to the seasons, weather, and climate topic but also the concept of dual perspective as affective goals. The dual perspective is located among the specific objectives of the curriculum. For example, in various degrees, they addressed the environmental problems (e.g., climate change) and tried to provide students to become conscious of these problems they will encounter in the future. Thus, teachers tried to ensure that students have responsibility towards the environment, nature and living things, and become action competent citizens (i.e., dual perspective). On the other hand, all of them took interdisciplinary nature of the seasons, weather, and climate topic into consideration by mentioning about the formation of tsunami and typhoon or Beaufort scale that used for measuring the wind which are presented in Geography curriculum (e.g., 10^{th} grade), but in doing so, they went beyond the curriculum.

These findings are not surprising because the fact that experienced science teachers have taught the seasons, weather, and climate topic for many years may have enabled them to become familiar with the concepts (e.g., objectives) in the curriculum. At the same time, they were able to establish relationships between this topic and other science topics as horizontally and vertically. In the pre-PCK interview, all of them frequently emphasized that teaching the seasons, weather, and climate topic means teaching life itself and thus associated weather and climate topic with everyday life through giving some advanced information in their teaching practices (i.e., curriculum violation), believing that additional knowledge may have expanded students' horizons. Therefore, we agreed with Friedrichsen and Dana (2005) and Friedrichsen, Van Driel and Abell (2011) who stated that teachers' teaching beliefs have an impact on their teaching.

Similar to the findings of this study, several PCK studies conducted with experienced in-service teachers regarding different science topics showed that teachers were able to express objectives, the location of the topic, vertical and horizontal connections related to science topic, such as nuclear reactions and electrochemical cells (Aydın et al., 2014), mixtures (Ekiz Kıran, 2016), osmosis and diffusion (Lankford, 2010), genetics (Mthethwa-Kunene et al., 2015), cell division (Şen, 2014; Şen et al., 2018), density (Şen, & Öztekin, 2019), ecosystems (Tıraş, 2019), states of matter and interactions between chemical species (Üner, 2016), biogeochemical cycles (Yılmaz Yendi, 2019). For instance, Üner (2016) stated that experienced chemistry teachers' ability to establish horizontal and vertical relationships between states of matter and interactions between chemical species topics, and other topics found in the curriculum can be attributed to their teaching experience. In Yılmaz Yendi's (2019) study with three experienced science teachers on biogeochemical cycles, the researcher concluded that science teachers' possessing over ten years of teaching experiences could explain why they were knowledgeable with regards to the curriculum. Contrary to the findings of studies conducted with experienced in-service teachers, pre-service teachers or beginning teachers were reported to have a lack of knowledge as to the location of the related topic and related objectives found in the curriculum (Canbazoğlu, 2008; Friedrichsen, Abell, Pareja, Brown, Lankford, & Volkmann, 2009; Graf, Tekkaya, Kılıç, & Özcan, 2011; Hanuscin et al., 2011; Tekkaya, & Kılıç, 2012; Tiras, Öztekin, & Sen, 2017). For example, Graf et al. (2011) found that both Turkish and German pre-service science teachers' knowledge of curriculum related to evolution were deficient as they did not have knowledge regarding how the evolution topic was mentioned in textbook, the grade level that evolution topic was taught and the location of the evolution topic in the curriculum.

Above mentioned studies also revealed that teachers went beyond the curriculum in different science topics (e.g., Lankford, 2010; Şen, 2014; Tıraş, 2019; Üner, 2016; Yılmaz Yendi, 2019). For instance, Şen (2014) stated that the reason why experienced science teachers provided knowledge outside of the curriculum regarding cell division can be their deficient knowledge, their desire to mention about the topic they are care with, and their teaching beliefs. In USA context, Lankford (2010) attributed the reason why experienced biology teachers gave information about diffusion and osmosis beyond the curriculum to their desires to associate this topic with the daily lives of their students. To conclude, as can be seen, these studies conducted with experienced teachers support the findings of the present study by linking the reasons for teachers' exceeding the curriculum to their teaching beliefs or their desire to relate the topic with daily life.

Science teachers' knowledge about students' understandings were found as incomplete. Even they noticed the some of the students' learning difficulties and misconceptions, they generally follow teacher-centered teaching methods to address them. Current study attributed participants' lack of knowledge about students' understanding both to their teacher-centered orientation and to their lack of subject matter knowledge. On the other hand, current study attributed participants' having knowledge regarding students' prerequisite knowledge to their teaching experience.

In particular, the findings of this study indicated that while all science teachers seem to be aware of the prerequisite knowledge that students need to know, they did not mention about their learning difficulties and misconceptions about the concepts of climate change, global warming and greenhouse effect in their pre-PCK interview, and they failed to recognize their misconceptions mainly regarding these concepts. This finding can be explained in terms of lack of their SMK which is rather limited compared to the that of seasons, weather and climate. For instance, during the teaching of climate change, global warming and greenhouse effect, it was observed that students associated the ozone layer depletion with global warming. This finding is compatible with students' misconception in the literature (e.g., Daniel et al., 2004; Rye et al., 1997). Teachers however, neither noticed this misconception nor attempted to eliminate it. In contrast, they easily recognized students' misconception about the association between the seasons and the Earth's distance from the sun, which is common students' misconceptions in the literature (e.g., Hsu, 2008; Starakis, & Halkia, 2013; Philips, 1991; Tsai, & Chang, 2005). They tried to overcome it by using verbal scientific explanation, drawing figure and showing video, but they generally used these methods depending on direct teaching (i.e., teacher-centered), and students often were passive participants. In the same way, they noticed students' learning difficulties regarding the Earth's tilted axis and its' impact on the formation of seasons, and this finding is compatible with students' learning difficulties in the literature (e.g., Dankenbring, & Capobianco, 2016; Sung, & Oh, 2018). They utilized verbal scientific explanation, analogy, drawing figures, showing video, experiment, and drama to overcome their learning difficulties, yet they again generally applied these methods depending on direct teaching. Therefore, it can be assumed that teachers' knowledge of learners was filtered by their orientations to teaching science (Aydin, & Boz, 2013; Friedrichsen et al., 2009; Padilla, & van Driel, 2011). To make it clear, Aydin and Boz (2013) stated that teachers' decisions regarding ways to overcome students' misconceptions and learning difficulties are influenced by their orientation towards science teaching. In parallel with the findings in Aydin and Boz's (2013) study, in this study, it can be concluded that science teachers preferred teacher-centered methods or different methods based on direct teaching, which coincides with their teacher-centered orientation, in order to tackle with students' learning difficulties and misconceptions regarding the concept of seasons. Similarly, Aydın (2012) reported that in order to eliminate the students' misconceptions came from past years, experienced chemistry teachers either provided a scientific explanation or gave warning them regarding this issue due to their didactic orientations. On the topics of heredity and photosynthesis, Park and Chen (2012) reported that biology teacher with didactic orientation tended to employ didactic teaching methods like asking students to do experiments by giving a laboratory protocol**.** The researchers concluded that his ideas about students' learning (e.g., they do not possess any knowledge or misconceptions, the knowledge is conveyed by teacher) might have led him to utilize didactic teaching methods. Park and Chen (2012) claimed that the association between the teacher's knowledge of instructional strategies and their knowledge of students' understanding is prevented by his orientation.

To conclude, current study seemed to support the claim that teachers' lack of subject matter knowledge might have an effect on their knowledge of students' understanding (Aydın, 2012; Magnusson et al., 1999). Specifically, the current study revealed that teachers who were knowledgeable about the seasons, weather and climate tended to be knowledgeable about students' learning difficulties as well as their misconceptions. Nevertheless, teachers having a lack of knowledge the concepts of climate change, global warming and greenhouse effect were less likely to be aware of students' misconceptions and learning difficulties regarding these concepts. There are studies reporting similar findings in the literature as well (e.g., Canbazoğlu, 2008; Canbazoğlu, Demirelli, & Kavak, 2010; Käpylä et al., 2009; Park, & Oliver, 2008a; Rollnick, 2016). For example, in support of this study, Canbazoğlu (2008) concluded that within the scope of the particulate nature of matter unit, to predict what misconceptions and learning difficulties students have, pre-service teachers' subject matter knowledge can be influential on this point. Park and Oliver (2008a) stated the necessity of PCK components and subject matter knowledge in order for teachers to evaluate and notice whether the students have learned the topic and have confusion about the topic. In Finland context, regarding the plant growth and photosynthesis topic, Käpylä et al. (2009) reported that compared to content novices, content experts detected conceptual difficulties of students better, and that due to having own misconceptions, a content novice has a lot of difficulty in detecting misconceptions of students. The finding of the present study also supports the latter finding of Käpylä et al. (2009) because in the present study, it was found that science teachers had similar misconceptions with students had about the concepts of climate change, global warming, and greenhouse effect (See more in discussion on SMK section), and therefore they neither detected nor overcame these misconceptions of students.

As shown in the current study, several PCK research also reported inadequacy of science teachers' knowledge about students' misconceptions and learning difficulties (e.g., Barendsen, & Henze, 2019; Çaylak, 2017; Ekiz Kıran, 2016; Friedrichsen et al., 2009; Hanuscin, Cisterna, & Lipsitz, 2018; Han-Tosunoğlu, 2018; Lane, 2015a; Park, & Chen, 2012; Tıraş, 2019; Üner, 2016). For example, in the context of friction force, work and energy, and simple machines, Çaylak (2017) found that the science teacher had deficient knowledge about students' misconceptions. For example, although she mentioned some misconceptions about the topics prior to her teaching, extra misconceptions appeared in her teaching such as "energy is lost when it changes from kinetic to potential" (Çaylak, 2017, p.229). But it was observed that for eliminating their misconceptions, the methods like analogy and concept map were not applied by her. In the context of ecosystem topic, Tıraş (2019) concluded that experienced science teachers had incomplete knowledge regarding students' misconceptions and learning difficulties, and the researcher stated that their lack of knowledge about students' understanding could be attributed to their content knowledge and teacher-centered orientation. In Australia context, Lane (2015a) found that among sixteen experienced geography teachers with five or more than five years of experiences, six of them expressed little or no students' alternative conceptions with regards to tropical cyclones. Lane (2015a) stated that in planning their lessons, most of these teachers did not take alternative conceptions of students into account, and their main task was to cover the topic and make teaching with the aim of enriching the existing knowledge of students. Lane (2015a) concluded that it did not guarantee that teachers' knowledge regarding common alternative conceptions is comprehensive or detailed even if teaching experience to a certain extent (i.e., being an experienced teacher) seemed to be essential for teachers to advance their knowledge regarding these issues. The finding of current study also supported Lane’s results. Despite their over ten years of experiences, science teachers struggled to recognize their students’ misconceptions and learning difficulties, especially if they possessed low SMK.

Participating science teachers’ awareness of students’ prerequisite knowledge partly associated positively with their years of teaching experiences. Having over ten years of teaching experiences, they have been teaching the concepts of seasons, weather and climate to their students and found opportunity to be familiar with students’ prerequisite knowledge. Similarly, PCK studies relate science teacher’s awareness of students’ prerequisite knowledge of their students’ understanding to levels of teaching experiences (e.g., Çaylak, 2017; Şen, & Öztekin, 2019; Van Driel et al., 2002; Yılmaz Yendi, 2019). On the other hand, some PCK studies reported that teachers' SMK have an effect on their knowledge of students' prerequisite knowledge (e.g., Aydın, 2012; Aydın et al., 2014; Şen et al., 2018). For example, Aydın et al. (2014) explained that SMK might help to provide teachers to understand the students' understanding (i.e., misconceptions, prerequisite knowledge, difficulties) when teachers have strong SMK on a topic. Şen et al. (2018) claimed that when teachers are knowledgeable regarding the topic, they possess knowledge regarding the students' learning difficulties and prerequisite knowledge.

Uncovering the teachers’ knowledge of instructional strategies also provided us some clues about their knowledge of students’ understanding of science since related research implied an association between teachers’ knowledge of instructional strategies and teachers’ knowledge of students’ understanding (Boz, & Boz, 2008; Brown et al., 2013; Hanuscin et al., 2011; Henze et al., 2008; Park, & Oliver, 2008a;

Şen et al., 2022). In this study, science teachers' use of questioning method, which is a teacher-centered teaching method, gave them information with respect to the students' learning difficulties and misconceptions especially about the concept of seasons. However, current study was also in agreement with the assertion that even participants noticed some of the students' learning difficulties and misconceptions, they, again, depended on teacher-centered teaching methods to eliminate them.

Also, depending on the available data, it can be inferred that science teachers' deficiency regarding knowledge about students' understanding (i.e., their misconceptions, learning difficulties) may have restricted them in terms of assessing their students' conceptual understanding (i.e., knowledge of assessment). To make it clear, participating science teachers' knowledge of students' misconceptions about the concepts of global warming, climate change, greenhouse effect was found to be deficit, and besides, they had their own misconceptions regarding these concepts. It can be said that this situation may have caused a deficiency in their assessment of students' conceptual understanding in terms of these concepts. Our claim was supported by Henze et al. (2008) who stated that the development of teachers' knowledge of assessment is related to the development of their knowledge of students' understanding. Hence, we agreed with the claim of Park and Oliver (2008a) who stated that to shape PCK in terms of teaching, planning, and assessment, teachers' awareness about students' misconceptions was defined as a main factor.

Lastly, science teachers' knowledge of assessment seems to be deficient. The findings indicated the science teachers' tendency to apply traditional assessment methods and assess students' knowledge in terms of conceptual understanding. Based on available data, their tendency can be explained through a) their teacher-centered orientation, b) the existence of the high school entrance exam, c) their deficiency regarding knowledge about alternative assessment methods, and d) the content of objectives in the curriculum (e.g., the deficiency of NOS objectives).

At first, participating science teachers' teacher-centered orientation seems to be a crucial factor that determines their knowledge of assessment. Their central goals were detected as to teach objectives related to the seasons, weather, and climate topic and equip students with knowledge required to be successful in high school entrance exam. In their teachings, they were faced with a loaded curriculum and so, they needed to complete teaching of many topics in the curriculum, which necessarily limited their teaching time. Therefore, it can be inferred that consistent with their orientation, they generally preferred to perform traditional assessment methods with which they are familiar, and which are more convenient to apply in their limited time instead of applying alternative assessment methods. Also, they assessed just students' conceptual understanding rather than NOS understandings and scientific process skills. For example, all of them frequently used questioning method as a formative assessment and also, open-ended, true/false, matching type and filling in the blanks were another types of questions used as summative assessment. Similar findings were reported in several PCK studies (e.g., Aydın, 2012; Ekiz Kıran, 2016; Friedrichsen et al., 2009; Şen, 2014; Tıraş, 2019; Üner, 2016). For example, Şen (2014) stated that the reason why experienced science teachers generally apply traditional assessment methods may be due to their deficiency regarding alternative assessment methods and their orientation towards science teaching (i.e., teacher-centered). Şen (2014) also attributed the reason for their tendency to assess their students' knowledge in terms of conceptual understanding to the presence of the high school entrance exam, their orientations, and the deficiency of objectives about the relevant scientific literacy' components in the curriculum. Likewise, in Friedrichsen et al.'s (2009) study, it was reported that trainees and teachers mentioned about general assessment methods such as homework, tests, and the researchers attributed their restricted knowledge of assessment methods to their didactic orientation.

Second, another factor that has impact on science teachers' knowledge about assessment was found as high school entrance exam. In the scope of the exam, multiple choice questions are prepared for students to solve in the specified time by MoNE, and therefore, with the aim of providing students to become familiar with these types of questions, majority of teachers preferred to have their students to solve multiple choice questions (i.e., traditional assessment method). The questions in the exam are asked by taking the objectives in the curriculum into consideration, and therefore, to prepare their students for the exam, science teachers emphasized the importance of exams in their teachings by giving example about concepts that asked in the exam (e.g., seasons, weather events). Accordingly, they may have preferred to focus on the assessment of the students’ conceptual understanding due to the content of the exam. Related literature indicated that there are similar studies reporting the effect of nationwide exams (i.e., high school entrance exam, university entrance exam) upon teachers' knowledge of assessment (e.g., Aydın, 2012; Ekiz Kıran, 2016; Şen et al., 2018; Tıraş, 2019; Üner, 2016; Yılmaz Yendi, 2019), and similar situation were also seen in other countries such as Israil (Cohen, & Yarden, 2009), India (Nargund-Joshi et al., 2011), China (Zhang et al., 2003). For example, Üner (2016), in her study on states of matter and interactions between chemical species, concluded that the reason why experienced chemistry teachers tended to assess their students' conceptual understanding and perform traditional assessment methods can be attributed to the presence of university entrance exam and their didactic orientation. In Israel context, in the study of Cohen and Yarden (2009) with experienced high school science teachers regarding the topic of cell, it was found that they applied traditional assessment methods, for example, directing basic questions about the structure of the cell, and the researchers stated that their choices about assessment methods could be related to the national evaluation system. Similarly, in India context, Nargund-Joshi et al. (2011) expressed that secondary science teachers took board exams into account in terms of assessing their students' knowledge and also, gave feedback to ensure that their students were successful in the exam.

Third, science teachers' assessment of only their students' conceptual understanding regarding the topic of seasons, weather, and climate can be explained by the content of the curriculum objectives (i.e., MoNE 2018). As mentioned before, science teachers stated in the pre-PCK interview that they have adopted to follow the curriculum and teach the topics with taking the curriculum into consideration. In the curriculum, there are objectives for students to learn subject matter knowledge about the seasons, weather, and climate topic. Also, as mentioned before, the concept of dual perspective was addressed among the specific objectives of the curriculum, and also the topic-specific objectives of the topic of seasons, weather, and climate. Therefore, two science teachers tried to assess students’ understanding with respect to being action competent citizens (i.e., dual perspective) even if using few questions. But there is deficiency of topic-specific objective for them to learn NOS in the curriculum. Considering the aforementioned situations, it can be said that it is not a surprising finding that science teachers did not assess their students' knowledge in terms of the other dimensions such as NOS understandings. Similar findings were also found in previous PCK studies (e.g., Aydın, 2012; Hanuscin et al., 2011; Park, & Oliver, 2008a). For example, Aydın (2012) found in her study that none of experienced chemistry teachers assessed students' knowledge in terms of the nature of science, and the researcher stated that it is more possible for teachers to make assessment and teaching related to NOS understanding, in case the curriculum contains NOS understanding. Park and Oliver (2008a) found in their study that experienced chemistry teachers took into account the objectives and goals within the scope of the curriculum while assessing students' knowledge. To conclude, as can be seen from these explanations, it can be thought that the content of the objectives in the curriculum is an important issue that teachers consider in assessing their students' knowledge.

