EXPERIENCED SCIENCE TEACHERS' SUBJECT MATTER KNOWLEDGE AND PEDAGOGICAL CONTENT KNOWLEDGE REGARDING BIOGEOCHEMICAL CYCLES IN THE CONTEXT OF EDUCATION FOR SUSTAINABLE DEVELOPMENT

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I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

EXPERIENCED SCIENCE TEACHERS' SUBJECT MATTER KNOWLEDGE AND PEDAGOGICAL CONTENT KNOWLEDGE REGARDING BIOGEOCHEMICAL CYCLES IN THE CONTEXT OF EDUCATION FOR SUSTAINABLE DEVELOPMENT

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This study investigated experienced science teachers' subject matter (SMK) and pedagogical content knowledge (PCK) regarding biogeochemical cycles in the context of education for sustainable development (ESD). Three science teachers (one male, two females) from different schools participated in the study. In this qualitative research, multiple case studies were used as research design. Data were obtained through interviews, content representations, observations, card sorting activity and teacher documents.

Considering the results, it was observed that teachers had lack of knowledge in both their substantive and syntactic structures in the topic of biogeochemical cycles. The results also revealed that teachers conceptually associated sustainable development with the carbon cycle mostly but they could not reflect their SD understanding to their teaching of the cycles. When teachers' PCK were examined, it was found that teachers differed in the central and peripheral goals of science education. In addition, teachers were knowledgeable about both the objectives in the curriculum and the horizontal and vertical relations of the topic. Although teachers were aware of the students' prerequisite knowledge in order to comprehend the topic, they did not consider students' different learning styles during their teaching practice. Moreover, it was found that teachers had limited knowledge of both subject-specific and topic-specific instructional strategies. Teachers generally used teacher-centered strategies which caused them to be incompetent for implementing ESD. Similarly, teachers adopted traditional assessment methods. Eventually, it is recommended that teacher educators and program developers should enhance teacher education programs where teachers can gain experience especially in terms of instructional and assessment strategies specific to ESD and integrate their SD understanding with different topics.

Keywords: Pedagogical Content Knowledge, Education for Sustainable Development, Science Education, Matter Cycles.

ÖZ

DENEYİMLİ FEN BİLİMLERİ ÖĞRETMENLERİNİN SÜRDÜRÜLEBİLİR KALKINMA EĞİTİMİ KAPSAMINDA MADDE DÖNGÜLERİ KONUSUYLA İLGİLİ KONU ALAN VE PEDAGOJİK ALAN BİLGİLERİ

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Bu çalışma, deneyimli fen bilgisi öğretmenlerinin madde döngüleri konusundaki konu alan ve pedagojik alan bilgilerini sürdürülebilir kalkınma eğitimi kapsamında araştırmayı amaçlamıştır. Çalışmaya farklı ortaokullarda görev yapan, deneyimli üç (bir erkek, iki kadın) fen bilgisi öğretmeni katılmıştır. Nitel araştırma yaklaşımının benimsendiği bu çalışmada, araştırma deseni olarak çoklu durum çalışması kullanılmıştır. Çalışmanın verileri, röportajlar, içerik gösterimleri, sınıf içi gözlemler, kart gruplama aktivitesi ve öğretmen dökümanları aracılığıyla elde edilmiştir.

Sonuçlar göz önüne alındığında; öğretmenlerin madde döngüleri konusunda hem kavramsal hem de bilimin doğasına yönelik konu alan bilgilerinin eksik olduğu gözlemlenmiştir. Öte yandan, çalışmanın bulguları, öğretmenlerin sürdürülebilir kalkınma kavramı ile madde döngüleri konusunu kavramsal anlamda an çok

karbon döngüsünde ilişkilendirebildiklerini ancak öğretimlerine yansıtamadıklarını ortaya çıkarmıştır. Öğretmenlerin madde döngüleri ile ilgili pedagojik alan bilgileri incelendiğinde, öğretmenlerin fen eğitiminin amaçlarına yönelik farklı görüşlere sahip olduğu ortaya çıkmıştır. Bunun yanısıra öğretmenler, öğretim programındaki konu ile ilgili kazanımları bilmekte ve ilgili konunun diğer sınıf düzeylerindeki konularla ilişkisini kurabilmektedirler. Öğretmenler, öğrencilerinin madde döngüleri konusunu kavrayabilmeleri için sahip olmaları gereken ön bilgilerinin farkında olmalarına rağmen, öğrencilerin farklı öğrenme biçimlerini ve becelerini dikkate alan bir öğretim sergilemedikleri gözlemlenmiştir. Çalışmanın bulguları, öğretmenlerin hem alana hem de konuya özel öğretim stratejileri konusunda sınırlı bilgiye sahip olduklarını ortaya çıkarmıştır. Öğretmenlerin genel olarak öğretmen merkezli öğretim stratejilerini kullandıkları, bunun da öğretmenlerin sürdürülebilir kalkınma eğitimi konusunda yetersiz kalmalarına neden olduğu saptanmıştır. Aynı şekilde, öğretmenler geleneksel değerlendirme yöntemlerini benimsemişlerdir. Sonuç olarak, program geliştirme uzmanları ve eğitimcilere, öğretmenlerin hem sürdürülebilir kalkınma eğitimine özel öğretim ve değerlendirme yöntemleri açısından deneyim kazanabilecekleri hem de sürdürülebilir kalkınma kavramını konu alan bilgilerine entegre edebilecekleri eğitimleri içeren programlar geliştirmeleri önerilmektedir.