Fourth, it can be inferred that science teachers’ choosing traditional assessment methods can be associated with their incomplete knowledge regarding alternative assessment methods. Considering their pre-PCK interview findings, generally, all of them mentioned that they would apply traditional assessment methods for assessing students’ understanding. Unlike other teachers, only Beyza applied alternative assessment methods such as poster activity and peer assessment to assess students’ understanding. However, the predominance of the traditional assessment methods in their observation findings together with the interview findings made us think that they were not knowledgeable regarding alternative assessment methods. There are also similar studies in the literature reporting the teachers’ deficit knowledge on alternative assessment methods (e.g., Canbazoğlu, 2008; Canbazoğlu et al., 2010;

Kaya, 2009; Şen, & Öztekin, 2019; Üner, 2016). For example, Kaya (2009) emphasized the lack of courses relevant to the assessment methods in universities of Turkey and he stated that the just one course whose called is measurement and assessment related to the assessment methods and strategies is found in all universities found in Turkey. Also, Kaya (2009) added that traditional assessment methods were generally applied in the assessment of conceptual knowledge of pre-service science teachers in their undergraduate education in Turkey. In this respect, it can be inferred that the participating science teachers' incomplete knowledge regarding alternative assessment methods may stem from their undergraduate education. Besides science teachers' incomplete knowledge with regards to alternative assessment methods, their knowledge of how to perform these methods may be deficient as well. Thus, we agreed with the assertion of Yılmaz Yendi (2019) who stated that the teachers' deficient experience related to applying authentic techniques that were acquired in trainings within their professions and undergraduate courses can explain their preference for traditional assessment methods.

Until this section, discussion regarding in-service science teachers' SMK and PCK related to the seasons, weather, and climate topic were reported by taking the dual perspective into consideration. Following section, implications and recommendations of this study were presented.

5.3 Implications

In this section, based on the findings of this study, implications for science educators, in-service teachers, and curriculum developers were presented.

Based on the available data, participating experienced science teachers had deficiencies regarding SMK in terms of both syntactic and substantive knowledge. First, as compared to seasons, weather and climate, their substantive knowledge regarding the concepts of greenhouse effect, climate change, global warming were found as not adequate. On the other hand, they were aware of the climate as a system, and addressed some components and interactions among them. Second, as a part of SMK, regarding syntactic knowledge, their knowledge regarding some NOS aspects (e.g., theory and law, tentativeness, sociocultural embeddedness, creativity, subjectivity) and their embedded NOS knowledge especially in the context of climate change, greenhouse effect and global warming were found as not adequate. As for their PCK, their science teaching orientations were found as teacher-centered, their knowledge of assessment methods and instructional strategies were generally limited to traditional methods, and they were found as not adequate in terms of knowledge of students' understanding (i.e., misconceptions and learning difficulties). Furthermore, their PCK for NOS were found as not adequate. Lastly, they addressed dual perspective in their teachings in various degrees.

In the literature, PCK' main source is described as teaching experience (van Driel, Verloop, & de Vos, 1998), but in the context of science teaching, PCK development are not provided with having experience all the time (Lankford, 2010). Accordingly, knowledge and experience of teaching prepared in a professional environment enable teachers to develop their practice and knowledge (Lankford, 2010). Considering the current study findings, a professional development program should be developed to improve in-service teachers' PCK and PCK for NOS in which substantive knowledge is handled together with syntactic knowledge. Within this program, several implications are recommended for the development of in-service teachers' SMK, PCK and PCK for NOS. Primarily, the topic of seasons, weather and climate bring together different disciplines, and this topic is commonly found in the science and geography curriculum, and therefore, the interdisciplinary nature of teaching of the seasons, weather and climate topic should be emphasized. In this sense, the teaching of these topics can be enriched by integrating various disciplines such as biology, physics, chemistry, and geography. It should be put emphasis on the world as a complex system and teaching the concept of climate should be addressed with taking the systems thinking perspective into consideration. Subsequently, in-service teachers should be encouraged to develop a more holistic approach to the teaching of the climate, changes occurred in the climate system and comprehend the complex interactions among the climate system’ components. By this way, in-service teachers' adoption of a systematic thinking perspective can enable them to establish systematic relationships among seasons, weather, climate, and related concepts and thus broaden their horizons about their teaching.

As mentioned before, the aim of planned professional development program is to improve not only substantive knowledge of in-service teachers but also syntactic knowledge. Therefore, within this program, substantive knowledge and syntactic knowledge should be given in an integrated way. In this sense, several researchers (Bilican, Cakıroglu, & Oztekin, 2015; Matkins, & Bell, 2007; Matkins, Bell, Irving, & McNall, 2002) in their study with the preservice elementary teachers reported that their NOS understandings developed through explicit and contextualized NOS instruction. Accordingly, it is thought that NOS instruction with explicit and contextualized approach can be integrated into trainings in professional development programs and thus contribute to the development of in-service teachers' NOS understandings and also substantive knowledge. At the same time, in-service teachers can learn how to teach substantive knowledge and NOS in their lessons in an integrated manner, and thus, this may offer opportunity to develop their PCK for NOS. In this respect, it should be emphasized how to teach the seasons topic through the nature and history of science. To illustrate, in-service teachers can be desired to create models of the Earth and the Sun. Through these models, they can observe the Earth's tilted axis and the movements of the Earth around the Sun, make inferences about the formation of seasons based on their observations, and then, construct hypotheses and test their hypotheses through models. In doing so, the differences between inference and observation can also be emphasized. For example, it can be addressed that Galileo supported the heliocentric universe model theorem by making observations, but at that time he faced with a punishment because Galileo's view was contrary to the church. At this point, it can be emphasized that the experiment cannot always be done, and observations or inferences can be made in such cases and how scientific knowledge is impacted by social and cultural values can be discussed with examples.

Following, it should be emphasized how to teach the weather and climate topic through the nature and the history of science. For example, in this program, NOS aspects can be emphasized in describing the meteorologists' and climatologists' data collection and analysis processes regarding the weather and climate. It should be addressed that meteorologists make predictions regarding weather events through obtaining data about weather using various tools and making observations, and climatologists determine the climate of a place by examining the weather data of the past long years. For example, climate change and global warming should be taught by means of scientific evidence, and then, the scientists' different opinions regarding these evidences can be presented and it can be made discussion on why they have different opinions about the same evidence. The occurrence of the greenhouse effect should be shown with scientific data graphically such as a graph showing the increase in carbon dioxide level over the years. Along with explaining the formation of the greenhouse effect, it can be addressed whether the greenhouse effect is a theory or a law by presenting the correct justifications, and following, the differences between the law and theory can be explained. As a matter of fact, it can be said that understanding these environmental problems well can prevent the formation of relevant misconceptions in teachers, and in this way, by transferring through teachers, possible misconceptions that may occur in students can be prevented. In this respect, the formation process of climate change, greenhouse effect and global warming and followed by the cause-effect relationship among these three environmental problems should be specified. In addition, it should be emphasized that students should be aware of the formation process of these environmental problems as well as the taking precautions to eliminate these problems in order to become responsible and action competent citizens on behalf of the society (i.e., dual perspective). It should be given examples from human-based (e.g., using renewable energy sources, reducing the use of fossil fuels) and government-based actions (e.g., signing Kyoto protocol) to be taken to prevent environmental problems.

As mentioned earlier, planned professional development program should also focus on improving in-service teachers' knowledge of PCK components because their PCK should be supported by the development of their knowledge on PCK components. For example, it should be emphasized that the active participation of students may decrease in the implementation of teacher-centered orientation, and therefore, in-service teachers should be directed to the implementation of student-centered orientations comply with constructivist approach. They should be provided with well-equipped knowledge with respect to the alternative assessment methods and constructivist teaching methods. Following, it should be dwelled on how these methods should be implemented in order to provide students to understand the topic better and provide teachers to assess students' understanding better. Trainings should be designed to improve teachers' knowledge of topic-specific instructional strategies by applying student-centered activities specific to the seasons, weather, and climate topic, and they should be given the opportunity to apply them in a real classroom environment. For example, a field trip related to meteorology or observations in an environmental laboratory can be planned. In addition, a scientist such as a climatologist or meteorologist can be invited to the lesson, and it can be provided students to become informed by using the relevant scientific data. They should be educated about students' misconceptions and learning difficulties with regard to the seasons, weather and climate topic including climate change, global warming and greenhouse effect, and how they can be identified and eliminated through constructivist teaching methods. Afterwards, they should be directed to assess whether students' misconceptions and learning difficulties were eliminated or not.

Along with the development of their PCK for NOS, and embedded NOS knowledge regarding the seasons, weather and climate including greenhouse effect, climate change, and global warming, the inclusion of topic specific NOS objectives in the curriculum should be taken into account by curriculum developers in order to enable science teachers to integrate NOS understandings into their teachings. As a matter of fact, in their pre-PCK interviews, participating science teachers emphasized that they preferred to follow the curriculum to teach the topics. Accordingly, related objectives can be added to the curriculum by integrating NOS aspects into the concepts of seasons, weather, and climate. To conclude, the presence of topic-specific NOS objectives in the curriculum can encourage science teachers to teach the seasons, weather, and climate topic by including the aspects of the NOS, and thus they can assess students' understandings of NOS aspects.

5.4 Recommendations

In this section, recommendations for future studies were suggested.

Several recommendations are presented for science education researchers to conduct their future studies. In this study, experienced science teachers' SMK and PCK on seasons, weather, and climate topic were investigated. It can be seen that studies conducted with experienced teachers and in-service teachers regarding the basic concepts of seasons, weather and climate are rather limited. In this aspect, the current study contributes to our understanding of experienced teachers' SMK regarding seasons, weather and climate. This topic has the feature of being an interdisciplinary topic. In future studies, the topic of seasons, weather, and climate can be studied with in-service teachers from different disciplines such as social studies, geography, biology, and following, their PCK can be compared. By doing so, it can be examined whether there is a difference between teachers' PCK on this topic among disciplines. This study can also be carried out with experienced science teachers working in private schools, so that it can be examined whether there is a difference in the topic-specific PCK of science teachers working in private and public schools. Moreover, comparative studies can be conducted if possible. For example, conducting study with different countries are recommended, and then, in-service teachers' PCK can be compared among different countries.

In this study, while two science teachers were graduated from science education department of faculty of education, the other science teacher was graduated from biology department of art and science faculty. Although it is beyond the scope of this study, further studies should compare and contrast PCK of science teachers who were graduated from science education and those who teach science outside of their field (e.g., graduated from biology, chemistry or physic departments).

Current study investigated in-service science teachers' PCK in the context of the seasons, weather, and climate topic by taking the dual perspective into consideration, and examined whether the concept of dual perspective is emphasized in their teachings. Accordingly, in the future research, it is recommended that the dual perspective concept can be studied in the context of different topics (e.g., matter cycles, biodiversity, sustainability, climate change education) and different disciplines (e.g., chemistry, geography, physic). In-service science teachers should be trained on the integration of the concept of dual perspective into different topics and different disciplines by means of interactive workshops so that they can teach their students. Moreover, it is recommended that studies should be conducted with focusing on students as well as teachers, and students' development into being action competent citizens should be observed and assessed by considering aspects of action competence (i.e., action experiences, knowledge, visions, commitment) during the teaching practice. For example, the concept of dual perspective can be integrated into the context of education for sustainable development by real stories (UA, 2017). In addition, field trips can be arranged to places where they have educational sites, observatories, and test and measurement sites. In this way, it can be ensured that students understand the relationship between nature and human, reach the level where they can use the concept of sustainable development in their daily lives, develop behaviors towards the sustainable development and become responsible individuals (UA, 2017). Also, the dual perspective can be integrated into climate change education by using constructivist-based experiential learning, which enables students to improve their critical thinking, awareness as well as learning regarding climate change (Karpudewan, & Mohd Ali Khan, 2017). Within this learning approach, there are various activities, consisting of four learning stages (i.e., abstract conceptualization, concrete experience, active experimentation, reflective observation), such as field trip, modelling activity, calculation of carbon footprint, role-playing activity. For example, in a field trip, students can be triggered to find out the causes and impacts of climate change and make observations on weather conditions. Students can be encouraged to construct a model related to the greenhouse effect, and then, they can observe the changes in temperatures. Various roles (e.g., environmentalist, teacher, farmer, doctor) can be given to each group, and the mitigation strategies needed to be applied to prevent the adverse effects of climate change can be discussed among groups (Karpudewan, & Mohd Ali Khan, 2017).

Current study basically examined science teachers' views about the climate system, its' components and the processes occurring in the climate system. In further research, it is recommended that science teachers' knowledge regarding the climate system can be examined by using systems thinking framework, so that it can be obtained detail, comprehensive and rich data from science teachers.

In current study, science teachers' SMK including substantive and syntactic knowledge were not categorized. Therefore, in further study, science teachers' SMK including substantive and syntactic knowledge can be categorized as naïve, transitional and informed.

In this study, utilizing Magnusson et al. (1999) PCK model, science teachers' PCK related to seasons, weather, and climate topic were examined. When the Gess-Newsome (2015) PCK model was examined, it was revealed that the dimension of students' achievement was taken into consideration. Accordingly, in future studies, it is recommended that the relationship between students' achievement and science teachers' PCK in the context of seasons, weather, and climate topic can be examined through using the Gess-Newsome (2015) PCK model.

Since NOS and the dual perspective are discipline-specific, further studies should be conducted in the framework of Carlson and Daehler’s (2019) Refined Consensus Model which explicitly specifies collective PCK which includes concept-specific PCK, topic-specific PCK and discipline-specific PCK (Carlson and Daehler, 2019).

Moreover, although we constructed a concept map showing the interactions among components of PCK, further study should examine Park and Chen’s (2012) pentagon PCK model to clear out the interactions among PCK components in more detail.

In the future research, as an intervention study, a professional development program can be designed to improve in-service teachers' PCK, in which substantive knowledge is given together with syntactic knowledge, regarding the seasons, weather, and climate topic, and then, the effect of this program on the development of their PCK can be investigated.

REFERENCES

Abd-El-Khalick, F. (2006). Preservice and experienced biology teachers' global and specific subject matter structures: Implications for conceptions of pedagogical content knowledge. *Eurasia Journal of Mathematics, Science and Technology Education, 2*(1), 1-29.

Abd-El-Khalick, F., Bell, R.L., & Lederman, N.G. (1998). The nature of science and instructional practice: Making the unnatural natural. *Science Education, 82*, 417-436.

Abd-El-Khalick, F., & BouJaoude, S. (1997). An exploratory study of the knowledge base for science teaching. *Journal of Research in Science Teaching, 34*(7), 673-699.

Abell, S.K. (2007). Research on science teacher knowledge (Chapter 36). In S.K. Abell & N.G. Lederman (Eds.). *Handbook of Research on Science Education,* pp.1105-1149, New York: Routledge.

Abell, S.K. (2008). Twenty years later: Does pedagogical content knowledge remain a useful idea? *International Journal of Science Education, 30*(10), 1405-1416. DOI: 10.1080/09500690802187041

Aguado, E., & Burt, J.E. (2010). *Understanding weather and climate.* (5th ed.). Upper Saddle River, NJ: Pearson.

Ahrens, C.D. & Henson, R. (2019). *Meteorology today: An introduction to weather, climate, and the environment.* (12th ed.). Boston, MA: Cengage.

Akerson, V.L. (2005). How do elementary teachers compensate for incomplete science content knowledge? *Research in Science Education, 35*, 245-268. DOI: 10.1007/s11165-005-3176-8

Appleton, K. (2002). Science activities that work: Perceptions of primary school teachers. *Research in Science Education, 32*, 393-410.

Arzi, H.J., & White, R.T. (2008). Change in teachers' knowledge of subject matter: A 17-year longitudinal study. *Science Education*, *92*, 221-251. DOI: 10.1002/sce.20239

Assaraf, O.B.Z., & Orion, N. (2005). Development of system thinking skills in the context of earth system education. *Journal of Research in Science Teaching, 42*(5), 518-560. DOI: 10.1002/tea.20061

Assaraf, O.B.Z., & Orion, N. (2010). System thinking skills at the elementary school level. *Journal of Research in Science Teaching*, *47*(5), 540-563. DOI: 10.1002/tea.20351

Arslan, H.O., Cigdemoglu, C., & Moseley, C. (2012). A three-tier diagnostic test to assess pre-service teachers' misconceptions about global warming, greenhouse effect, ozone layer depletion, and acid rain. *International Journal of Science Education, 34*(11), 1667-1686. DOI: 10.1080/09500693.2012.680618

Atwood, C.H., & Sheline, R.K. (1989). Nuclear chemistry: Include it in your curriculum. *Journal of Chemical Education, 66*(5), 389-393.

Atwood, R.K., & Atwood, V.A. (1996). Preservice elementary teachers' conceptions of the causes of seasons. *Journal of Research in Science Teaching, 33*(5), 553-563.

Atwood, R.K., & Atwood, V.A. (1997). Effects of instruction on preservice elementary teachers' conceptions of the causes of night and day and the seasons. *Journal of Science Teacher Education, 8*(1), 1-13. DOI: 10.1023/A:1009455201314

Avraamidou, L. (2013). Prospective elementary teachers' science teaching orientations and experiences that impacted their development. *International Journal of Science Education, 35*(10), 1698-1724. DOI: 10.1080/09500693.2012.708945

Aydemir, M. (2014). *The investigation of pedagogical content knowledge of teachers: The case of teaching genetics*. Doctoral Dissertation. Middle East Technical University, Ankara.

Aydın, S. (2012). *Examination of chemistry teachers' topic-specific nature of pedagogical content knowledge in electrochemistry and radioactivity.* Doctoral Dissertations, Middle East Technical University, Ankara.

Aydın, S., Boz, N., & Boz, Y. (2010). Factors that are influential in pre-service chemistry teachers' choices of instructional strategies in the context of methods of separation of mixtures: A case study. *The Asia-Pacific Education Researcher, 19*(2), 251-270.

Aydın, S., & Boz, Y. (2012). Fen öğretmen eğitiminde pedagojik alan bilgisi araştırmalarının derlenmesi: Türkiye örneği. *Educational Sciences: Theory & Practice, 12*(1), 479-505.

Aydın, S., Demirdogen, B., Tarkin, A., Kutucu, S., Ekiz, B., Akın, F.N., Tuysuz, M., & Uzuntiryaki, E. (2013). Providing a set of research-based practices to support preservice teachers' long-term professional development as learners of science teaching. *Science Education, 97,* 903-935. DOI 10.1002/sce.21080

Aydın, S., Friedrichsen, P.M., Boz, Y., & Hanuscin, D.L. (2014). Examination of the topic-specific nature of pedagogical content knowledge in teaching electrochemical cells and nuclear reactions. *Chemistry Education: Research and Practice, 15,* 658-674. DOI: 10.1039/c4rp00105b

Aydın, F., & Tasar, M. F. (2010). An investigation of pre-service science teachers' cognitive structures and ideas about the nature of technology. *Ahi Evran Ünv. Kırsehir Eğitim Fakültesi Dergisi, 11*(4), 209-221.

Aydin, S., & Boz, Y. (2013). The nature of integration among PCK components: A case study of two experienced chemistry teachers. *Chemistry Education Research and Practice, 14,* 615-624. DOI: 10.1039/c3rp00095h

Bahar, M., Johnstone, A.H., & Sutcliffe, R.G. (1999). Investigation of students' cognitive structure in elementary genetics through word association tests. *Journal of Biological Education, 33*(3), 134-141. DOI: 10.1080/00219266.1999.9655653

Bailie, A.L. (2017). Developing preservice secondary science teachers' pedagogical content knowledge through subject area methods courses: A content analysis. *Journal of Science Teacher Education, 28*(7), 631-649. DOI: 10.1080/1046560X.2017.1394773

Barendsen, E., & Henze, I. (2019). Relating teacher PCK and teacher practice using classroom observation. *Research in Science Education, 49,* 1141-1175. DOI: 10.1007/s11165-017-9637-z

Barnett, E., & Friedrichsen, P.J. (2015). Educative mentoring: How a mentor supported a preservice biology teacher's pedagogical content knowledge development. *Journal of Science Teacher Education, 26*(7), 647-668. DOI: 10.1007/s10972-015-9442-3

Bektaş, O., Ekiz, B., Tüysüz, M., Kutucu, E.S., Tarkin, A., & Uzuntiryaki-Kondakçı, E. (2013). Pre-service chemistry teachers' pedagogical content knowledge of the nature of science in the particle nature of matter. *Chemistry Education Research and Practice, 14,* 201-213. DOI: 10.1039/c3rp20177e

Bell, R.L., Matkins, J.J., & Gansneder, B.M. (2011). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. *Journal of Research in Science Teaching, 48*(4), 414-436. DOI: 10.1002/tea.20402

Bilican, K. (2014). *Development of pre-service science teachers' nature of science views and nature of science instructional planning within a contextualized explicit reflective approach.* Doctoral Dissertations, Middle East Technical University, Ankara.

Bilican, K., Cakıroglu, J., & Oztekin, C. (2015). How contextualized learning settings enhance meaningful nature of science understanding. *Science Education International, 27*(4), 463-487.

Bogdan R.C., & Biklen S.K. (2007). *Qualitative research for education: An introduction to theories and methods* (5th ed.). Boston, Mass.: Pearson A & B.

Bostrom, A., Morgan, M.G., Fischhoff, B., & Read, D. (1994). What do people know about global climate change? 1. Mental models. *Risk Analysis, 14*(6), 959-970.

Boyes, E., & Stanisstreet, M. (1992). Students' perceptions of global warming. *International Journal of Environmental Studies, 42*, 287-300.

Boz, N., & Boz, Y. (2008). A qualitative case study of prospective chemistry teachers' knowledge about instructional strategies: Introducing particulate theory. *Journal of Science Teacher Education, 19*(2), 135-156. DOI: 10.1007/s10972-007-9087-y

Bravo, P., & Cofré, H. (2016). Developing biology teachers' pedagogical content knowledge through learning study: The case of teaching human evolution. *International Journal of Science Education, 38*(16), 2500-2527, DOI: 10.1080/09500693.2016.1249983

Brown, P., Friedrichsen, P., & Abell, S. (2013). The development of prospective secondary biology teachers PCK. *Journal of Science Teacher Education, 24*(1), 133-155. DOI: 10.1007/s10972-012-9312-1

Bulunuz, N., & Jarrett, O.S. (2010). The effects of hands-on learning stations on building American elementary teachers' understanding about Earth and space science concepts. *Eurasia Journal of Mathematics, Science & Technology Education, 6*(2), 85-99.

Canbazoğlu, S. (2008). *Fen bilgisi öğretmen adaylarının maddenin tanecikli yapısı ünitesine ilişkin pedagojik alan bilgilerinin değerlendirilmesi*. Master Thesis. Gazi University, Ankara.

Canbazoğlu, S., Demirelli, H., & Kavak, N. (2010). Investigation of the relationship between pre-service science teachers' subject matter knowledge and pedagogical content knowledge regarding the particulate nature of matter. *Elementary Education Online, 9*(1), 275-291

Carlson, J., & Daehler, K.R. (2019). The refined consensus model of pedagogical content knowledge in science education. In A. Hume, R. Cooper & A. Borowski (Eds.), *Repositioning pedagogical content knowledge in teachers' knowledge for teaching science* (pp.77-92). Gateway East, Singapore: Springer

Cepni, O. (2014). The concept of weather event: A qualitative perspective from students. *The Anthropologist, 18*(2), 345-356. DOI: 10.1080/09720073.2014.11891552

Chan, K.K.H., & Yung, B.H.W. (2018). Developing pedagogical content knowledge for teaching a new topic: More than teaching experience and subject matter knowledge. *Research in Science Education, 48*, 233-265. DOI 10.1007/s11165-016-9567-1

Childs, A., & McNicholl, J. (2007). Investigation of the relationship between subject content knowledge and pedagogical practice through the analysis of classroom discourse. *International Journal of Science Education, 29*(13), 1629-1653.

Clausen, S.W. (2016). The pedagogical content knowledge of Danish geography teachers in a changing schooling context. *Journal of Humanities and Social Science Education, 1*, 1-22.

Clausen, S.W. (2017). Exploring the pedagogical content knowledge of Danish geography teachers: Teaching weather formation and climate change. *International Research in Geographical and Environmental Education,* 1-14. DOI: 10.1080/10382046.2017.1349376

Cochran, K.F., DeRuiter, J.A., & King, R.A. (1993). Pedagogical content knowing: An integrative model for teacher preparation. *Journal of Teacher Education, 44*(4), 263-272.

Coetzee, C., Rollnick, M., & Gaigher, E. (2020). Teaching electromagnetism for the first time: A case study of pre-service science teachers' enacted pedagogical content knowledge. *Research in Science Education.* DOI: 10.1007/s11165-020-09948-4

Cohen, R., & Yarden, A. (2009). Experienced junior-high-school teachers' PCK in light of a curriculum change: "The cell is to be studied longitudinally". *Research in Science Education, 39,* 131-155. DOI: 10.1007/s11165-008-9088-7

Çaylak, B. (2017). *Examination of topic-specific nature of pedagogical content knowledge: A case of science teacher of gifted students.* Doctoral Dissertations, Middle East Technical University, Ankara.

Daniel, B., Stanisstreet, M., & Boyes, E. (2004). How can we best reduce global warming? School students' ideas and misconceptions. *International Journal of Environmental Studies, 61*(2), 211-222. DOI: 10.1080/0020723032000087907

Dankenbring, C., & Capobianco, B.M. (2016). Examining elementary school students' mental models of sun-earth relationships as a result of engaging in engineering design. *International Journal of Science and Mathematics Education, 14*, 825-845. DOI: 10.1007/s10763-015-9626-5

Daskolia, M., Flogaitis, E., & Papageorgiou, E. (2006). Kindergarten teachers' conceptual framework on the ozone layer depletion. Exploring the associative meanings of a global environmental issue*. *Journal of Science Education and Technology, 15*(2), 168-178. DOI: 10.1007/s10956-006-9004-8

Demirdöğen, B. (2012). *Development of pre-service chemistry teachers' pedagogical content knowledge for nature of science: An intervention study.* Doctoral Dissertation, Middle East Technical University, Ankara.

Demirdöğen, B. (2016). Interaction between science teaching orientation and pedagogical content knowledge components. *Journal of Science Teacher Education, 27,* 495-532. DOI 10.1007/s10972-016-9472-5

Demirdöğen, B., Hanuscin, D.L., Uzuntiryaki-Kondakci, E., & Köseoğlu, F. (2016). Development and nature of preservice chemistry teachers' pedagogical content knowledge for nature of science. *Research in Science Education, 46,* 575-612. DOI: 10.1007/s11165-015-9472-z

Denzin, N.K., & Lincoln, Y.S. (2005). Introduction: The discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (3rd ed., pp. 1-32). Thousand Oaks, CA: Sage.

Doğan, N., Çakıroğlu, J., Çavuş, S., Bilican, K., & Arslan, O. (2011). Öğretmenlerin bilimin doğası hakkındaki görüşlerinin geliştirilmesi: Hizmetiçi eğitim programının etkisi. *Hacettepe Üniversitesi Eğitim Fakültesi Dergisi, 40*, 127-139.

Doğar, Ç., & Başıbüyük, A. (2005). The understanding levels on weather and climate concepts for primary and secondary students. *Kastamonu Education Journal, 13*(2), 347-358.

Dove, J. (1996). Student teacher understanding of the greenhouse effect, ozone layer depletion and acid rain. *Environmental Education Research, 2*(1), 89-95.

Earle, S. (2014). Formative and summative assessment of science in English primary schools: Evidence from the primary science quality mark. *Research in Science & Technological Education, 32*(2), 216-228. DOI: 10.1080/02635143.2014.913129

Ekiz Kıran, B. (2016). *Interaction between experienced chemistry teachers' science teaching orientations and other components of pedagogical content knowledge in mixtures.* Doctoral Dissertation. Middle East Technical University, Ankara.

Faikhamta, C. (2013). The development of in-service science teachers' understandings of and orientations to teaching the nature of science within a PCK-based NOS course. *Research in Science Education, 43,* 847-869. DOI 10.1007/s11165-012-9283-4

Flick, L.B. (1996). Understanding a generative learning model of instruction: A case study of elementary teacher planning. *Journal of Science Teacher Education, 7*(2), 95-122.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to design and evaluate research in education* (8th ed.). New York: McGraw-Hill.

Friedrichsen, P.J., Abell, S.K., Pareja, E.M., Brown, P.L., Lankford, D.M., & Volkmann, M.J. (2009). Does teaching experience matter? Examining biology teachers' prior knowledge for teaching in an alternative certification program. *Journal of Research in Science Teaching, 46*(4), 357-383. DOI: 10.1002/tea.20283

Friedrichsen, P.M., & Dana, T.M. (2005). Substantive-level theory of highly regarded secondary biology teachers' science teaching orientations. *Journal of Research in Science Teaching*, *42*(2), 218-244. DOI: 10.1002/tea.20046

Friedrichsen, P., Van Driel, J.H., & Abell, S.K. (2011). Taking a closer look at science teaching orientations. *Science Education, 95,* 358-376. DOI: 10.1002/sce.20428

Gess-Newsome, J. (1999). Pedagogical content knowledge: An introduction and orientation. The nature and history of pedagogical content knowledge. In J. Gess-Newsome & N.G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp.3-17). Boston, MA: Kluwer Press.

Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK summit. In A. Berry, P. Friedrichsen, & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp.28-42). New York, NY: Routledge.

Gess-Newsome, J., Taylor, J.A., Carlson, J., Gardner, A.L., Wilson, C.D., & Stuhlsatz, M.A.M. (2017). Teacher pedagogical content knowledge, practice, and student achievement. *International Journal of Science Education.* Advance online publication. doi: 10.1080/09500693.2016.1265158

Gowda, M.V.R., Fox, J.C., & Magelky, R.D. (1997). Students' understanding of climate change: Insights for scientists and educators. *Bulletin of the American Meteorological Society, 78*(10), 2232-2240.

Graf, D., Tekkaya, C., Kılıç, D.S., & Özcan, G. (April, 2011). Alman ve türk fen bilgisi öğretmen adaylarının evrim öğretimine ilişkin pedagojik alan bilgisinin, tutumlarının ve pedagojik alan kaygılarının araştırılması, *2nd International Conference on New Trends in Education and Their Implications,* Antalya, 418-425.

Grossman, P.L. (1990). *The making of a teacher: Teacher knowledge and teacher education.* New York/London: Teachers College Press.

Hanuscin, D.L., Cisterna, D., & Lipsitz, K. (2018). Elementary teachers' pedagogical content knowledge for teaching structure and properties of matter. *Journal of Science Teacher Education, 29*(8), 665-692. DOI: 10.1080/1046560X.2018.1488486

Han-Tosunoğlu, Ç. (2018). *Biyoloji öğretmenlerinin sosyobilimsel konularla ilgili pedagojik alan bilgilerinin incelenmesi*. Doctoral Dissertation. Marmara Üniversitesi, İstanbul.

Hanuscin, D.L., de Araujo, Z., Cisterna D., Lipsitz, K., & van Garderen, D. (2020). The re-novicing of elementary teachers in science? Grade level reassignment and teacher PCK. *Journal of Science Teacher Education, 31*(7), 780-801. DOI: 10.1080/1046560X.2020.1778845

Hanuscin, D.L., Lee, M.H., & Akerson, V.L. (2011). Elementary teachers' pedagogical content knowledge for teaching the nature of science. *Science Teacher Education, 95*, 145-167. DOI: 10.1002/sce.20404

Hashweh, M.Z. (1987). Effects of subject matter knowledge in the teaching of biology and physics. *Teaching & Teacher Education, 3*(2), 109-120.

Hattie, J. (2012). The source of the ideas (Chapter 2). In J. Hattie, *Visible learning for teachers: Maximizing impact on learning* (pp.9-21). New York, NY: Routledge.

Helmke, A. (2003). *Unterrichtsqualität erfassen, bewerten, verbessern [Measuring, rating and improving quality of instruction]*. Seelze: Kallmeyer.

Henriques, L. (2002). Children's ideas about weather: A review of the literature. *School Science and Mathematics, 102*(5), 202-215.

Henze, I., van Driel, J.H., & Verloop, N. (2008). Development of experienced science teachers' pedagogical content knowledge of models of the solar system and the universe. *International Journal of Science Education, 30*(10), 1321-1342. DOI: 10.1080/09500690802187017

Herman, B.C., Feldman, A., & Vernaza-Hernandez, V. (2017). Florida and Puerto Rico secondary science teachers' knowledge and teaching of climate change science. *International Journal of Science and Mathematics Education, 15*, 451-471. DOI: 10.1007/s10763-015-9706-6

Hsu, Y.S. (2008). Learning about seasons in a technologically enhanced environment: The impact of teacher-guided and student-centered instructional approaches on the process of students' conceptual change. *Science Education, 92*, 320-344. DOI: 10.1002/sce.20242

Jacobson, M.Z. (2012). *Air pollution and global warming: History, science, and solutions* (2nd ed.). Cambridge: Cambridge University Press

Jensen, B.B., & Schnack, K. (1997). The action competence approach in environmental education. *Environmental Education Research, 3*(2), 163-178. DOI: 10.1080/1350462970030205

Karpudewan, M., & Mohd Ali Khan, N.S. (2017). Experiential-based climate change education: Fostering students' knowledge and motivation towards the environment. *International Research in Geographical and Environmental Education, 26*(3), 207-222. DOI: 10.1080/10382046.2017.1330037

Kaya, O.N. (2009). The nature of relationships among the components of pedagogical content knowledge of preservice science teachers: 'Ozone layer depletion' as an example. *International Journal of Science Education, 31*(7), 961-988. DOI: 10.1080/09500690801911326

Käpylä, M., Heikkinen, J.P., & Asunta, T. (2009). Influence of content knowledge on pedagogical content knowledge: The case of teaching photosynthesis and plant growth. *International Journal of Science Education, 31*(10), 1395-1415. DOI: 10.1080/09500690802082168

Keller, M.M., Neumann, K., & Fischer, H.E. (2017). The impact of physics teachers' pedagogical content knowledge and motivation on students' achievement and interest. *Journal of Research in Science Teaching, 54*(5), 586-614. DOI 10.1002/tea.21378

Khalid, T. (2001). Pre-service teachers' misconceptions regarding three environmental issues. *Canadian Journal of Environmental Education, 6*, 102-120.

Khalid, T. (2003). Pre-service high school teachers' perceptions of three environmental phenomena. *Environmental Education Research, 9*(1), 35-50. DOI:10.1080/13504620303466

Khishfe, R. & Lederman, N. (2006). Teaching nature of science within a controversial topic: Integrated versus nonintegrated. *Journal of Research in Science Teaching, 43*(4), 395-418. DOI: 10.1002/tea.20137

Kikas, E. (2004). Teachers' conceptions and misconceptions concerning three natural phenomena. *Journal of Research in Science Teaching, 41*(5), 432-448. DOI: 10.1002/tea.20012

Kinchin, I.M., Hay, D.B., & Adams, A. (2000). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Research, 42*(1), 43-57.

Kind, V. (2009). Pedagogical content knowledge in science education: Perspectives and potential for progress. *Studies in Science Education, 45*(2), 169-204. DOI: 10.1080/03057260903142285

Kind, V. (2016). Preservice science teachers' science teaching orientations and beliefs about science. *Science Education, 100*(1), 122-152. DOI 10.1002/sce.21194

King-Heiden, T.C., & Litster, M. (2019). Using case-study based modules to promote a better understanding of evolution in an undergraduate anatomy and physiology course. *Journal of Biological Education, 53*(5), 477-491. DOI: 10.1080/00219266.2018.1501406

Kutluca, A. Y. (2021). An investigation of elementary teachers' pedagogical content knowledge for socioscientific argumentation: The effect of a learning and teaching experience. *Science Education, 105*, 743–775. DOI: 10.1002/sce.21624

Kücüközer, H. (2007). Prospective science teachers' conceptions about astronomical subjects. *Science Education International, 18*(2), 113-130.

Lambert, J.L., Lindgren, J., & Bleicher, R. (2012). Assessing elementary science methods students' understanding about global climate change. *International Journal of Science Education, 34*(8), 1167-1187. DOI: 10.1080/09500693.2011.633938

Lane, R. (2009). Articulating the pedagogical content knowledge of accomplished geography teachers. *Geographical Education, 22*, 40-50.

Lane, R. (2015a). Experienced geography teachers' PCK of students' ideas and beliefs about learning and teaching. *International Research in Geographical and Environmental Education, 24*(1), 43-57. DOI: 10.1080/10382046.2014.967113

Lane, R. (2015b). Primary geography in Australia: Pre-service primary teachers' understandings of weather and climate. *Review of International Geographical Education Online, 5*(2), 199-217.