Anahtar Kelimeler: Pedagojik Alan Bilgisi, Sürdürülebilir Kalkınma Eğitimi, Fen Eğitimi, Madde Döngüleri.

To My Dear Son Deniz Aras Yendi

&

To My Love Atak Yendi

&

To My Family

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LIST OF ABBREVIATIONS

PCK	Pedagogical Content Knowledge
SMK	Subject Matter Knowledge
PK	Pedagogical Knowledge
KofC	Knowledge of Context
CK	Content Knowledge
CoRe	Content Representation
SD	Sustainable Development
ESD	Education for Sustainable Development
NOS	Nature of Science
VNOS	Views of Nature of Science

CHAPTER 1

INTRODUCTION

In all sub- fields of education, the main aim of teaching is to ensure students' learning and understanding. However, teachers' ability to teach (Kind, 2009) is the most influential factor on classroom learning (Lumpe 2007). Thus, teachers have enormous impact on students' understanding and achievement (Aydin, 2012; Brown, Friedrichsen, & Abell, 2013; Lumpe, 2007; Sanders, 2000; van Driel, Beijaard, & Verloop, 2001). Since 1980's, education researchers have focused on the topics like ''teacher knowledge'' and ''teacher practical knowledge'' to provide rich and valuable data to explain the effects of teachers' knowledge and practice on students' success (Abell, 2007; Aydin, 2012; Carter, 1990; Friedrichsen, 2008; Grossman, 1990; Hashweh, 2005; Magnusson, Krajcik, & Borko, 1999; Shulman, 1986, 1987; Şen, 2014; Zembylas, 2007; Rollnick, Bennett, Rhemtula, Dharsey, & Ndlovu, 2008).

In the first half of 20th century, researchers concluded that teachers' content knowledge is the most important indicator of qualified teachers. Afterward, researchers started to investigate pedagogical knowledge in latter half of the 20th century (Shulman, 1986). Shulman, however, claimed that content knowledge and pedagogical knowledge are linked. Thus, problems of teaching and teacher knowledge have led Shulman to introduce the construct of "pedagogical content knowledge (PCK)" as missing paradigm (Shulman, 1987). According to Shulman (1987), PCK has been a combination of content and pedagogy which is defined as:

> the special amalgam of content knowledge and pedagogical knowledge in particular topics which is organized, represented and adapted to the diverse interests and abilities of learners, and presented for instruction (p.8).

Shulman's PCK construct explained the question of what successful teachers should know about ways to lead students' understanding. (Grossman, 1990; Lederman, Gess-Newsome & Latz, 1994; Mulhall, Berry, & Loughran, 2003). PCK can be conceived as teachers' detailed knowledge about both subject matter and the general pedagogy regarding the learners' prior knowledge and difficulties, the use of assessment and instructional strategies (representations, figures, activities) and curricular resources (Abell, 2007; Magnusson et al., 1999; Tobin & McRobbie, 1999). Consequently, PCK is regarded as central to effective teaching and learning (Cochran, DeRuiter & King, 1993; Magnusson, Krajcik, & Borko 1999).

As a construct, PCK also offers a perspective for science education researchers. Especially, Magnusson et al.'s (1999) transformative PCK model has been used dominantly in most of PCK studies in the field of science teacher education (Abell, 2008; Kind, 2009). In this model, researchers concluded that teachers have four main knowledge domains as subject matter knowledge (SMK), pedagogical knowledge (PK), knowledge of educational context and PCK (Figure 1.1). Following Grossman's (1990) PCK construct, Magnusson et al. (1999) argued that the other three domains of teacher knowledge form and shape PCK. Differently, in their model, Magnusson and her friends included teacher beliefs in addition to teacher knowledge since they thought that beliefs affect teachers' teaching.

Inspired by Tamir (1988), they incorporated "knowledge of assessment" in their PCK model. Moreover, the term "conception of teaching purposes" used by Grossman was changed to "orientation to science teaching". Thus, in their PCK model for science teaching (Figure 1.2), Magnusson et al. (1990) described five components which are (a) knowledge of science curricula, (b) knowledge of students' understanding, (c) knowledge of assessment of scientific literacy, (d) knowledge of instructional strategies, and (e) orientation to teaching science. It is worth noting that this model also includes beliefs of teacher in each component along with knowledge. Using this model as a framework, this study focused on teachers' SMK and PCK to give insights into the practical value of PCK in the topic of biogeochemical cycles in the context of sustainable development.