Lankford, D. (2010). *Examining the pedagogical content knowledge and practice of experienced secondary biology teachers for teaching diffusion and osmosis.* Published Doctoral Thesis. University of Missouri, USA.

Lederman, N.G. (1999). The state of science education: Subject matter without context. *The Electronic Journal for Research in Science & Mathematics Education, 3*(2), 1-24.

Lederman, N.G., Abd-El-Khalick, F., Bell, R.L., & Schwartz, R.S. (2002). Views of nature of science questionnaire: Toward valid and meaningful assessment of learners' conceptions of nature of science. *Journal of Research in Science Teaching, 39*(6), 497-521. DOI: 10.1002/tea.10034

Lederman, N.G., Schwartz, R.S., Abd-El-Khalick, F., & Bell, R.L. (2001). Preservice teachers' understanding and teaching of nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education, 1*(2), 135-160.

Lewis, J., & Wood-Robinson, C. (2000). Genes, chromosomes, cell division and inheritance – do students see any relationship? *International Journal of Science Education, 22*(2), 177-195. DOI: 10.1080/095006900289949

Lincoln, Y.S., & Guba, E.G. (1985). *Naturalistic inquiry.* Newbury Park, CA: Sage. (Chapter 11: Establishing Trustworthiness)

Loughran, J., Mulhall, P., & Berry, A. (2004). In search of pedagogical content knowledge in science: Developing ways of articulating and documenting professional practice. *Journal of Research in Science Teaching, 41*(4), 370-391. DOI 10.1002/tea.20007

Lucero, M.M., Petrosino, A.J., & Delgado, C. (2017). Exploring the relationship between secondary science teachers' subject matter knowledge and knowledge of student conceptions while teaching evolution by natural selection. *Journal of Research in Science Teaching, 54*(2), 219-246. DOI: 10.1002/tea.21344

Luft, J.A., & Roehrig, G.H. (2007). Capturing science teachers' epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education, 11*(2), 38-63.

Lumpe, A.T. (2007). Application of effective schools and teacher quality research to science teacher education. *Journal of Science Teacher Education, 18*(3), 345-348. DOI: 10.1007/s10972-007-9042-y

Lutgens, F.K., & Tarbuck, E.J. (2010). *The atmosphere: An introduction to meteorology.* (11th ed.). Upper Saddle River, NJ: Pearson Education.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, source, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N.G. Lederman (Eds.), *Examining pedagogical content knowledge* (pp.95-132). Boston, MA: Kluwer Press

Mandrikas, A., Stavrou, D., & Skordoulis, C. (2017). Teaching air pollution in an authentic context. *Journal of Science Education Technology, 26*, 238-251. DOI: 10.1007/s10956-016-9675-8

Mant, J., & Summers, M. (1993). Some primary-school teachers' understanding of the Earth's place in the universe. *Research Papers in Education, 8*(1), 101-129. DOI: 10.1080/0267152930080107

Marshall, C., & Rossman, G.B. (1995). *Designing qualitative research.* (2th ed.). Thousand Oaks, CA: SAGE Publications.

Martin, B.L., Mintzes, J.J., & Clavijo, I.E. (2000). Restructuring knowledge in biology: Cognitive processes and metacognitive reflections. *International Journal of Science Education, 22*(3), 303-323. DOI: 10.1080/095006900289895

Matkins, J.J., & Bell, R.L. (2007). Awakening the scientist inside: Global climate change and the nature of science in an elementary science methods course. *Journal of Science Teacher Education, 18,* 137-163. DOI: 10.1007/s10972-006-9033-4

Matkins, J.J., Bell, R., Irving, K., & McNall, R. (2002). Impacts of contextual and explicit instruction on preservice elementary teachers' understandings of the nature of science. *Proceedings of the Annual International Conference of the Association for the Education of Teachers in Science,*1-27.

Mavhunga, E. (2018). Revealing the structural complexity of component interactions of topic-specific PCK when planning to teach. *Research in Science Education,* 1-22. DOI: 10.1007/s11165-018-9719-6

Mavhunga, E., & Rollnick, M. (2013). Improving PCK of chemical equilibrium in pre-service teachers. *African Journal of Research in Mathematics, Science and Technology Education, 17*(1-2), 113-125.

Mavhunga, E., & Rollnick, M. (2016). Teacher- or learner-centred? Science teacher beliefs related to topic specific pedagogical content knowledge: A South African case study. *Research in Science Education, 46*, 831-855. DOI 10.1007/s11165-015-9483-9

Mazibe, E.N., Coetzee, C., & Gaigher, E. (2018). A comparison between reported and enacted pedagogical content knowledge (PCK) about graphs of motion. *Research in Science Education*. DOI 10.1007/s11165-018-9718-7

Merriam, S. B. (2009). *Qualitative research: A guide to design and implementation.* San Francisco, CA: Jossey-Bass.

Merriam, S.B. & Tisdell, E.J. (2016). *Qualitative research: A guide to design and implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

Mıhladız, G., & Timur, B. (2011). Pre-service science teachers views of in-service science teachers' pedagogical content knowledge. *Eurasian Journal of Physics and Chemistry Education,* January (Special Issue), 89-100.

Michail, S., Stamou, A.G., & Stamou, G.P. (2007). Greek primary school teachers' understanding of current environmental issues: An exploration of their environmental knowledge and images of nature. *Science Education,* 91, 244-259. DOI: 10.1002/sce.20185

Ministry of National Education (2005). *Science and Technology Curriculum.* Ankara: Ministry of National Education Publications.

Ministry of National Education (2013). *Elementary 3rd, 4th, 5th, 6th, 7th and 8th Grades Science Curriculum.* Ankara: Ministry of National Education Publications.

Ministry of National Education (2018). (*Primary and Elementary Schools 3rd, 4th, 5th, 6th, 7th, and 8th Grades) Science Curriculum.* Ankara: Ministry of National Education Publications.

Ministry of National Education (2018). (*Primary and Elementary Schools 4th, 5th, 6th, and 7th Grades) Social Science Curriculum.* Ankara: Ministry of National Education Publications.

Ministry of National Education (2018). *Secondary School Geography Curriculum (9th, 10th, 11th, and 12th Grades).* Ankara: Ministry of National Education Publications.

Mthethwa-Kunene, E., Onwu, G.O., & de Villiers, R. (2015). Exploring biology teachers' pedagogical content knowledge in the teaching of genetics in Swaziland science classrooms. *International Journal of Science Education, 37*(7), 1140-1165. DOI: 10.1080/09500693.2015.1022624

Nargund-Joshi, V., Rogers, M.A.P., & Akerson, V.L. (2011). Exploring Indian secondary teachers' orientations and practice for teaching science in an era of reform. *Journal of Research in Science Teaching, 48*(6), 624-647. DOI: 10.1002/tea.20429

National Oceanic and Atmospheric Administration (NOAA). (2009). *Climate literacy: The essential principles of climate science.* U.S. Global Change Research Program's Site. Retrieved from https://downloads.globalchange.gov/Literacy/climate_literacy_highres_english.pdf

Nilsson, P. (2014). When teaching makes a difference: Developing science teachers' pedagogical content knowledge through learning study. *International Journal of Science Education, 36*(11), 1794-1814, DOI: 10.1080/09500693.2013.879621

Nilsson, P., & Loughran, J. (2012). Exploring the development of pre-service science elementary teachers' pedagogical content knowledge. *Journal of Science Teacher Education, 23*(7), 699-721. DOI: 10.1007/s10972-011-9239-y

Norville, K., & Park, S. (2021). The impact of the cooperating teacher on master of arts in teaching preservice science teachers' pedagogical content knowledge. *Journal of Science Teacher Education, 32*(4), 444-468. DOI: 10.1080/1046560X.2020.1850614

Ocal, A., Kisoglu, M., Alas, A., & Gurbuz, H. (2011). Turkish prospective teachers' understanding and misunderstanding on global warming. *International Research in Geographical and Environmental Education, 20*(3), 215-226. DOI: 10.1080/10382046.2011.588504

Ohle, A., Boone, W.J., & Fischer, H.E. (2015). Investigating the impact of teachers' physics CK on students outcomes. *International Journal of Science and Mathematics Education, 13*, 1211-1233.

Österlind, K. (2005). Concept formation in environmental education: 14-year olds' work on the intensified greenhouse effect and the depletion of the ozone layer. *International Journal of Science Education, 27*(8), 891-908. DOI: 10.1080/09500690500038264

Padilla, K., & van Driel, J. (2011). The relationships between PCK components: The case of quantum chemistry professors. *Chemistry Education Research and Practice, 12*(3), 367-378.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effect, and ozone layer depletion. *Journal of Science Education and Technology, 13*(2), 299-307.

Park, S., & Chen, Y.C. (2012). Mapping out the integration of the components of pedagogical content knowledge (PCK): Examples from high school biology classrooms. *Journal of Research in Science Teaching, 49*(7), 922-941. DOI: 10.1002/tea.21022

Park, S., & Oliver, J.S. (2008a). Revisiting the conceptualisation of pedagogical content knowledge (PCK): PCK as a conceptual tool to understand teachers as professionals. *Research in Science Education, 38*, 261–284. DOI 10.1007/s11165-007-9049-6

Park, S., & Oliver, J.S. (2008b). National Board Certification (NBC) as a catalyst for teachers' learning about teaching: The effects of the NBC process on candidate Teachers' PCK development. *Journal of Research in Science Teaching,* 45(7), 812-834.

Parker, J., & Heywood, D. (1998). The earth and beyond: Developing primary teachers' understanding of basic astronomical events. *International Journal of Science Education, 20*(5), 503-520. DOI: 10.1080/0950069980200501

Patton, M. Q. (1987). *How to use qualitative methods in evaluation* (2nd ed.). Newbury Park, CA: Sage Publications, the International Professional Publishers.

Patton, M. Q. (2002). *Qualitative research & evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Philips, W.C. (1991). Earth science misconceptions. *The Science Teacher, 58*(2), 21-23.

Pitjeng-Mosabala, P., & Rollnick, M. (2018). Exploring the development of novice unqualified graduate teachers' topic-specific PCK in teaching the particulate nature of matter in South Africa's classrooms. *International Journal of Science Education, 40*(7), 742-770, DOI: 10.1080/09500693.2018.1446569

Plutzer, E., & Hannah, A. L. (2018). Teaching climate change in middle schools and high schools: Investigating STEM education's deficit model. *Climatic Change, 149,* 305–317. DOI: 10.1007/s10584-018-2253-8

Porter, D., Weaver, A.J., & Raptis, H. (2012). Assessing students' learning about fundamental concepts of climate change under two different conditions. *Environmental Education Research, 18*(5), 665-686. DOI: 10.1080/13504622.2011.640750

Ratinen, I. J. (2013). Primary student-teachers' conceptual understanding of the greenhouse effect: A mixed method study. *International Journal of Science Education, 35*(6), 929–955. DOI: 10.1080/09500693.2011.587845

Ratinen, I., Viiri, J., & Lehesvuori, S. (2013). Primary school student teachers' understanding of climate change: Comparing the results given by concept maps and communication analysis. *Research in Science Education, 43*, 1801-1823. DOI: 10.1007/s11165-012-9329-7

Rollnick, M. (2016). Learning about semi conductors for teaching—The role played by content knowledge in pedagogical content knowledge (PCK) development. *Research in Science Education,* DOI 10.1007/s11165-016-9530-1

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education, 30*(10), 1365-1387. DOI: 10.1080/09500690802187025

Rye, J.A., Rubba, P.A., & Wiesenmayer, R.L. (1997). An investigation of middle school students' alternative conceptions of global warming. *International Journal of Science Education, 19*(5), 527-551. DOI: 10.1080/0950069970190503

Sadler, D.R. (1989). Formative assessment and the design of instructional systems. *Instructional Science, 18*(2), 119-144.

Sadler, D.R. (1998). Formative assessment: Revisiting the territory. *Assessment in Education: Principles, Policy & Practice, 5*(1), 77-84. DOI: 10.1080/0969595980050104

Salierno, C., Edelson, D., & Sherin, B. (2005). The development of student conceptions of the Earth-Sun relationship in an inquiry-based curriculum. *Journal of Geoscience Education, 53*(4), 422-431. DOI: 10.5408/1089-9995-53.4.422

Samuelowicz, K., & Bain J.D. (1992). Conceptions of teaching held by academic teachers. *Higher Education,* 24(93), 93-111.

Schwab, J.J. (1964). The structure of disciplines: Meanings and significance. In G.W. Ford & L. Pugno (Eds.), *The structure of knowledge and the curriculum.* Chicago: Rand McNally.

Schwab, J.J. (1978). *Science, curriculum and liberal education.* Chicago: University of Chicago Press.

Schwartz, R.S., & Lederman, N.G. (2002). "It's the nature of the beast": The influence of knowledge and intentions on learning and teaching nature of science. *Journal of Research in Science Teaching, 39*(3), 205-236. DOI: 10.1002/tea.10021

Sebastià, B.M., & Torregrosa, J.M. (2005). Preservice elementary teachers' conceptions of the sun-earth model: A proposal of a teaching-learning sequence. *Astronomy Education Review, 4*(1), 121-126.

Settlage, J. (2000). Understanding to learning cycle: Influences on abilities to embrace the approach by preservice elementary school teachers. *Science Education, 84,* 43-50.

Shepardson, D.P., Niyogi, D., Choi, S., & Charusombat, U. (2009). Seventh grade students' conceptions of global warming and climate change. *Environmental Education Research, 15*(5), 549-570. DOI: 10.1080/13504620903114592

Shepardson, D.P., Niyogi, D., Choi, S., & Charusombat, U. (2011). Students' conceptions about the greenhouse effect, global warming, and climate change. *Climatic Change, 104,* 481-507. DOI: 10.1007/s10584-009-9786-9

Shepardson, D.P., Niyogi, D., Roychoudhury, A., & Hirsch, A. (2011). Conceptualizing climate change in the context of a climate system: Implications for climate and environmental education. *Environmental Education Research,* 1-30. DOI: 10.1080/13504622.2011.622839

Shepardson, D.P., Niyogi, D., Roychoudhury, A., & Hirsch, A. (2012). Conceptualizing climate change in the context of a climate system: Implications for climate and environmental education. *Environmental Education Research, 18*(3), 323-352. DOI: 10.1080/13504622.2011.622839

Shepardson, D.P., Roychoudhury, A., Hirsch, A., Niyogi, D., & Top, S.M. (2014). When the atmosphere warms it rains and ice melts: Seventh grade students' conceptions of a climate system. *Environmental Education Research, 20*(3), 333-353. DOI: 10.1080/13504622.2013.803037

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher, 15*(2), 4-14.

Shulman, L.S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1), 1-21.

Sisco, M.R., Pianta, S., Weber, E.U., & Bosetti, V. (2021). Global climate marches sharply raise attention to climate change: Analysis of climate search behavior in 46 countries. *Journal of Environmental Psychology, 75*, 1-8. DOI: 10.1016/j.jenvp.2021.101596

Sneider, C., Bar, V., & Kavanagh, C. (2011). Learning about seasons: A guide for teachers and curriculum developers. *Astronomy Education Review*, 10, 010103-1-22. DOI: 10.3847/AER2010035

Soysal, Y. (2018). An exploration of the interactions among the components of an experienced elementary science teachers' pedagogical content knowledge. *Educational Studies*, *44*(1), 1–25. DOI: 10.1080/03055698.2017.1331839

Stake, R.E. (2005). Qualitative case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (3rd ed., pp. 443-466). Thousand Oaks, CA: Sage.

Starakis, I., & Halkia, K. (2013). Addressing k-5 students' and pre-service elementary teachers' conceptions of seasonal change. *Physics Education, 49*(2), 231-239.

Stewart, A.E., Knox, J.A., & Schneider, P. (2018). Reaching students and parents through weather science and safety workshops for teachers. *American Meteorological Society,* 1545-1555. DOI: 10.1175/BAMS-D-17-0114.1

Suh, J. K., & Park, S. (2017). Exploring the relationship between pedagogical content knowledge (PCK) and sustainability of an innovative science teaching approach. *Teaching and Teacher Education, 64,* 246–259. DOI: 10.1016/j.tate.2017.01.021

Sung, J.Y., & Oh, P.S. (2018). Sixth grade students' content-specific competencies and challenges in learning the seasons through modeling. *Research in Science Education, 48,* 839-864. DOI: 10.1007/s11165-016-9589-8

Şen, M. (2014). *A study on science teachers' pedagogical content knowledge and content knowledge regarding cell division.* Master's Thesis, Middle East Technical University, Ankara.

Şen, M., Demirdöğen, B., & Öztekin, C. (2022). Interactions among topic-specific pedagogical content knowledge components for science teachers: The impact of content knowledge. *Journal of Science Teacher Education,* DOI: 10.1080/1046560X.2021.2012630

Şen, M., & Öztekin, C. (2019). Interaction among contextual knowledge and pedagogical content knowledge: Sociocultural perspective. *Education and Science, 44*(198), 57-97. DOI: 10.15390/EB.2019.7927

Şen, M., Öztekin, C., & Demirdöğen, B. (2018). Impact of content knowledge on pedagogical content knowledge in the context of cell division. *Journal of Science Teacher Education,* 1-26. DOI: 10.1080/1046560X.2018.1425819.

Teed, R., & Franco, S. (2014). Increasing teachers' confidence and pedagogical content knowledge through a workshop and follow-up program on climate change. *Journal of Geoscience Education, 62*(4), 587-597. DOI: 10.5408/13-039.1

Teed, R., & Wright, C. (2014). Personal timeline. Available at http://serc.carleton.edu/NAGTWorkshops/time/activities/61059.html (accessed 29 April 2014).

Tekkaya, C., & Kılıç, D.S. (2012). Pre-service biology teachers' pedagogical content knowledge regarding teaching evolution. *Hacettepe University Journal of Education, 42*, 406-417.

Tıraş, İ. (2019). *Exploring experienced science teachers' topic-specific pedagogical content knowledge in teaching ecosystems.* Master's Thesis, Middle East Technical University, Ankara.

Tiras, I., Öztekin, C., & Sen, M. (August, 2017). Preservice elementary science teachers' pedagogical content knowledge for sustainable development. *ESERA 2017 Conference*, Dublin.

Tsai, C.C., & Chang, C.Y. (2005). Lasting effects of instruction guided by the conflict map: Experimental study of learning about the causes of the seasons. *Journal of Research in Science Teaching, 42*(10), 1089-1111. DOI: 10.1002/tea.20089

UA (2017). *BenBizHepimiz-Ortak Sürdürülebilir Kalkınma İçin Eğitim Kitabımız*. Ankara, Ziraat Gurup Matbaacılık A.Ş.

Uşak, M. (2009). Preservice science and technology teachers' pedagogical content knowledge on cell topics. *Educational Science: Theory & Practice, 9*(4), 2033-2046.

Üner, S. (2016). *Examination of the topic-specific nature of chemistry teachers' pedagogical content knowledge and students' perceptions of their teachers' pedagogical content knowledge.* Doctoral dissertation, Gazi University, Ankara, Turkey.

Van Driel, J.H., De Jong, O., & Verloop, N. (2002). The development of preservice chemistry teachers' pedagogical content knowledge. *Science Education, 86*, 572-590. DOI: 10.1002/sce.10010

van Driel, J.H., Verloop, N., & de Vos, W. (1998). Developing science teachers' pedagogical content knowledge. *Journal of Research in Science Teaching, 35*(6), 673-695.

Veal, W.R., & Kubasko Jr., D.S. (2003). Biology and geology teachers' domain-specific pedagogical content knowledge of evolution. *Journal of Curriculum and Supervision, 18*(4), 334-352.

Veal, W.R., & MaKinster, J.G. (1999). Pedagogical content knowledge taxonomies. *The Electronic Journal for Research in Science & Mathematics Education, 3*(4), 1-15.

Wahbeh, N., & Abd-El-Khalick, F. (2014). Revisiting the translation of nature of science understandings into instructional practice: Teachers' nature of science pedagogical content knowledge. *International Journal of Science Education, 36*(3), 425-466. DOI: 10.1080/09500693.2013.786852

Wheeldon, R. (2017). Improving preservice chemistry teachers' content knowledge through intervention activities. *International Journal of Science Education, 39*(9), 1238-1261. DOI: 10.1080/09500693.2017.1333655.

Willis, J.W. (2007). *Foundations of qualitative research: Interpretive and critical approaches.* Thousand Oaks, CA: Sage Publications.

Wise, S. B. (2010). Climate change in the classroom: Patterns, motivations, and barriers to instruction among Colorado science teachers. *Journal of Geoscience Education, 58*(5), 297–309. DOI: 10.5408/1.3559695

Yılar, B. (2007). *İlköğretim 5. Sınıf öğrencilerinin bazı coğrafya kavramlarını anlama düzeyleri ve kavram yanılgıları.* Master's Thesis, Atatürk University, Erzurum.

Yılmaz Yendi, B. (2019). *Experienced science teachers' subject matter knowledge and pedagogical content knowledge regarding biogeochemical cycles in the context of education for sustainable development.* Doctoral Dissertation, Middle East Technical University, Ankara.

Yin, R. K. (1994). *Case study research: Design and methods* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Yin, R. K. (2011). *Qualitative research from start to finish.* New York, NY: Guilford Press.

Zhang, B., Krajcik, J.S., Sutherland, L.M., Wang, L., Wu, J., & Qian, Y. (2003). Opportunities and challenges of China's inquiry-based education reform in middle and high schools: Perspectives of science teachers and teacher educators. *International Journal of Science and Mathematics Education, 1,* 477-503.

APPENDICES

A. CONTENT REPRESENTATION (CoRe) INTERVIEW FORM (IN TURKISH)

Sayın Öğretmenlerim,

Merhaba, ben Kübra SAĞBİLGE. Orta Doğu Teknik Üniversitesi, Eğitim Fakültesi Matematik ve Fen Alanları Eğitimi Bölümü Yüksek Lisans öğrencisiyim. Fen bilimleri öğretmenlerinin hava ve iklim konusunda konu alan bilgileri ve pedagojik alan bilgileri üzerine bir araştırma yapmaktayım. Bunun için sizden hava ve iklim kavramlarının tanımı ve bu konuların bilimin doğası ile olan ilişkisi hakkında görüşlerinizi almak istiyorum. Bu çalışma, hava ve iklim ile ilgili siz fen bilimleri öğretmenlerinin mevcut görüş ve bilgilerini ortaya koymak ve bu konunun eğitim sistemindeki yerini anlamak açısından çok önemlidir. Bu nedenle konu ile ilgili içten ve samimi cevaplarınız benim için oldukça değerlidir. Yardımlarınız için sizlere teşekkür ederim.

Görüşme esnasında söyledikleriniz ve kimlik bilgileriniz kesinlikle gizli kalacaktır. Görüşme içeriği sadece araştırma amaçlı kullanılacak. Görüşmeyi kaydetmek için izninizi istiyorum. Bu hem görüşmenin akışı hem de cevaplarınızın analizi açısından önemlidir. İstediğiniz zaman görüşmeyi bırakabilirsiniz.

Bana sormak istediğiniz herhangi bir soru varsa yanıtlayabilirim.

Kübra SAĞBİLGE

ODTÜ-Eğitim Fakültesi

KİŞİSEL BİLGİLER

-Adınız, Soyadınız:

- Yaşınız: Cinsiyet:

-Görev yapmakta olduğunuz okul:

-Mezun olduğunuz üniversite/Bölüm:

-Ne kadar süredir öğretmenlik yapıyorsunuz?:

-Kaç yıldır bu okulda görev yapıyorsunuz?

-Okulun demografik yapısını nasıl tanımlarsınız? (Büyüklüğü, öğrencilerin Sosyo-ekonomik seviyesi…vb.):

-8. Sınıflarınızın ortalama öğrenci sayısı:

-Daha önce hizmet içi eğitime katıldınız mı?:

-Katıldıysanız, hizmet içi eğitimin içeriği/konusu:

-Daha önce hava ve iklim konusu yada diğer fen konularına yönelik etkinlik/seminer/konferans vs. katıldınız mı? :

-Katıldıysanız, içeriği:

-Bu konuya özel bir ilginiz var mı?:

-Bu konu ile ilgili yaşanmış bir tecrübeniz var mı?:

İÇERİK GÖSTERİMİ MÜLAKAT SORULARI

Konu Alanı 1: Öğrencilerin Öğrenmesi Gereken Konular

Ana Soru: Mevsimlerin oluşumu/ İklim ve Hava Hareketleri ünitesinde öğrencilerin neleri (hangi temel noktaları) öğrenmesini istiyorsunuz?

1. Programda Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunda bulunan kavramların sıralanışları nasıl?

2. Programda Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusuna temel oluşturan konular nelerdir? Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusundan önce ve sonra gelen konular nelerdir?

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

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

5. Bu konu ile ilgili ortaokul fen bilimleri programında bulunan kazanımlar nelerdir? (Programda bu konu ile ilgili öğrencilerin hangi kavram/becerileri geliştirmeleri bekleniyor?)

Konu Alanı 2: Konuyu Bilmenin Önemi

Ana Soru: Öğrencilerin Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunu bilmesi neden önemlidir?

1. Mevsimlerin oluşumu/ İklim ve Hava Hareketleri öğrenmeleri öğrencilere ne gibi avantajlar sağlar? Neden?

2. Öğrencilerin bu kavramları bilmeleri neden önemlidir? Onlara nasıl bir katkısı olabilir?

3. Öğrenciler öğrendikleri bu bilgi ve becerileri nasıl kullanacaklar? Eğer öğrenciler fen alanında bir meslek seçmezlerse, bu bilgi ve beceriler onlara nasıl faydalı olacak?
    - Olmayacaksa nedenini açıklar mısınız?

Ana soru: Fen bilimleri öğretiminin amaçları

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

1. Bahsettiğiniz bu amaçları hedefleri nasıl belirlediniz? Amaçları belirlemenize neler yardımcı oldu?
2. Fen öğretiminde öğretmenin rolü nedir, öğrencinin rolü nedir? (Söylediğiniz amaçlara paralel düşünebilirsiniz).

Konu Alanı 3: Konuyu öğretmek ile İlgili Zorluk ve Sınırlılıklar

Ana Soru: Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunu öğretirken yaşadığınız zorluklar nelerdir?

1. Sizce bu konuyu öğretmek neden zordur? Bu konuyu öğretmeyi zorlaştıran etkenler nelerdir? Neden?

2. Bu konuyu öğretmenin zorluklarını nasıl öğrendiniz? (Bu konuyu öğretmenin zor olduğuna nasıl kanaat getirdiniz?)

3. Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunun öğretimine yönelik kaygılarınız var mı?

   a. Evet derse: kaygılarınız nelerdir?
   b. Kaygılanma nedeniniz nedir?
   c. Hangi faktörlerin sizin Mevsimlerin oluşumu/ İklim ve Hava Hareketleri öğretimini etkileyeceğini düşünüyorsunuz?
   d. Mevsimlerin oluşumu/ İklim ve Hava Hareketleri öğretimi ile ilgili zorluklar ve sizi sınırlayan faktörler olabilir mi?
   e. Bu konuyu öğretmenizi etkileyen diğer faktörler nelerdir?
   f. Bu konuyu öğretmenin zorlukları nelerdir?
   g. Bu konuyu öğretirken yaşadığınız sınırlılıklar nelerdir?

Konu Alanı 4: Öğrencilerin Düşünceleri

Ana Soru: Bu aşamada öğrencilerin Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusundaki düşünceleri/kavramaları hakkında konuşmak istiyorum. Öğrenciler Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunu öğrenirken hangi noktalarda zorlanıyorlar?

1. Öğrencilerin yukarıda bahsettiğiniz ana kavramlarla ilgili olarak zorlandıkları noktalar neler olabilir?

2. Öğrencilerin yukarıda bahsettiğiniz ana kavramlarla ilgili olarak sahip oldukları yanlış kavramalar neler olabilir?

3. Neden böyle bir yanlış kavramaya sahip olabilirler? Sebepleri neler olabilir?

4. Öğrenciler Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunu öğrenebilmeleri için hangi ön bilgi ve becerilere sahip olmalıdırlar? Neden?
5. Öğrenciler bu bilgileri nereden öğrenmiş olabilir?
6. Öğrencilerin Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusundaki yanlış kavramalarını ve zorlandıkları noktaları nasıl öğrendiniz? Kaynaklarınız nelerdir? (Sadece kitap vb. kaynakları kastedilmediği vurgulanacak)
7. Öğrencilerin Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusundaki kavram yanılgıları ve yaşadıkları zorluklar sizin öğretiminizi etkiliyor mu? Nasıl?
    - Evet ise, ders planınızı yaparken öğrencilerin zorlandıkları noktaları ve yanlış kavramalarını nasıl kullanıyorsunuz?
    - Hayır derse, nedeni nedir?

Konu Alanı 5: Öğretmenin Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunu öğretmesini etkileyen faktörler

Ana Soru: Yukarıda bahsettiğiniz kavramların öğretimini etkileyen diğer etkenler nelerdir?

1. Bu faktörler yaptığınız öğretimi nasıl etkilemektedir?
2. Bu konuyu öğretirken kendinizi ne kadar özgür/bağımsız/seçme hakkına sahip hissediyorsunuz?

Konu Alanı 6: Öğretim Prosedürleri

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

1. O stratejileri kullanmayı tercih etmenizin nedenleri nelerdir?

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

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

4. Öğrencilerin kafası karıştığında ne kadar alternatif açıklama ya da örnek sağlayabilirsiniz?

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

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

7. Amaçlarınızla seçtiğiniz metotlar arasında nasıl bir bağlantı var, seçtiğiniz metotlar amaçlarınızı ne ölçüde yansıtıyor?

8. Günlük hayatta Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunun uygulamasını gördüğünüz alanlar var mı? Bunu yaptığınız öğretimde kullanıyor musunuz?

9. Öğrencileri katmada ne kadar iyisiniz? Neden iyi/kötü olduğunuzu düşünüyorsunuz? Ya da bu kanıya nasıl vardınız?

10. Yaptığınız öğretimin etkili olup olmadığını nasıl anlarsınız?

Konu Alanı: 7 Öğrencilerinin Anladıklarının Ölçülmesi:

_Ana Soru: Öğrencilerin konuyu anlayıp anlamadıklarını nasıl ölçersiniz?

1. Öğrencilerin Mevsimlerin oluşumu/ İklim ve Hava Hareketleri konusunda ne öğrendiklerini hangi ölçme tekniklerini kullanarak ölçersiniz?

2. Niçin bu ölçme tekniklerini kullanmayı tercih ediyorsunuz?

3. Değerlendirme sonuçlarını nasıl kullanıyorsunuz? Bu sonuçlar size neler anlatıyor?

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

B. PEDAGOGICAL CONTENT KNOWLEDGE INTERVIEW FORM (IN TURKISH)

YARI YAPILANDIRILMIŞ PEDAGOJİK ALAN BİLGİSİ GÖRÜŞME FORMU

Pedagojik Alan Bilgisi Ön Görüşme Soruları

1-Fen Öğretimine karşı Yönelimler

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

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

3. Özel olarak "Mevsimlerin oluşumu/İklim ve Hava Hareketleri" konusunu ele alırsak bir fen bilimleri öğretmeni olarak bu konuyu öğretmek sizin için ne anlama geliyor? Cevabınızı açıklar mısınız?

a) Mevsimlerin oluşumu/İklim ve Hava Hareketleri konusunu siz, neden öğretiyorsunuz?

1.1. Fen Öğretimine yönelik Öğretmen inançları (Luft ve Roehrig, 2007)

- **a.** Öğrencilerin sınıfta öğrenmelerini en üst seviyeye çıkarmak için ne yaparsınız?
- **b.** Sınıftaki öğretmen rolünüzü nasıl tanımlarsınız?
- **c.** Öğrencilerinizin anladığını nasıl bilirsiniz?
- **d.** Okul ortamında, neyi öğretip neyi öğretmeyeceğinize nasıl karar verirsiniz?
- **e.** Sınıfta yeni konuya ne zaman geçeceğinize nasıl karar veriyorsunuz?
- **f.** Öğrencileriniz fen bilimlerini en iyi nasıl öğrenirler?
- **g.** Sınıfta öğrenme ne zaman oluyor nasıl anlıyorsunuz?

2-Müfredat Bilgisi

1. Sizce Mevsimlerin oluşumu/İklim ve Hava Hareketleri konularına öğretim programında neden yer verilmiştir?

(Bu konunun öğretmenlerin öğretim programına göre konunun önemine vurgu yapmaları beklenmektedir.)

2. Mevsimlerin oluşumu/İklim ve Hava Hareketleri konusunun müfredattaki yerini biliyor musunuz?

- Sizce "Mevsimlerin oluşumu/İklim ve Hava Hareketleri" konusu kaçıncı sınıfta okutulmaktadır?
- Mevsimlerin oluşumu/İklim ve Hava Hareketleri konusu (8.sınıf ders programında) kaçıncı ünitededir?
- Bu konulardan önceki ve sonraki üniteler nelerdir? Cevabınızı açıklar mısınız?

3. Öğretim programında Mevsimlerin oluşumu/İklim ve Hava Hareketleri konusu diğer konularla, ünitelerle veya sınıflarla ilişkilendirilmiş mi?

- Eğer ilişkilendirilmişse önceki yıllarda işlenen hangi fen konuları ile ilişkilidir?
  - Eğer ilişkilendirilmişse 8.sınıftaki hangi konularla ilişkilendirilmiştir?
- Eğer ilişkilendirilmemişse, sizce hangi konularla ilişkilendirilse konunun öğretimi ve öğrenilmesi daha iyi olur? Neden böyle düşündüğünüzü açıklayınız.

4. Bu konuların öğretilmesinden önce hangi kavramların öğretilmesi gerekir?

5. Fen bilimleri öğretim programında Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili olarak öğretilmesi amaçlanan temel kazanımlar nelerdir?

6. Bu kazanımları önem sırasına göre sıralar mısınız?

7. Bu kazanımlardan farklı olarak sizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili önemli gördüğünüz noktalar var mıdır?

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

8. Fen bilimleri öğretim programında Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili kavram yanılgılarına ve konunun anlatımı sırasında uyulması gereken sınırlamalara yer verilmiş midir?

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

9. Öğrencilerinize Mevsimlerin oluşumu/İklim ve Hava Hareketleri konularını anlatırken hangi kaynakları kullanıyorsunuz?

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

3. Öğrenci Bilgisi

1. Sizce öğrencilerinizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri konusunu öğrenebilmeleri için gerekli olan ön bilgiler neler olmalıdır? Neden böyle düşünüyorsunuz? Cevabınızı açıklar mısınız?

2. Öğrencilerinizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili olarak, hangi konuları anlamakta zorluk çektiklerini düşünüyorsunuz?

3. Sizce öğrencilerinizin bu konuları anlamakta zorlanmalarının sebepleri nelerdir?

4. Öğrencilerinizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili kavram yanılgıları var mıdır? Varsa bu kavram yanılgıları nelerdir? Cevabınızı açıklar mısınız?

5. Öğrencilerinizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili sahip oldukları kavram yanılgılarının nedenleri sizce neler olabilir?

6. Öğrencilerinizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri sahip olduğu kavram yanılgılarını nasıl saptarsınız? Kavram yanılgılarını saptamak için hangi yöntemleri kullanıyorsunuz?

- Eğer öğrencilerinizin kavram yanılgılarını saptamıyorsanız nedenini belirtiniz.

7. Saptadığınız bu kavram yanılgılarını gidermeye çalışıyor musunuz?

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

4.Değerlendirme Stratejileri Bilgisi

1. Öğrencilerinizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili bilgilerini ölçerken tam olarak neyi ölçmeyi hedefliyorsunuz?

2. Mevsimlerin oluşumu/İklim ve Hava Hareketleri konularında hangi ölçme ve değerlendirme yöntemlerini kullanıyorsunuz? Neden bu yöntemi seçtiğinizi açıklar mısınız?

- Neden diğer ölçme ve değerlendirme yöntemlerini tercih etmediğinizi açıklar mısınız?

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

- Neden bu zaman dilimini seçtiğinizi açıklar mısınız?

5.Öğretim Stratejileri Bilgisi

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

2. Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili sınıfta etkinlik yapıyor musunuz?

- Eğer yapıyorsanız bu etkinlikler nelerdir?
- Eğer Mevsimlerin oluşumu/İklim ve Hava Hareketleri ile ilgili etkinlik yapmıyorsanız neden etkinlik yapmadığınızı açıklayınız.

3. Mevsimlerin oluşumu/İklim ve Hava Hareketleri konusunu öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyorsunuz?

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

4. Öğrencilerinizin Mevsimlerin oluşumu/İklim ve Hava Hareketleri konularını öğrenmeleri ve kavramlarını anlamaları için gösterimler, figürler, simülasyonlar, çizimler ya da metaforlar kullanıyor musunuz?