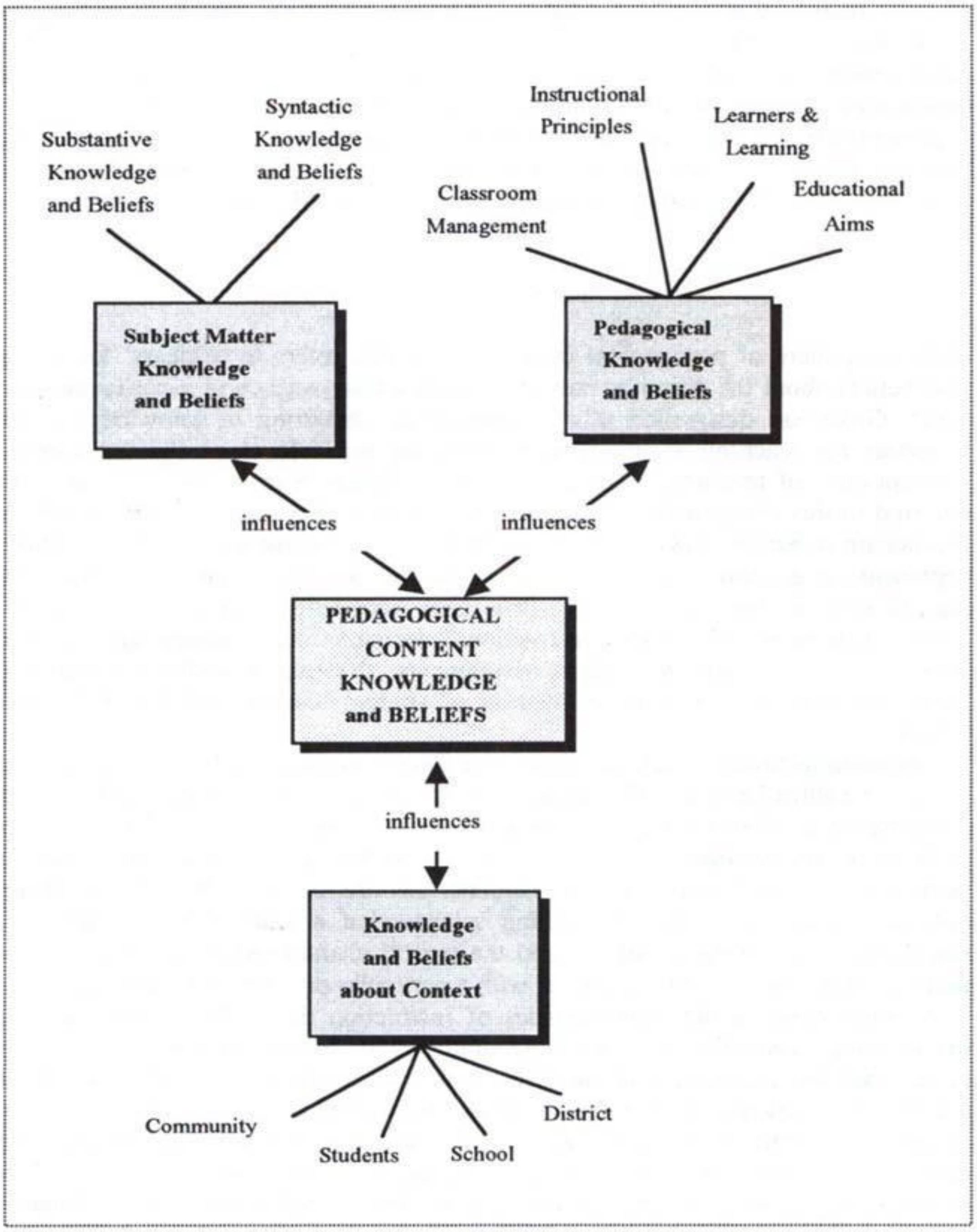

Figure 1.1. Magnusson et al. (1999)'s Model of the Relationships among the Domains of Teacher Knowledge [modified from Grossman, 1990] (p. 98)