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

C. PERMISSION FOR CONTENT REPRESENTATION (CoRe) INSTRUMENT

Konu:	Re: PCK doküman kullanımı için izin-Kübra sağbilge
Gönderen:	Sevgi Aydın <sevgiaydin@yyu.edu.tr>
Tarih:	7 Ağustos 2018, Salı, 2:16 pm
Alıcı:	kubra.sagbilge@metu.edu.tr
Öncelik:	Normal
Seçenekler:	Tüm Başlıkları Göster | Yazdırılabilir Şekilde Göster | Bunu dosya olarak indir | HTML olarak göster

```
Merhabalar;
tabiki kullanabilirsiniz.
Başarılar dilerim.

SAG.

7 Ağustos 2018 14:04 tarihinde Kubra Sagbilge <kubra.sagbilge@metu.edu.tr>
yazdı:

> Sayın Doç. Dr. Sevgi AYDIN,
>
> Ben Kübra SAĞBİLGE. Orta Doğu Teknik Üniversitesi Fen eğitimi bölümünde
> yüksek lisans yapmaktayım. Ceren ÖZTEKİN hocamızın danışmanlığında ''Fen
> bilimleri öğretmenlerinin hava ve iklim konusuna ilişkin Pedagojik Alan
> Bilgileri'' konusunu çalışmaktayım. İzniniz olursa doktora tezinizde
> kullanmış olduğunuz dokümanları tezimde kullanmak istiyorum.
>
> Saygılarımla,
>
> Kübra SAĞBİLGE
>
>
```

D. BURAK'S PCK POST-INTERVIEW QUESTIONS

1. During pre-interview, you said that you will use several teaching methods such as discussion, direct instruction, investigation. But, in your teaching you did not use the discussion and investigation as teaching methods or didn't do any activity. What changed your mind?
2. During pre-interview, you mentioned that you will use simulations, smart board, EBA [Education Information Network], and videos while teaching the seasons, weather, and climate topic. You did not use them during your teaching. What changed your mind?
3. You mentioned that you will do poster, drama, concept map activities and demonstrations regarding the seasons, weather, and climate topic in the classroom during the pre-interview. Although you did concept map and drama activities, you did not perform poster activity and demonstration in your classroom. What changed your mind?

E. BEYZA’S PCK POST-INTERVIEW QUESTIONS

1. During the pre-interview, you didn't mention that you will use a globe model. What changed your mind?
2. During the pre-interview, you said that you will perform written exams and verbal exams as assessment methods to assess students' understanding related to the seasons, weather, and climate topic. During the lesson, you performed verbal exams by asking questions to the students. Are you going to do written exams later?

F. ESRA'S PCK POST-INTERVIEW QUESTIONS

1. During pre-interview, you did not mention that you will prepare worksheets for the students. What are your reasons for preparing these worksheets?
2. During pre-interview, you didn't mention that you will use a globe model in the lesson. What makes change your mind?
3. During the pre-interview, you stated that you can do a model building activity. However, you did not perform model building activity in your classroom. What changed your mind?
4. During the pre-interview, you did not mention that you give homework about the seasons, weather, and climate topic to the students. But in your teaching, you gave several homework such as research homework, tests to your students. Can you explain the reason why you give homework?
5. At the end of the pre-interview, you mentioned that you will also assess the students' understanding with a general assessment after the seasons, weather, and climate topic is completed. Will you make the general assessment at later times?

G. VNOS-C QUESTIONNAIRE

BİLİMİN DOĞASI HAKKINDA GÖRÜŞLER FORMU

1) Sizce bilim nedir? Bilimi; din, felsefe gibi diğer disiplinlerden ayıran özellikler nelerdir?

2) Bilim insanları küresel ısınmanın meydana geldiği konusunda emin midir?

Evet; Nasıl emin olmaktadırlar? Onların bu konuda emin olmalarını sağlayan faktörler nelerdir?

Hayır; Nedenini açıklayabilir misiniz?

3) Bilim insanları küresel ısınmanın sebepleri konusunda görüş ayrılığına düşmektedirler. Bazı araştırmacılar, insanların fosil yakıtları sürekli kullanmasının gezegenimizin ısınmasına sebep olduğunu söylerken, diğer bir kısım bilim insanı ise milyonlarca yıldır hava koşullarını belirleyen doğal kuvvetlerin buna sebep olduğunu söylemektedirler. Örnekten hareketle, bilim insanları aynı verileri kullanarak nasıl farklı sonuçlara ulaşabilmektedirler? Açıklayabilir misiniz?

4) Sera etkisi, bilimsel bir kanun mudur yoksa bilimsel bir teori midir?

Kanun: Nedenini açıklayabilir misiniz?

Teori: Nedenini açıklayabilir misiniz?

5) Bilimsel teori ve bilimsel kanun arasında bir fark var mıdır?

*Evet, Nedenini açıklayabilir misiniz?

*Hayır, Nedenini açıklayabilir misiniz?

6) Bilimsel teoriler (örn: İklim değişikliği ile ilgili bir teori) zaman içinde değişir mi?

* Evet, Teorilerin neden değiştiğini açıklar mısınız?

* Hayır, Nedenini açıklar mısınız?

7) Bilimsel kanunlar zaman içinde değişir mi?

*Evet; Neden değişirler? Açıklayabilir misiniz?

*Hayır; Nedenini açıklayabilir misiniz?

8) Bilim insanlarının araştırmalarında takip ettikleri bilimsel bir yöntem var mıdır?

*Evet, Bu yöntem/yöntemler nelerdir? Örnek vererek açıklayabilir misiniz?

*Hayır, Nedenini açıklayabilir misiniz?

9) Bilimsel bilginin gelişmesi için deney gerekli midir?

10) Evetse, niçin? Görüşünüzü destekleyen bir örnek veriniz.

11) Hayırsa, niçin? Görüşünüzü desteleyen bir örnek veriniz.

12) Bilim insanları yenilenebilir enerji kaynakları/iklim değişikliği ile ilgili bilimsel deneyler ve araştırmalar yapmaktadırlar. Bilim insanları bu araştırmalarını yaparken kendi hayal gücü ve yaratıcılıklarını kullanırlar mı?

*Evet, (a) Araştırmalarının hangi aşamasında kullanırlar?

(b) Bilim insanlarının neden yaratıcılık ve hayal güçlerini kullanırlar? Açıklayabilir misiniz?

*Hayır, Nedenini açıklayabilir misiniz?

13) Bazı iddialara göre bilim oluşturulduğu toplumun değerlerinden etkilenir- din, sosyal, kültürel değerler, felsefik varsayımlar ve entellektüel normlar gibi. Bazılarına göre ise bilim evrenseldir, sosyal, kültürel değerler, felsefik varsayımlar ve entellektüel normlar gibi kavramlardan bağımsızdır.

*Eğer bilimin sosyal, kültürel değerlere bağımlı olduğunu düşünüyorsanız, nedenini uygun örneklerle açıklayınız.

*Eğer bilimin sosyal, kültürel değerlerden bağımsız olduğunu düşünüyorsanız nedenini uygun örneklerle açıklayınız.

H. PERMISSION FOR VNOS-C QUESTIONNAIRE

Konu: Ynt: Doküman Kullanım Onayı (VNOS-C)
Gönderen: Kader BİLİCAN-Akademik <kaderbilican@kku.edu.tr>
Tarih: 15 Ağustos 2018, Çarşamba, 7:22 pm
Alıcı: "kubra.sagbilge@metu.edu.tr" <kubra.sagbilge@metu.edu.tr>
Öncelik: Normal
Seçenekler: Tüm Başlıkları Göster | Yazdırılabilir Şekilde Göster | Bunu dosya olarak indir | HTML olarak göster

Merhaba

dokümanı kullanabilirsiniz

kolaylıklar diliyorum

Kader Bilican

____
Gönderen: Kubra Sagbilge <kubra.sagbilge@metu.edu.tr>
Gönderildi: 15 Ağustos 2018 Çarşamba 12:16:23
Kime: Kader BİLİCAN-Akademik
Konu: Doküman Kullanım Onayı (VNOS-C)

Sayın Dr. Kader Bilican,

Ben Kübra SAĞBİLGE. Orta Doğu Teknik Üniversitesi Fen eğitimi bölümünde yüksek lisans yapmaktayım. Ceren ÖZTEKİN hocamızın danışmanlığında ''Fen bilimleri öğretmenlerinin hava ve iklim konusuna ilişkin Pedagojik Alan Bilgileri'' konusunu çalışmaktayım. İzniniz olursa tezinizde kullanmış olduğunuz Bilimin doğası hakkında Görüşler (VNOS-C) dokümanını tezimde kullanmak istiyorum.

Saygılarımla,

Kübra SAĞBİLGE

İ. SUBSTANTIVE KNOWLEDGE INTERVIEW FORM REGARDING SEASONS, WEATHER AND CLIMATE (IN TURKISH)

YARI YAPILANDIRILMIŞ KONU BİLGİSİ FORMU

1. Mevsim nedir?

- **a.** Nasıl oluşur? Açıklayabilir misiniz?
- **b.** Çizerek açıklayabilir misiniz?
- **c.** Sizce mevsimlerin oluşmasının sebepleri nelerdir?

2. Sizce hava nedir? Nasıl açıklarsınız?

- **a.** Lütfen hava deyince aklınıza gelen 12 kelimeyi söyler misiniz?
- **b.** Söylediğiniz kelimeler arasında nasıl bir ilişki var?
- **c.** Bu kelimeler arasındaki ilişkiyi bir kavram haritası yardımıyla açıklayabilir misiniz?

3. Havanın yapısı nasıldır?

- **a.** İçeriği nedir? Nelerden oluşur?
- **b.** (Eğer Gazlar derse);
  - **i.** Oranlarını hatırlıyor musunuz?
  - **ii.** En fazla bulunan gaz nedir?

4. Hava olayları/hareketleri denilince aklınıza neler geliyor? Açıklar mısınız?

5. Hava olaylarının/hareketlerinin doğası nasıldır?

- **a.** Değişkenlik gösterir mi?
  - **i.** Statik midir, Dinamik midir?
  - **ii.** Neden öyle düşünüyorsunuz?
    - ➢ Eğer değişkenlik gösterdiğini düşünüyorsanız, sizce bu değişkenliğin sebepleri neler olabilir?
    - ➢ Eğer değişkenlik gösterdiğini düşünmüyorsanız, neden?

6. Doğada ne tür hava olayları/hareketleri yaşanır?

a. Peki bu hava olayları/hareketleri nasıl oluşur? (Söyledikleri hava olaylarının/hareketlerinin nasıl oluştuğunu sor.)

7. Yıkıcı doğa olaylarından korunma yolları var mıdır?

i. Varsa bunlar nelerdir? Açıklayabilir misiniz?
ii. Yoksa neden?

8. Hava olayları/hareketleri ve çevre arasında bir etkileşim var mıdır?

a. Eğer var olduğunu düşünüyorsanız, nasıl bir ilişki vardır?

i. Eğer olursa, nasıl etkileri olabilir?
ii. Örnek verebilir misiniz?

b. Eğer olmadığını düşünüyorsanız neden yoktur?

9. Bilim insanları hava olaylarını/hareketlerini nasıl tahmin eder?

a. Peki hava tahminleri nasıl yapılır?

i. Nerede, nasıl, ne şekilde, veri toplar?
ii. Veri toplarken ne tür araçlar kullanır?
iii. Bu veriler ne yaparlar?
iv. Nasıl analiz ederler?
v. Nasıl sonuca varırlar?
vi. Eriştikleri bu bilgiler-hava tahmini- kesin midir?

- Evetse neden?
- Hayırsa neden?

b. Bu görevi yapan bilim insanlarına ne ad verilir?

c. Bunu araştıran bilim dalına ne ad verilir?

d. Hava tahminlerinin günlük yaşantımız için önemi nedir?

10. Sizce iklim nedir? Nasıl açıklarsınız?

a. Lütfen 12 kelime ile açıklayabilir misiniz?

b. Söylediğiniz kelimeler arasında nasıl bir ilişki var?

c. Bu kelimelerin arasındaki ilişkiyi bir kavram haritası yardımıyla açıklayabilir misiniz?

11. İklimi meydana getiren elemanlar nelerdir?

12. İklim ve hava olayları/hareketleri arasında fark var mıdır?

a. Eğer var derse, bu farklar nelerdir? Açıklayabilir misiniz?

i. Kavram haritası oluşturabilir misiniz?

b. Eğer yoksa, neden?

13. Hava ve iklim ile ilgili bana aklınıza gelen ilk 12 kelimeyi yazıp sonrasında bir kavram haritası oluşturdunuz. Peki sizden bu iki kavram haritasını birleştirmenizi istesek ve yeni bir kavram haritası oluşturmanızı istesek oluşturabilir misiniz?

a. Oluşturursanız nasıl oluşturursunuz?

14. Sizce iklim bir sistem midir? Nasıl tanımlarsınız?

a. Eğer sistem olduğunu düşünüyorsanız, bu sistemi oluşturan bileşenler neler olabilir?

i. Peki bize bu sistemi çizebilir misiniz?

b. Eğer sistem olduğunu düşünmüyorsanız, neden bu şekilde düşündünüz?

c. Bu sistemin içinde nasıl süreçler olabilir?

d. Peki bu sistemin içinde bulunan bileşenlerden herhangi birinde değişiklik olursa, sistem nasıl etkilenir?

i. Bu olayın ne gibi sonuçları olabilir?

15. İklimin özelliklerini inceleyen bilim dalının ismini biliyor musunuz?

a. İklim alanında çalışan bilim insanlarına ne ad verilir?

i. Nerede, nasıl, ne şekilde, veriler toplarlar?

ii. Veri toplarken ne tür araçlar kullanır?

iii. Bu veriler ile ne yaparlar?

iv. Nasıl analiz ederler?

v. Nasıl sonuca varırlar?

16. İklim değişikliği diye bir kavram duydunuz mu?

a. İklim değişikliği denilince aklınıza neler geliyor?

b. İklimlerin değiştiğini düşünüyor musunuz?

i. Eğer düşünüyorsanız, iklim değişikliğinin oluşmasında etkili olan faktörler neler olabilir?

ii. Eğer düşünmüyorsanız, neden bu şekilde düşünüyorsunuz?

c. Küresel iklim değişikliklerinin nedenlerini ve olası sonuçları nelerdir?

i. Örnek vererek açıklayabilir misiniz?

ii. Günlük hayatımıza etkisi var mıdır?

1. Günlük hayatımızı ne şekilde etkiler?

d. İklim değişikliğinin etkilerini azaltmak için sizce yapılabilecek bir şey olduğunu düşünüyor musunuz?

i. Eğer düşünüyorsanız, bunlar neler olabilir?

ii. Eğer olmadığını düşünüyorsanız, neden bu şekilde düşündünüz?

17. Dünya ülkelerinin küresel iklim değişikliğini önlemek için aldıkları önlemler nelerdir?

a. İklim değişikliğinin önlenmesinde bireylerin görev ve sorumlulukları hakkında ne düşünüyorsunuz?

i. Bireylerin görev ve sorumlulukları nelerdir?

18. İklim değişikliğiyle mücadele edebilmek için sizce yapılabilecek bir şey var mı?

19. Küresel ısınma diye bir kavram duydunuz mu?

a. Aklınıza neler geliyor? Sizce iklim değişikliğinden bir farkı var mı?

i. Eğer varsa, bu farklar nelerdir?

ii. Eğer yoksa, neden yoktur?

b. Küresel ısınmanın nedeni nedir?

i. Oluşmasında ne gibi faktörler etkilidir?

c. Küresel ısınmanın çevreye ve canlılara etkisi hakkında ne söyleyebilirsiniz?

d. Sizce küresel ısınmanın etkisini önleyici çalışmalar yapılabilir mi?

- **i.** Eğer yapılabileceğini düşünüyorsanız, bu çalışmalara örnek verebilir misiniz?
- **ii.** Eğer yapılamayacağını düşünüyorsanız, neden bu şekilde düşündünüz?

20. Sera etkisi diye bir kavram duydunuz mu?

a. Eğer duyduysanız, sizce ne demektir? Aklınıza neler geliyor?

b. Nasıl oluşur?

c. Oluşmasında etkili olan faktörler nelerdir?

21. Sera gazları nedir?

a. Örnek verebilir misiniz?

b. Sizce bu gazların var olması doğal bir olay mıdır?

- **i.** Evetse neden?
- **ii.** Hayırsa neden değil?

c. Bu gazların doğadaki rolü nedir? Ne tür bir fonksiyonu vardır?

d. Sera gazlarının miktarında değişmeler meydana gelebilir mi?

i. Bu nasıl oluşur?

ii. Artmasında veya azalmasında etkili olan faktörler nelerdir?

1. Örnek verebilir misiniz?

iii. Bu gazların artması ya da azalması doğadaki madde döngüleri etkiler mi?

1. Hangi madde döngülerini etkiler?

2. Etkilerse nasıl etkiler?

22. Peki, sizce sera gazları olmasaydı ne olurdu? Açıklayabilir misiniz?

23. Sizce, mevsimler, iklim ve hava olayları/hareketleri arasında bir ilişki var mıdır?

a. Varsa bu ilişkiyi açıklayabilir misiniz?

b. Yoksa neden yoktur?

24. Çevre sorunlarının dünyanın geleceğine nasıl bir etkisinin olabileceğini düşünüyorsunuz?