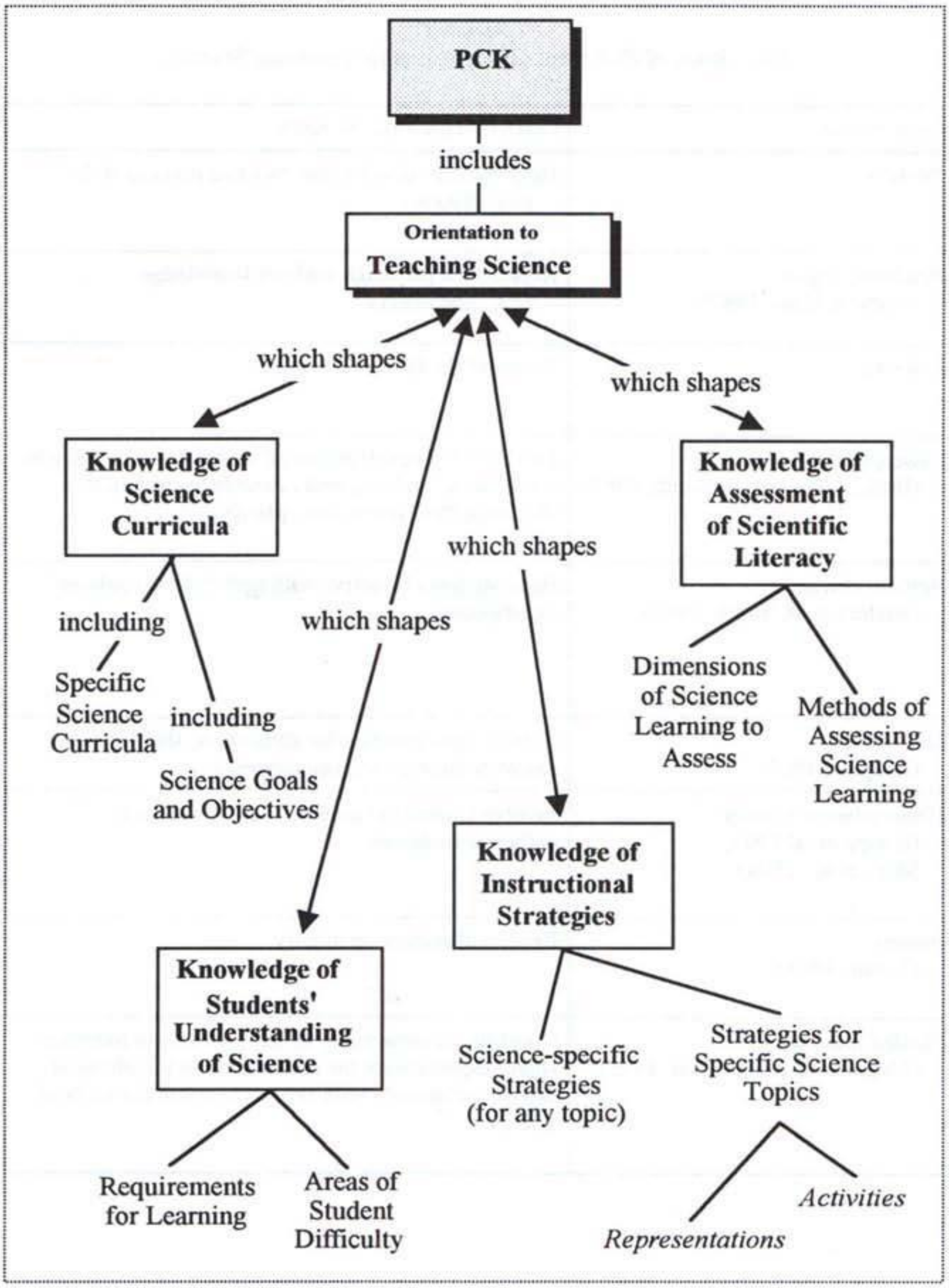

Figure 1.2. Magnusson et al. (1999)'s PCK Model for Science Teaching (p. 99)

1.1.Science Education and Education for Sustainable Development

Since 1950s, the perennial goal of science education has been to educate learners as scientifically literate citizens. Today, a number of researchers have argued that scientific literacy should meet the needs of the 21st century (Choi, Lee, Shin, Kim & Krajcik, 2011) in order to create a more sustainable world (Hodson, 2011; McFarlane, 2011). In the 21st century, science and technology have been progressing rapidly. Especially due to the environmental problems resulted by these rapid changes have caused individuals to change their ethical and moral concerns (Karaarslan, 2016). Thus, many science researchers have concluded that there is a need for reconceptualization of science education considering the rapid changes in both ethical and moral concerns and, therefore, the need to emphasize sustainable development (SD) issues due to the rise in environmental problems (e.g., Carter, 2008; Colucci-Gray, Perazzone, Dodman & Camino, 2013; Feldman & Nation, 2015). Carter (2008), for example, asserted that the aim of the science education in 21th century is to help students make critical judgments about science and to improve their skills and knowledge in order to be responsible citizens for more sustainable world. In response to needs of developing societies, the science education, as a discipline, should equip learners with knowledge and perspectives about sustainable development (Feldman & Nation, 2015), improve their skills, interests and motivation to take action regarding social and global problems (Tytler, 2007), and to change their values and attitudes to ensure a sustainable future (Stratton, Hagevik, Feldman & Bloom, 2015). In this regard, Science Curriculum in Turkey has been revised in 2013 and 2017 to integrate sustainability topics into existing curriculum. Accordingly, sustainable development was listed as one of the components of Science -Technology- Environment- Society (STES) learning domain in the national science curriculum revised in 2013 (MoNE, 2013). In there, sustainable development defined as ‘‘developing consciousness about using natural resources efficiently to meet the needs of the future generations and consider the individual, societal, economic benefits'' (MoNe, 2013). In 2017, although, STSE learning domain is excluded from the current science curriculum, sustainable development is still one of the general aims of the curriculum. In this curriculum, sustainable development defined by pointing out the interaction between people, environment and society and the awareness of the relation inside the society, natural resources and economy. Also, the concept of sustainable development is placed as one of the subtopics under the Energy Transformations and Environment Science of the 8th grade (MoNe, 2017). However, changes or revisions in the curricula do not guarantee a solution to educational problems and to raise responsible citizens to build up a sustainable future. Even if the new curricula suggest newtopics and also new strategies and methods for teaching and assessment, teachers might have difficulties in reflecting the new curriculum into their teaching" (Aydın & Çakıroğlu, 2010). Science education is seen as a leading factor to create more sustainable societies (UNCED, 1992); teachers' competencies have been discussed at all levels of education programs from pre-school to higher education (e.g., Rieckmann, 2012; UNECE, 2011). Due to the paradigm shifts in perspective of science education in the 21st century mentioned above, the role of science teachers specifically has been a matter of debate. This means that the reconceptualization of science education requires altering teachers' approaches related to content and PCK for teaching sustainable development issues. Therefore, in order to engage SD issues with every discipline from art to science and mathematics, teachers should possess necessary and appropriate knowledge, skills (especially, system thinking skills), values and pedagogy to implement education for sustainable development (ESD) (McKeown and Hopkins, 2003). Therefore, considering the challenges as a result of the curricula revisions, the need for research on teachers' SMK and PCK for SD in the discipline of science is inevitable (Kadji-Beltran, Zachariou, Liarakou & Flogaitis, 2014). Regarding these considerations, the current research which explores experienced science teachers'

SMK and PCK is supposed to provide valuable theoretical and practical information to the science teacher education literature in the context of ESD.

1.2.Significance of the Study

While PCK has been a subject of research since the 1980s, many researchers asserted that PCK is a topic-specific construct (Aydin, Friedrichsen, Boz, & Hanuscin, 2014; Cochran, King, & DeRuiter, 1993; Loughran, Mulhall, & Berry, 2004; Mavhunga, 2014; van Driel, et al., 1998; Veal & MaKinster, 1998). However, little is known about how teachers develop their PCK in different topics. Therefore, the PCK literature has underlined that there is a need for more research on PCK construct in different topics in different disciplines (Abell, 2008; Aydin, 2012; Aydin, Friedrichsen, Boz, & Hanuscin, 2014; De Jong, et al., 2005; Loughran, et al., 2004; Magnusson, Borko, & Krajcik, 1994; Pitjeng-Mobasala & Rollnick, 2018; Sen, 2014; van Driel et al., 1998). In response to this need, the current study initially aims to provide valuable information on experienced teachers' topic-specific PCK.

As mentioned above, previous studies in PCK literature call for more research on teachers' PCK structure in different topics. Furthermore, many educational researchers have chosen to investigate either teachers' subject matter knowledge or their pedagogical content knowledge separately. This research also contributed to PCK literature with regard to consider both teachers' SMK and PCK together. In this study, the transformative model of PCK developed by Magnusson et al. (1999) was adopted to gather detailed information on the nature of science teachers' PCK. From the perspective of this model, PCK is a new type of knowledge formed by conversion of subject matter knowledge (SMK), pedagogical knowledge (PK) and knowledge of context (KofC). As many researchers studying on PCK development have emphasized that there is a need of research to ascertain how teachers' transform SMK into their PCK within a discipline (Abell, 2008, Aydin, 2012, Sen, 2014; Magnusson et al., 1999), the current study is supposed to get valuable information on teachers' substantive and syntactic structure of SMK to provide evidence for the science teachers' PCK in the discipline of science education.

Specifically, PCK researches on the field of science education mostly have focused on the chemistry topics (Aydin & Boz, 2012). Since PCK research in biology topics is rare (Aydemir; 2014; Aydin & Boz, 2012; Kind, 2009; Sen, 2014), the topic of biogeochemical cycles not studied yet in PCK literature in the context of science education was selected. Another significant is that the current research aimed to identify science teachers' PCK in the context of education for sustainable development (ESD). In 2013-2014 education year, during the data collection of the study, the changes made for the integration of the sustainable development issues into the science curriculum had not been implemented yet in the 8th grades. However, based on the interdisciplinary nature of the concept of sustaianable development, the researcher concluded that, due to the being an environmental issue, the topic of biogeochemical cycles can be an important tool for reflecting teachers' understanding of sustainable development. It is important to highlight whether sceince teachers develop their perceptions for SD in the existing subjects rather adding the concept as a separate subject. Therefore, based on the interdisciplinary nature the concept of SD, the results of the current study are significant due to providing valuable evidence how science teachers connect the biogeochemical cycles and sustainable development issues

Researches on the transformative PCK model of Magnusson et al. (1999) have mostly focused on one or some components of PCK. However, because of the nature of PCK, studying only one or two components is really hard regarding the overlap of the components. Correspondingly, to mark off the components is difficult in terms of data collection, data analysis and discussion (Abell, 2008; Friedrichsen & Dana, 2005; Friedrichsen et al., 2010). Especially, among the components, the orientation towards science teaching was the least studied one. At this point, there is still need more research to better understand the overarching construct of this component. Therefore, to portray experienced teachers' PCK construct obviously, both orientations to science teaching and all components of PCK model offered by Magnusson et al. (1999) were examined in current research.