J. ORIGINAL VERSIONS OF BURAK'S WORD ASSOCIATION TESTS AND CONCEPT MAPS

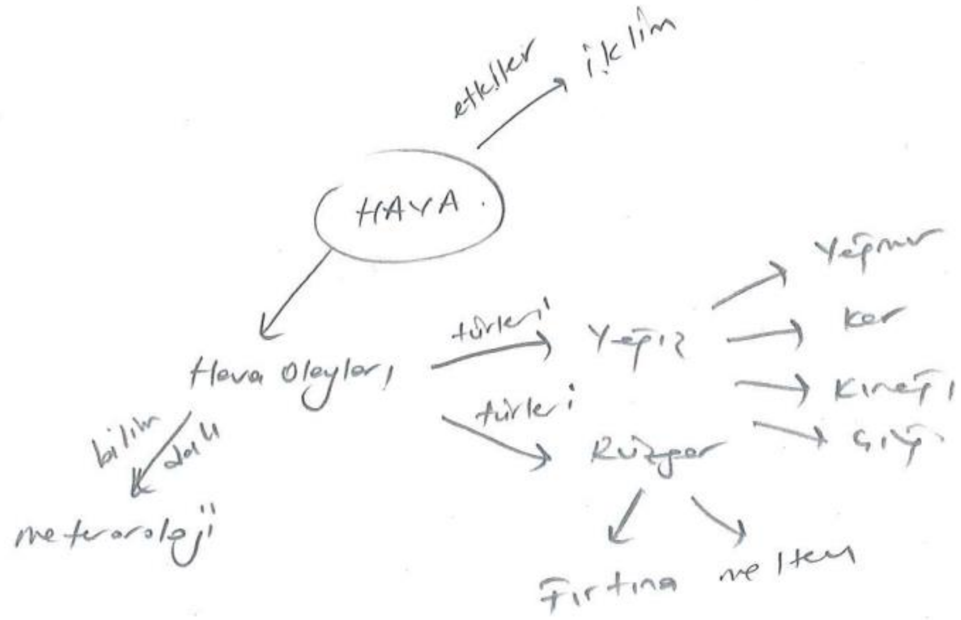
Burak's Word Association Test Regarding the Weather

HAVA

- Hava Durumu
- meteoroloji
- iklim
- Yağmur
- Kar
- Rüzgar
- Fırtına
- Kırağı
- Çiğ
- Doğa
- Sel
- meltem

Nem → su Buharı

Burak’s Concept Map Regarding Weather

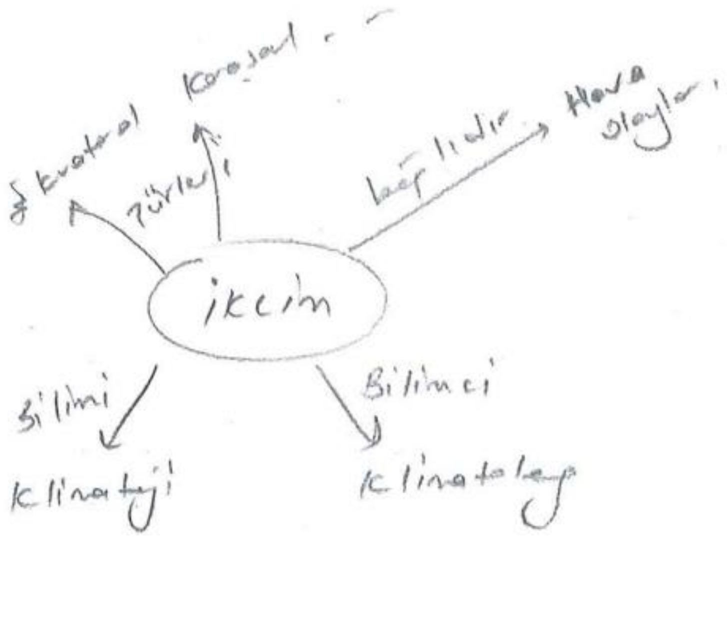


Burak’s Word Association Test Regarding the Climate

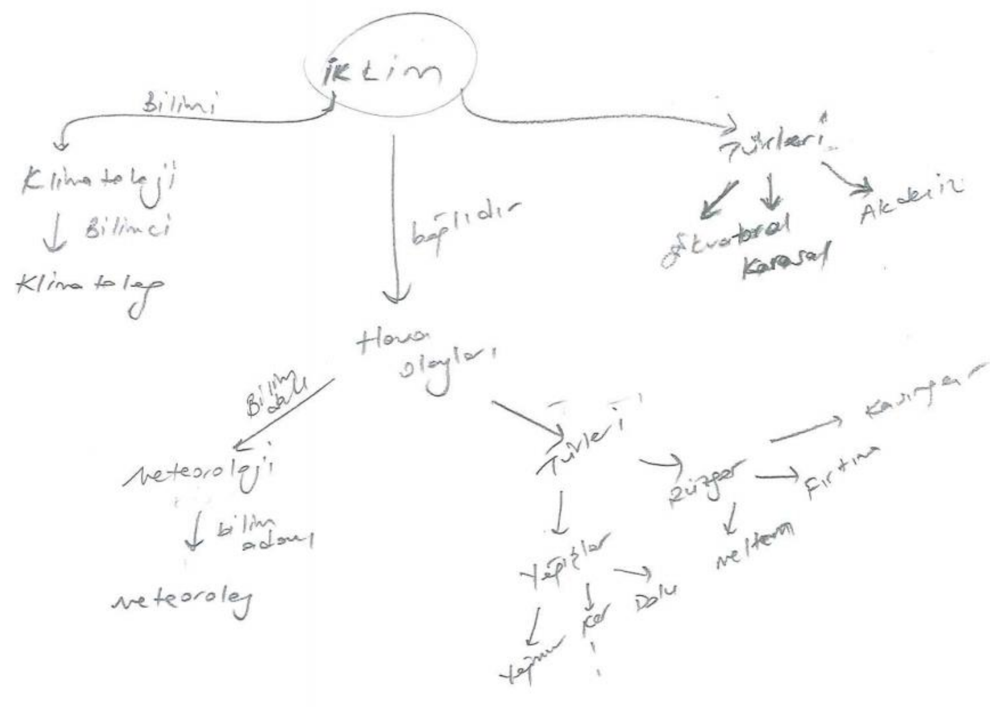
İKLİM

- Hava Olayları
- Klimatoloji
- Klimatolog
- Güneş
- Mevsimler
- Ekvatoral
- Karasal
-
-
-
-
-

Burak’s Concept Map Regarding the Climate

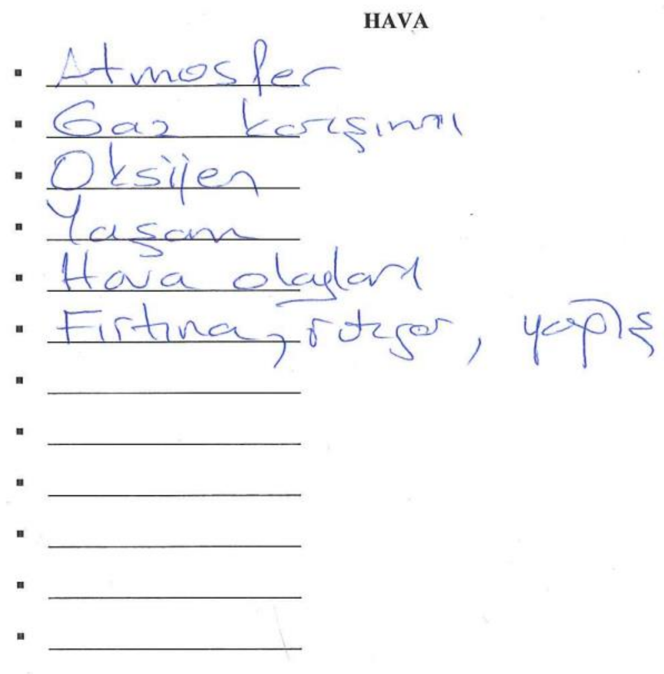


Burak’s Concept Map Regarding the Relationship Between Weather and Climate

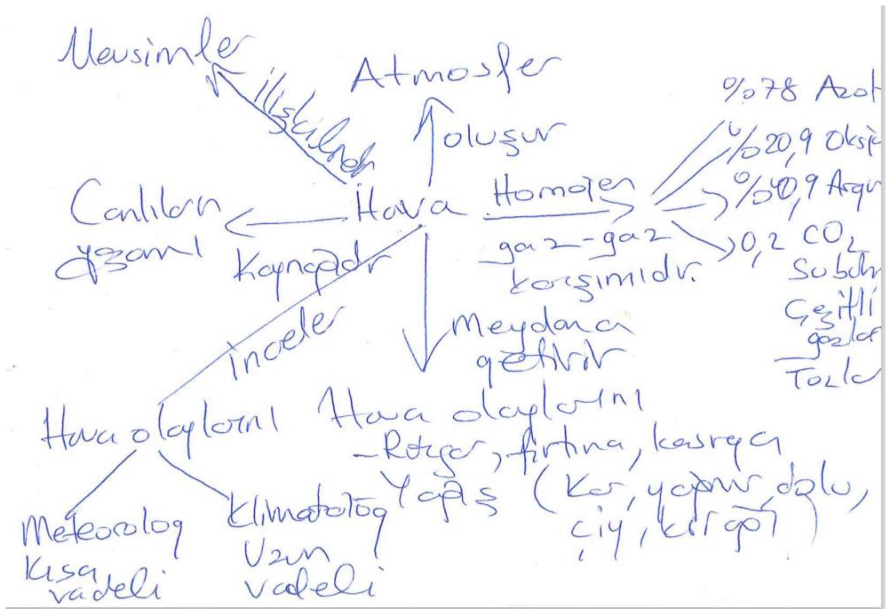


K. ORIGINAL VERSIONS OF BEYZA'S WORD ASSOCIATION TESTS AND CONCEPT MAPS

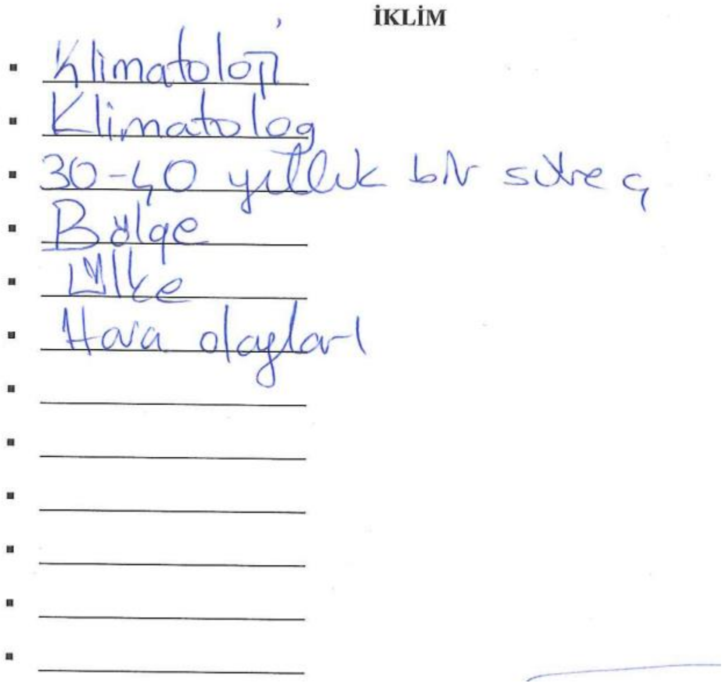
Beyza's Word Association Test Regarding the Weather



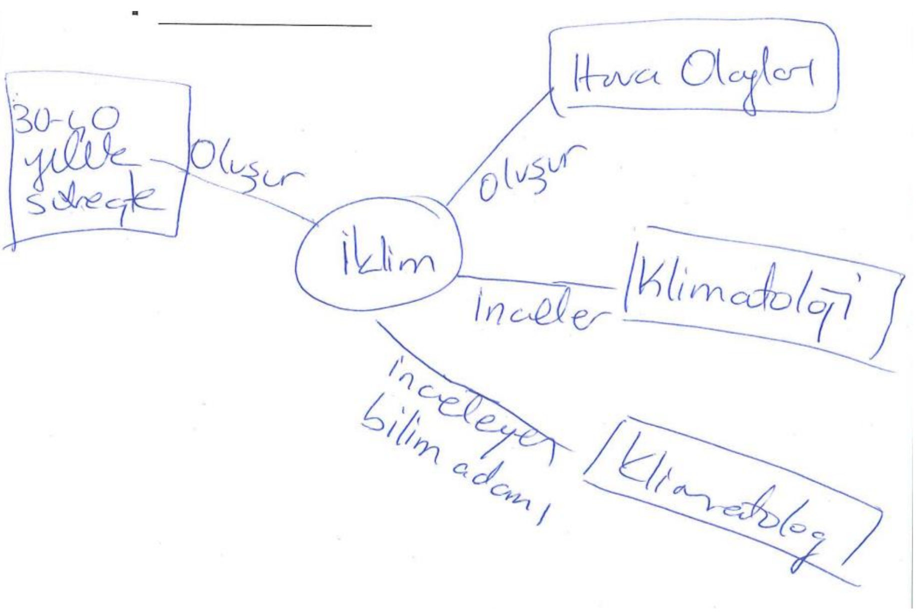
Beyza's Concept Map Regarding Weather



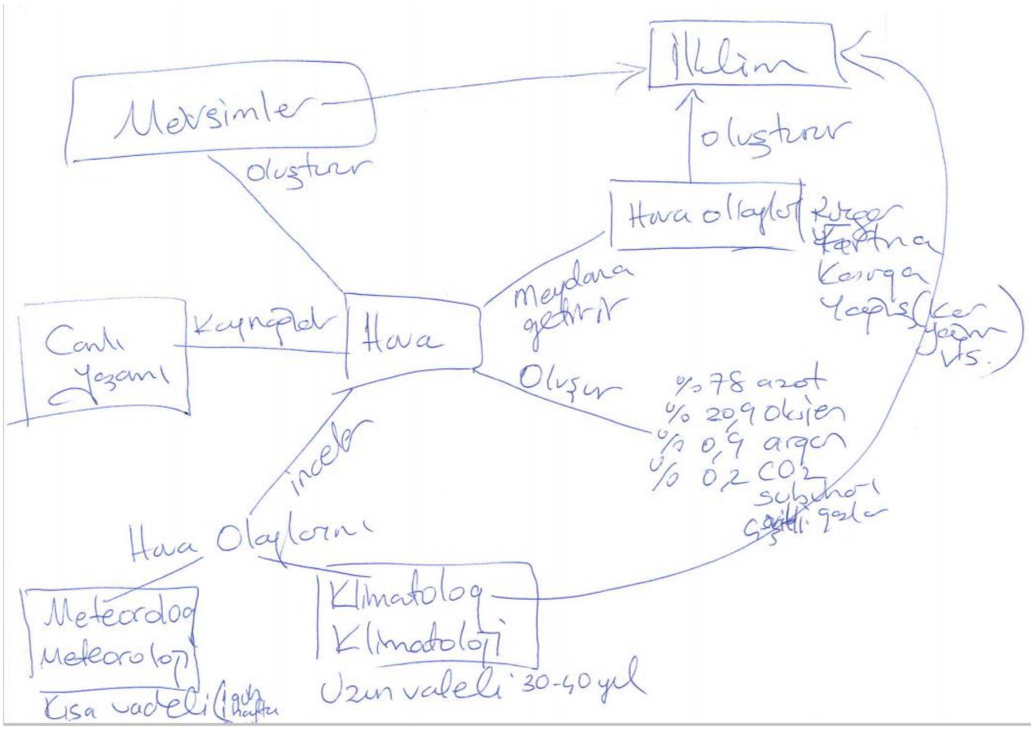
Beyza's Word Association Test Regarding the Climate



Beyza's Concept Map Regarding the Climate



Beyza’s Concept Map Regarding the Relationship Between Weather and Climate



L. ORIGINAL VERSIONS OF ESRA'S WORD ASSOCIATION TESTS AND CONCEPT MAPS

Esra's Word Association Test Regarding Weather

HAVA

- Atmosfer
- Dünya
- Yaşam
- Oksijen
- Azot
- Karbondioksit
- Hidrojen
- Karbonmonoksit
- Helyum
- Karbon
- Solunum
- Fotosentez

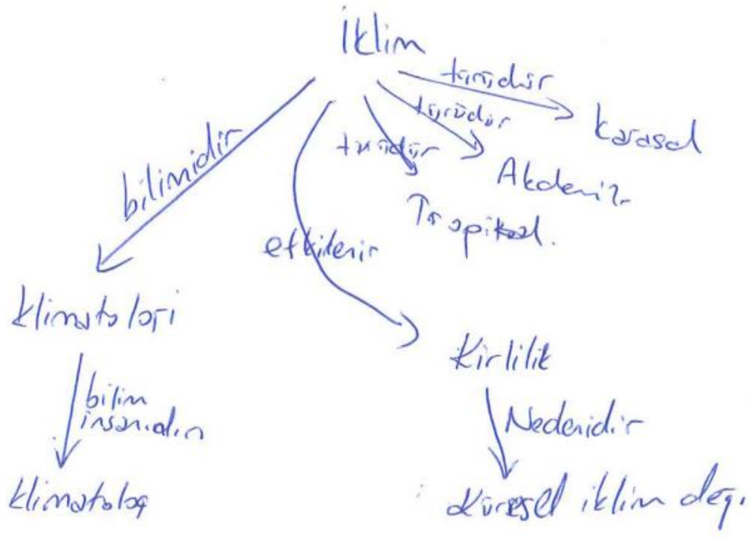
Su buharı

Esra’s Word Association Test Regarding Climate

İKLİM

- Karasal iklim
- Tropikal iklim
- Akdeniz iklimi
- Klimatoloji
- Klimatolog
- Hava
- Atmosfer
- Küresel iklim değişikliği
- Kirlilik
-
-
-

Esra’s Concept Map Regarding Climate



M. SUBSTANTIVE KNOWLEDGE RUBRIC

The Concepts	Scientific Definitions	Sources
Seasons	While revolving of the Earth around the Sun, Earth's rotation axis is tilted, which lead to form the seasons.	(Sung, & Oh, 2018)
Weather	The current state of meteorological elements (i.e., wind, temperature, atmospheric pressure, precipitation, humidity) that changes daily in a short-time is called weather.	(Shepardson, Roychoudhury, Hirsch, Niyogi & Top, 2014)
The Nature of Weather Events	"Weather—which is always changing—includes the elements of: **1.** *air temperature*—the degree of hotness or coldness of the air **2.** *air pressure*—the force of the air above an area **3.** *humidity*—a measure of the amount of water vapor in the air **4.** *clouds*—visible masses of tiny water droplets and/or ice crystals that are above Earth's surface **5.** *precipitation*—any form of water, either liquid or solid (rain or snow), that falls from clouds and reaches the ground **6.** *visibility*—the greatest distance one can see **7.** *wind*—the horizontal movement of air"	(Ahrens, & Henson, 2019, p.17)
Meteorology	The science discipline dealing with the processes that forming the weather (e.g., movement of wind, formation of cloud, lightning) and with atmosphere is called meteorology.	(Aguado, & Burt, 2010)
Meteorologist	Scientist benefiting from scientific principles with the aim of forecasting and clarifying the atmospheric phenomena is called meteorologist.	(Ahrens, & Henson, 2019)
Climatology	Climatology is a science discipline that dealing with the changeability in elements of weather, and the average values of characteristics of atmosphere on Earth's surface.	(Aguado, & Burt, 2010)
Climatologist	Climatologists deal with the atmospheric properties' average values on the Earth's surface, and besides, they follow changes in weather elements.	(Aguado, & Burt, 2010)