In respect of the methodological approach, qualitative research was selected in this study to examine teachers' topic-specific PCK. Abell (2008) highlighted that the structure of PCK hidden in teachers' mind is tacit. More recently, investigators (Ijeh & Onwu, 2013; Kapyla, Heikkinen, & Asunta, 2009; Rollnick et al., 2008) have suggested to conduct qualitative methods through using various data sources in order to disclose how teachers' PCK develops. McConnell et al. (2013) emphasized that especially interviews and lesson observations are vital to gain deep understanding of content knowledge and PCK structure. Therefore, this study used multiple case study design to obtain rich and deep information about teachers' PCK by the help of the multiple data sources such as interviews, classroom observations with help of the video recorder, teacher documents and card-sorting activity. Thus, the results of the study are supposed to gather marvelous evidence in order to clarify the complicated construct of PCK.

Most of the PCK studies have focused on the development of pre-service teachers' PCK (Loughran et al., 2004; Nilsson, 2008; Shannon, 2006; van Driel, de Jong, & Verloop, 2002; Zembal-Saul, Krajcik, & Bluemenfeld, 2002). However, PCK is developed by teachers with experiences on teaching. Therefore, expert teachers have more pedagogical content knowledge than less experienced ones (Abd-El-Khalick, 2006; Cochran et al., 1993; Käpylä, Heikkinen, & Asunta, 2008; Magnusson et al., 1999; Shulman, 1987). Because of this reason, the current research is hoped to provide beneficial insights into PCK literature in terms of the PCK development of experienced science teachers regarding the topic of biogeochemical cycles in the context of ESD.

In related literature, most studies asserted that due to the tacit nature of PCK, concrete examples of classroom settings that are useable and applicable in science teaching are difficult to find (Hume, 2010; Mthethwa-Kunene, Onwu & de Villiers, 2015; Park & Chen, 2012; Rollnick et al., 2008). In this manner, Loughran et al. (2004) and van Driel, Veal, and Janssen (2001) underlined the importance of the studies on real classroom practices of experienced teachers' PCK in particular topics. In this regard, ESD literature has also emphasized that there is a couple of studies on classroom-related practice (Anyolo, 2018; Birdsall, 2015; Corney & Reid, 2007). Therefore, it is significant that science teachers' practices in authentic classrooms were focused to provide more empirical evidence about how teachers develop their PCK in the context of ESD regarding biogeochemical cycles. Especially, the results of the study including concrete examples of real practitioners are supposed to enrich pre-service and other in-service science teachers' repertoire of teaching practices in the same topic providing rich and valuable data for professional development programs such as pre-service teacher education programs and in-service teacher training programs.

1.3.Statement of the Problem

The main aim of the study is to investigate experienced science teachers' SMK and PCK regarding biogeochemical cycles in the context of SD. Thus, the following research questions were put forward to guide the study:

1. What is the science teachers' subject matter knowledge for teaching biogeochemical cycles in the context of sustainable development?
    1.1. What is the science teachers' substantive knowledge regarding biogeochemical cycles?
    1.2. What is the science teachers' syntactic knowledge regarding nature of science?
    1.3. What are the science teachers' understanding of SD regarding biogeochemical cycles?

2. What is the science teachers' pedagogical content knowledge for teaching biogeochemical cycles?
   2.1. What are the science teachers' orientations to teaching science?
   2.2. What is the science teachers' knowledge of curriculum for teaching biogeochemical cycles?
   2.3. What is the science teachers' knowledge of instructional strategies for teaching biogeochemical cycles?
   2.4. What is the science teachers' knowledge of students for teaching biogeochemical cycles?
   2.5. What is the science teachers' knowledge of assessment for teaching biogeochemical cycles?

1.4.Definition of Important Terms

Pedagogical Content Knowledge (PCK) is a new type of teacher knowledge by the combination of subject matter knowledge, pedagogical knowledge and knowledge of context type of knowledge (Magnusson et al., 1999). The authors defined PCK as:

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

The pedagogical content knowledge were investigated with the adopted model of PCK (Magnusson et al., 1999) in terms of science teachers' orientations to science teaching, knowledge of curriculum, knowledge of instructional strategies, knowledge of students' understanding, and knowledge of assessment.

Orientations to Science Teaching is defined as teachers' knowledge and beliefs about the goals of science teaching at a specific grade level (Magnusson et al., 1999). This overarching component plays a central role so it guides teachers to decide the planning of instructional strategies, the content of the student assignments, the use of curricular materials and textbooks and the evaluation of students' understanding (Borko & Putnam, 1996; Magnusson et al., 1999).

Knowledge of Curriculum consists of two categories namely, knowledge of goals and objectives, and knowledge of specific curricular programs and materials (Magnusson et al., 1999). In this study, knowledge of specific curricular programs was not examined because of the national curriculum in Turkey. This curriculum is offered by Ministry of National Education and pursued in all elementary schools in the country.

Knowledge of Instructional Strategies includes two categories: knowledge of subject-specific strategies and knowledge of topic-specific strategies. Subject-specific strategies means teachers' overall approaches specific for science teaching. The strategies in this category represent the general approaches to enacting science instruction (Magnusson et al., 1999). In this study, teacher centered strategies and student centered strategies that participant teachers' handled to teach the biogeochemical cycles topic was used to analyze teachers' knowledge of subject specific strategies. Topic-specific strategies refer to teachers' knowledge of strategies to facilitate student learning of specific science concepts. Representations and activities are two categories of this type of strategies (Magnusson et al., 1999).

Knowledge of Students' Understanding means teacher knowledge that helps student to develop specific scientific knowledge. It consists of two categories: requirements for learning and the areas of students' difficulties (Magnusson et al., 1999). Knowledge of requirements for learning refers the knowledge about prerequisite knowledge for learning specific science concepts (Magnusson et al., 1999). Knowledge of areas of students' difficulties means that teachers' knowledge about the science concepts or areas that student learning is difficult.

Knowledge of Assessment refers to teachers' knowledge about the ways what and how students learn. There are two categories which are knowledge of dimensions of science learning and knowledge of methods (Magnusson et al., 1999). The category of dimensions of science learning includes the aspects of students' learning which are important to assess in the teaching of a particular topic. In the literature, the dimensions of science learning to assess were identified as conceptual understanding, interdisciplinary themes, nature of science, and science process skills. Thus, in this study, dimensions were adopted to gather data related to participant teachers' this type of knowledge. The other category of knowledge of assessment is the knowledge of methods of assessment. This knowledge refers to the methods that teachers employed to assess students' specific dimensions of science learning (Magnusson et al., 1999).

Subject Matter Knowledge (SMK) refers to elementary science teacher's content knowledge consisted of substantive and syntactic structures (Schwab, 1964) in the topic of biogeochemical cycles. Biology has a special standing concerning teachers' content knowledge (Abell 2007) due to being the only science subject that includes both substantive and syntactic structures (Schwab,1964). In this respect, substantive knowledge refers participant teachers' both conceptual understanding (basic concepts & processes) and SD understanding whereas syntactic knowledge is pertinent to the participant teachers' understanding of nature of science regarding biogeochemical cycles.

Sustainable Development (SD) has gained wide acceptance in the late 1980s, after its appearance in Our Common Future, also known as The Brundtland Report. The report defined the term as; ''development that meets the needs of the present without compromising the ability of future generations to meet their own needs (WCED, 1987, p. 41).'' Three pillars of society, economy and environment are needed to consider together at the core of sustainable development.

Education for Sustainable Development (ESD) refers to:

> all aspects of awareness, education and training provided to enhance an understanding of the linkages among the issues for sustainable development and to develop the knowledge, skills, perspectives and values empowering students to make informed decisions for environmental integrity, economic viability and a just society for present and future generations while respecting cultural diversity (UNESCO, 2013b).

Experienced Teachers are the practitioners having at least five or more years' experience in teaching. According to Berliner (2001), there is no particular time duration to be competent in the profession but five or more years in teaching is acceptable time in order to gain expertise.

CHAPTER 2

LITERATURE REVIEW

This chapter aims to give a glimpse of the studies that both theoretically and empirically lay the basis for this research. Initially, the studies regarding the development of PCK models in science education were reviewed. Then, considering science teachers' SMK regarding biology topics, PCK researches conducted in both Turkey and abroad were summarized. Finally, studies aiming to explore science teachers' PCK for both NOS and ESD were examined.

2.1. Pedagogical Content Knowledge

2.1.1. Development of PCK and PCK Models in Science Education

For more than three decades, pedagogical content knowledge (PCK) has been recognized as not only one of the most important components of professional knowledge but also one of the most complicated to understand (Gess-Newsome, 2015; Shulman, 1987; van Driel & Berry, 2012). Scholars consistently acknowledge that the two essential factors to achieving good teaching are content knowledge and pedagogical knowledge (Shulman 1986). Furthermore, Shulman (1986, 1987) stated that PCK should be considered when describing and evaluating teaching expertise since it refers to the way the teachers link their knowledge on the topic itself with the pedagogical knowledge they have. Shulman's (1987) definition of PCK is as below:

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

Shulman (1987) suggested that achieving effective teaching requires different types of knowledge from the teacher. He categorized these knowledge types as: 1) content knowledge; 2) general pedagogical knowledge; 3) curriculum knowledge; 4) pedagogical content knowledge; 5) knowledge of the learners and their characteristics; 6) knowledge of educational contexts; and 7) knowledge of educational ends, purposes, and values with their philosophical and historical grounds (Shulman, 1986). Shulman's definition of PCK is distinctive and useful as it shows the researchers in this area what successful teachers know about ensuring and achieving student understanding. After Shulman's first proposal, many other researchers modified and reinterpreted PCK (Gess-Newsome, 2015; Grossman, 1990; Lederman & Gess-Newsome, 1992; Magnusson, Krajcik, & Borko, 1999; Park & Oliver, 2008). A *paradigm shift* in the field of teacher education research was observed upon Shulman's definition and construction of PCK (Carlsen, 1999).