The Concepts	Scientific Definitions	Sources
System	"A system is an entity that maintains its existence and functions as a whole through the interaction of its parts."	(Assaraf, & Orion, 2005, p.519)
Climate	The averages of meteorological elements (i.e., atmospheric pressure, temperature, precipitation, humidity, wind) in the long-term might be called climate.	(Shepardson, Roychoudhury, Hirsch, Niyogi, & Top, 2014).
Climate as a System	Climate system is defined as processes, matter and energy which covered by interactions occurred between Sun and Earth, and among biosphere, cryosphere, atmosphere, lithosphere and hydrosphere of the Earth.	(NOAA, 2009)
	"the interconnections of a climate system into seven essential principles with concepts: (1) The Sun is the primary source of Earth's energy for Earth's climate system. (2) Climate is regulated by complex interactions among components of the Earth system. (3) Life on Earth depends on, is shaped by, and affects climate. (4) Climate varies over space and time through both natural and man-made processes. (5) Our understanding of the climate system is improved through observations, theoretical studies, and modeling. (6) Superimposed over natural variability, human activities are impacting the climate system. (7) Climate change will have consequences for the Earth system and human lives."	(Shepardson, Niyogi, Roychoudhury & Hirsch, 2012, p. 329)

The Concepts	Scientific Definitions	Sources
The Causes of Climate Change	**Natural causes:** The natural reasons to form the climate change are defined as variations in orbit of the Earth, plate tectonics, solar variability and volcanic activity.	(Lutgens, & Tarbuck, 2010)
	Anthropogenic Causes: As a result of human activities such as chemicals released to the atmosphere, rapidly increasing the activities in industrial and agricultural areas, burning fossil fuels and decreasing in forests, carbon dioxide gases are released to the atmosphere, which leads to alterations in the climate system's balance.	(NOAA, 2009)
Global Warming	"The observed increase in average temperature near the Earth's surface and in the lowest layer of the atmosphere."	(NOAA, 2009, p.16)
	In general, due to human activities, the amount of greenhouse gases emissions rises and so the warming occurs, which is called global warming.	(NOAA, 2009)

The Concepts	Scientific Definitions	Sources
The Consequences of Climate Change	▪ The rise in sea level occurs as a result of the thermal expansion occurred in sea water with the warming of the oceans, which joined with the glaciers and ice sheets' melting. ▪ The presence and distribution of freshwater resources will change in consequence of alterations in temperature and precipitation patterns. This situation will limit a lot of people's opportunities to access water in a reliable way that they can use for themselves and their crops. ▪ When the carbon dioxide is absorbed from the atmosphere, alterations occur in the ocean water' chemistry. For example, as the level of carbon dioxide rises, the acidity of ocean water increases. ▪ Climate change will keep going to harm ecosystems both placed in the ocean and on land. For example, due to climate change, migration of living things such as plants, viruses, animals, and bacteria toward new places having climatic conditions where they can sustain their own lives will be occurred. ▪ Climate change may bring about rises in the extreme weather events. ▪ Climate change will influence humans' mortality rates and their health in certain areas in the world at different rates.	(NOAA, 2009)

The Concepts	Scientific Definitions	Sources
The Consequences of Global Warming	▪ **Ice melting and Sea level rise:** The sea level is impacted by temperature values' rise. For example, the amount of water in the oceans are increased by increases in the glaciers', sea ice' and ice sheets' melting with higher temperatures. Another example is the expanding of sea water and increasing in the sea level occurs with the reducing in the density of liquid-water brought about by the rise in temperature values. ▪ **Alterations occurred in Diseases:** The rise in populations of some disease-carrying insects along with mosquitoes occurs on account of rising of land precipitation due to global warming.	(Jacobson, 2012)
	▪ "**Changes in Regional Climate, Severe Weather, and Agriculture:** Global warming is causing regional and temporal climate variations." o "The number of extremely hot days is increasing, and the number of extremely cold days is decreasing." ▪ "**Changes in Ocean Acidity and Ecosystems:** The increase in atmospheric $CO_2(g)$ increases the amount of dissolved and dissociated carbonic acid in the ocean by Reactions 3.15 and 3.16. The dissociation of carbonic acid increases the H^+ concentration in the ocean, decreasing the ocean pH, resulting in **ocean acidification**." o "Over land, rapid, continuous increases in temperature will lead to the extinction of some species that are accustomed to narrow climate conditions and are unable to migrate faster than the rate of global warming." ▪ "**Changes in Heat Stress:** Global warming affects human health by increasing heat stress. In warm climates, higher temperatures increase heat stress–related health problems, including mortality, more than they do in milder climates"	(Jacobson, 2012, p.295-300)

The Concepts	Scientific Definitions	Sources
The Definition of Greenhouse Effect	The process which adjusts the planet's temperature conditions is called the greenhouse effect. As the greenhouse effect takes place, on the one hand, the passing along of the majority of the incoming short-wave radiation of the Sun are enabled by particular atmospheric gases (e.g., carbon dioxide). On the other hand, the majority of the Earth's outgoing long-wave heat radiation are both reflected and absorbed by some of these gases.	(Österlind, 2005)
	In consequence of alterations in the wider biogeochemical cycles and carbon (e.g., destruction of forest, burning fossil fuels), the greenhouse effect increases. This situation brings about rising the level of carbon dioxide in the atmosphere, forming the global warming as well as influencing the climate.	(Shepardson, Niyogi, Roychoudhury, & Hirsch, 2011)
Greenhouse gases	Methane, carbon dioxide, perflurocarbons (PFCs), water vapor, chlorofluorocarbons (CFCs), ozone (at tropospheric altitudes), Sulphur hexafluoride, hydroflurocarbons (HFCs) and nitrous oxide are described as greenhouse gases.	(Daniel, Stanisstreet, & Boyes, 2004)
The Function of Greenhouse Gases	Maintaining the Earth as warm is the task of greenhouse gases. However, if greenhouse gases were not existed, lifeless and frozen planet would be existed at average -17 C global temperatures.	(Dove, 1996)

N. RUBRIC FOR CONCEPT MAP

Analysis of Concept Map developed by Kinchin, Hay, and Adams (2000, p.48)

	Map type		
	Spoke	*Chain*	*Net*
Hierarchy	One level only	Many levels, but often incorrect	Several justifiable levels
Processes	Simple association with no understanding of processes or interactions	Shown as a temporal sequence with no complex interactions or feedback	Described as complex interactions at different conceptual levels
Complexity	So little integration that concepts can be added without consequences for ‘map integrity’	Map integrity cannot cope with additions, particularly near the beginning of the sequence	Map integrity is high. Adding one or more concepts has minor consequences as ‘other routes’ through the map are available
Conceptual Development	Shows little or no ‘world view’. Addition or loss of a link has little effect on the overview	Integrated into a narrow ‘world view’, suggesting an isolated conceptual understanding. Loss of a link can lose meaning of the whole chain	Can support reorganization to emphasize different components to appreciate a ‘larger world view’ or to compensate for a ‘missing’ link
Represents	National Curriculum Structure	Lesson sequence	Meaningful learning

O. NOS RUBRIC REPRESENTING INFORMED VIEWS

NOS Aspects and Descriptions Rubric Developed by Lederman, Schwartz, Abd-El-Khalick, and Bell (2001, p.15)

Aspect	Description
Tentativeness	Scientific knowledge is subject to change with new observations and with the reinterpretations of existing observations. All other aspects of NOS provide rationale for the tentativeness of scientific knowledge.
Empirical basis	Scientific knowledge is based on and/or derived from observations of the natural world.
Subjectivity	Science is influenced and driven by the presently accepted scientific theories and laws. The development of questions, investigations, and interpretations of data are filtered through the lens of current theory. This is an unavoidable subjectivity that allows science to progress and remain consistent, yet also contributes to change in science when previous evidence is examined from the perspective of new knowledge. Personal subjectivity is also unavoidable. Personal values, agendas, and prior experiences dictate what and how scientists conduct their work.
Creativity	Scientific knowledge is created from human imaginations and logical reasoning. This creation is based on observations and inferences of the natural world.
Social/cultural embeddedness	Science is a human endeavor and, as such, is influenced by the society and culture in which it is practiced. The values and expectations of the culture determine what and how science is conducted, interpreted, and accepted.
Observations and inferences	Science is based on both observations and inferences. Observations are gathered through human senses or extensions of those senses. Inferences are interpretations of those observations. Perspectives of current science and the scientist guide both observations and inferences. Multiple perspectives contribute to valid multiple interpretations of observations.
Theories and laws	Theories and laws are different kinds of scientific knowledge. Laws describe relationships, observed or perceived, of phenomena in nature. Theories are inferred explanations for natural phenomena and mechanisms for relationships among natural phenomena. Hypotheses in science may lead to either theories or laws with the accumulation of substantial supporting evidence and acceptance in the scientific community. Theories and laws do not progress into one and another, in the hierarchical sense, for they are distinctly and functionally different types of knowledge.

P. ETHICAL PERMISSION RECEIVED FROM METU HUMAN SUBJECTS ETHICS COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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08 AĞUSTOS 2018

Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Ceren ÖZTEKİN

Danışmanlığını yaptığınız yüksek lisans öğrencisi Kübra SAĞBİLGE "**Fen Bilimleri Öğretmenlerinin Hava ve İklim Konusuna İlişkin Pedagojik Alan Bilgileri**" başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-EGT-118** protokol numarası ile **08.08.2018 - 30.12.2019** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan V

Prof. Dr. Ayhan SOL
Üye

Prof. Dr. Ayhan Gürbüz DEMİR
Üye

Doç. Dr. Yaşar KONDAKÇI
Üye

Doç. Dr. Zana ÇITAK
Üye

Doç. Dr. Emre SELÇUK
Üye

Dr. Öğr. Üyesi Pınar KAYGAN
Üye

Q. PERMISSION RECEIVED FROM MINISTRY OF NATIONAL EDUCATION

GK.

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.18302880 04.10.2018
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Eğitim Fakültesi)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) Bila Tarihli ve 54850036-044-E.33 sayılı yazınız.

Fakülteniz Matematik ve Fen Bilimleri Eğitimi Yüksek Lisans öğrencisi Kübra SAĞBİLGE'nin **"Fen Bilimleri Öğretmenlerinin Hava ve İklim Konusuna İlişkin Pedagojik Aln Bilgileri"** konulu tez çalışması kapsamında uygulama talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüklerine bilgi verilmiştir.

Görüşme formunun (22 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme (1) Şubesine gönderilmesini rica ederim.

Turan AKPINAR
Vali a.
Milli Eğitim Müdür

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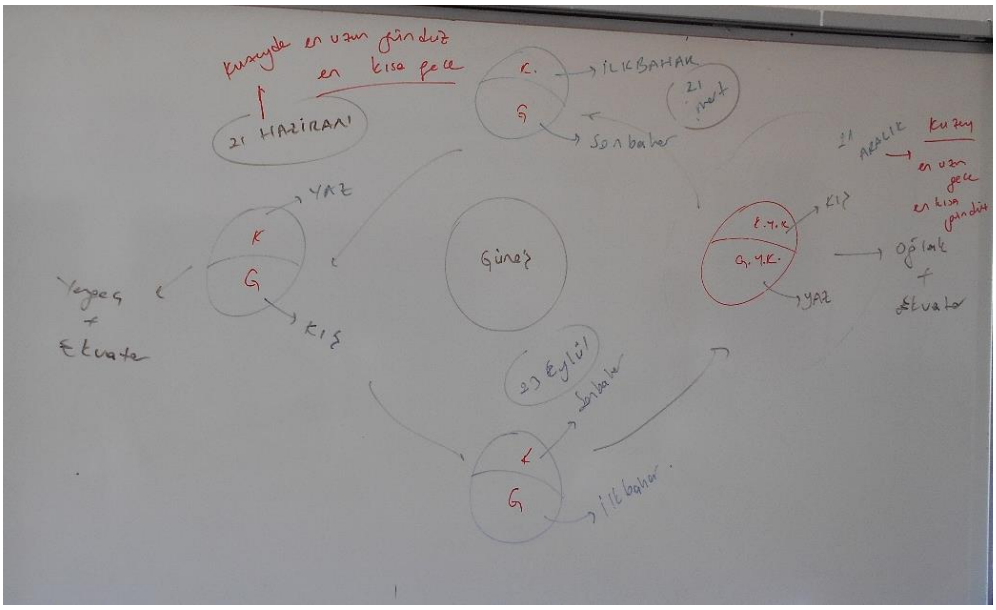
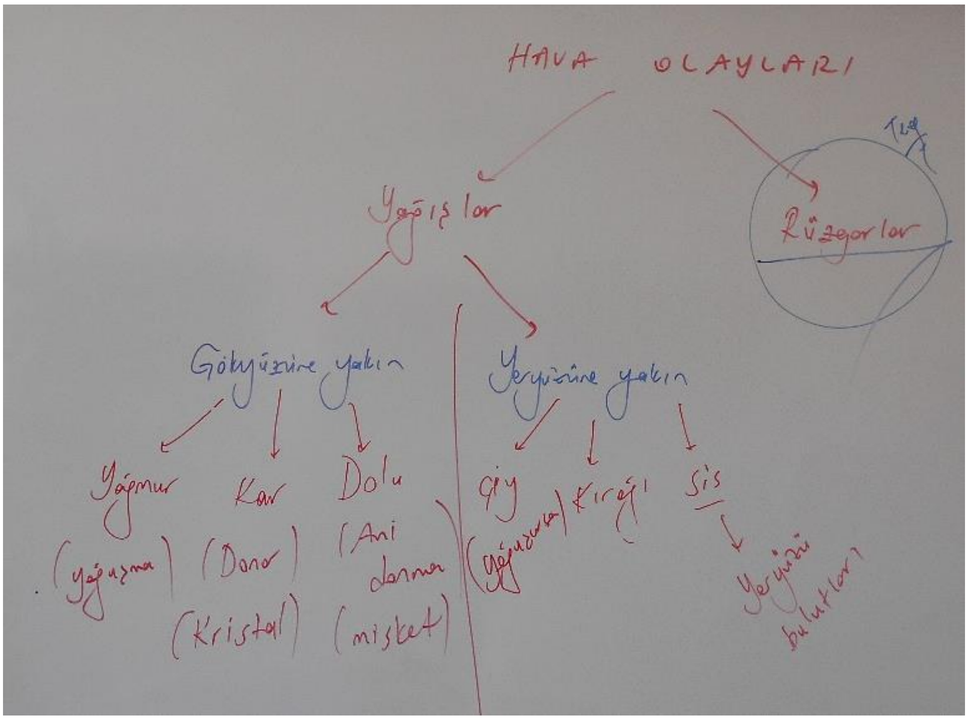
R. ORIGINAL VERSION OF BURAK'S DRAWINGS

Burak's Drawing a Model Regarding the Formation of Seasons

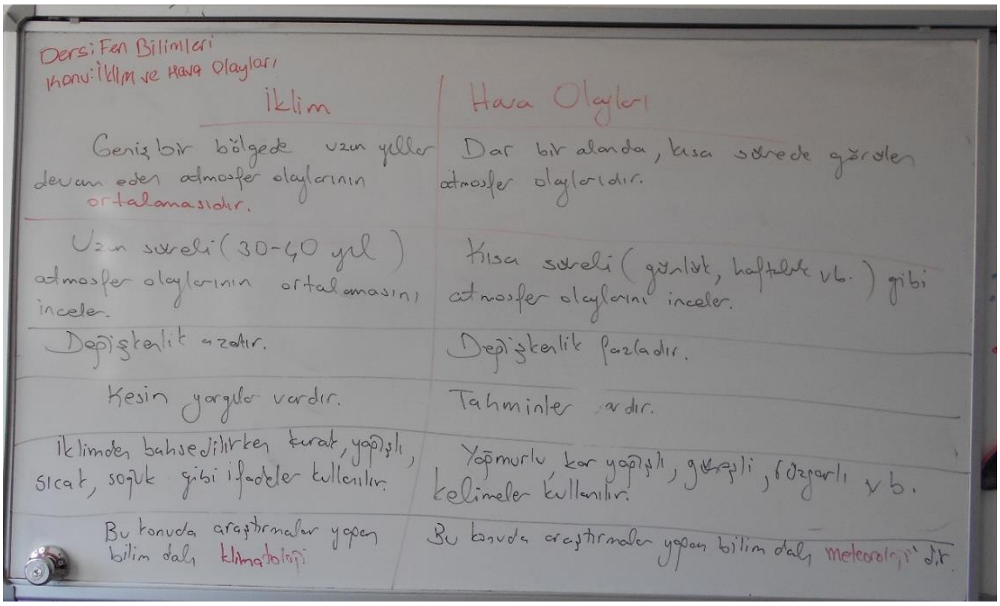


Burak's Concept Map Concerning Types of Weather Events

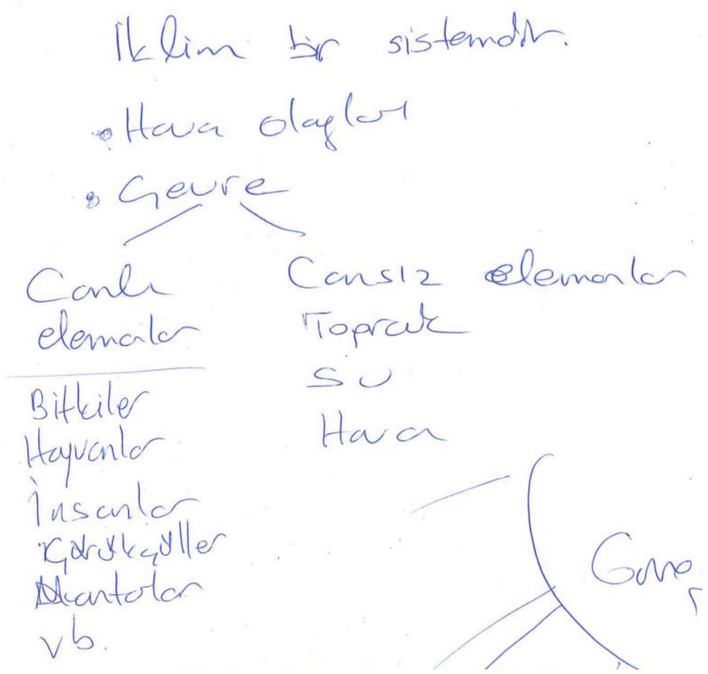


S. ORIGINAL VERSION OF BEYZA'S DRAWINGS

Beyza's Drawing a Table Regarding the Differences Between Weather Events and Climate



Beyza's Components of the Climate System



T. ORIGINAL VERSION OF ESRA'S DRAWINGS

Esra's Drawing a Table Regarding the Differences Between Weather Events and Climate