In the following year, Tamir (1988) was inspired by Shulman's view on PCK, and he focused on teacher knowledge. Teacher knowledge, in his view, has two basic components: subject matter knowledge and pedagogical knowledge. The latter consisted of subcategories that are general pedagogical knowledge and subject matter-specific pedagogical knowledge which is actually PCK. Knowledge of students' understanding, curriculum, instructional strategy, and assessment are the components of subject matter-specific pedagogical knowledge. Tamir's work contributed knowledge and skills for assessment to the PCK models.

Influenced by Shulman's PCK construct, Grossman (1990) became the first researcher to systematize the elements of teacher knowledge. She expanded Shulman's definition and schematized the constituents of PCK. In her model (Figure 2.1), PCK included three main dimensions: subject matter knowledge, general pedagogical knowledge, and contextual knowledge. She believed that the mentioned types of knowledge then formed pedagogical content knowledge. For Grossman (1990), PCK consisted of four elements: 1) conception of teaching purposes, 2) knowledge of students (their understanding or misunderstanding of a specific topic), 3) curricular knowledge, and 4) knowledge of instructional strategies. Grossman considered the "conception of teaching purposes" more important than other elements and labelled it as an overarching component. Despite the fact that Grossman (1990) developed a transformative PCK model, her explanation did not mention if PCK was an active or passive process. Besides, she stated that the division between the PCK components was not clear.

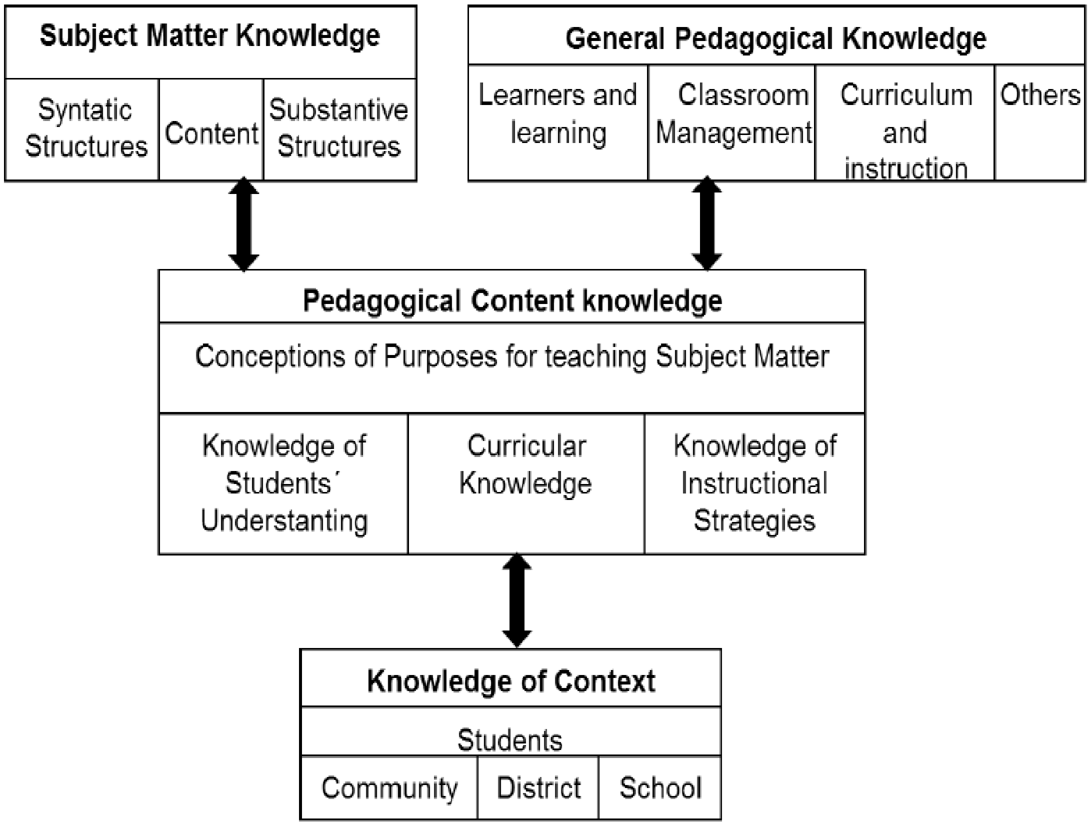

Figure 2.1. Grossman (1990)'s PCK Model (p.5)

Adopting a constructivist view of learning, Cochran, DeRuiter, and King (1993) suggested that there is a need for an alteration of Shulman and Grossman's conceptualization of PCK. They promoted the term "Pedagogical Content Knowing" (PCKg) through which they emphasized PCK has dynamic and developing nature. They criticized Shulman (1986) and Grossman (1990)'s views of transformative PCK. In their perspective, PCKg was whole rather distinct and developed simultaneously with the contribution of teacher's knowledge in other four components in the teaching context. Cochran et al. (1993) emphasized the significance of experience when it comes to teacher knowledge. Therefore, their PCKg model (Figure 2.2) is reflective of the development of PCKg over time with experience. The model also shows that pedagogy, subject matter, student, and environmental contexts are the ingredients of PCKg. The developed model visualizes how all four components are related to each other.

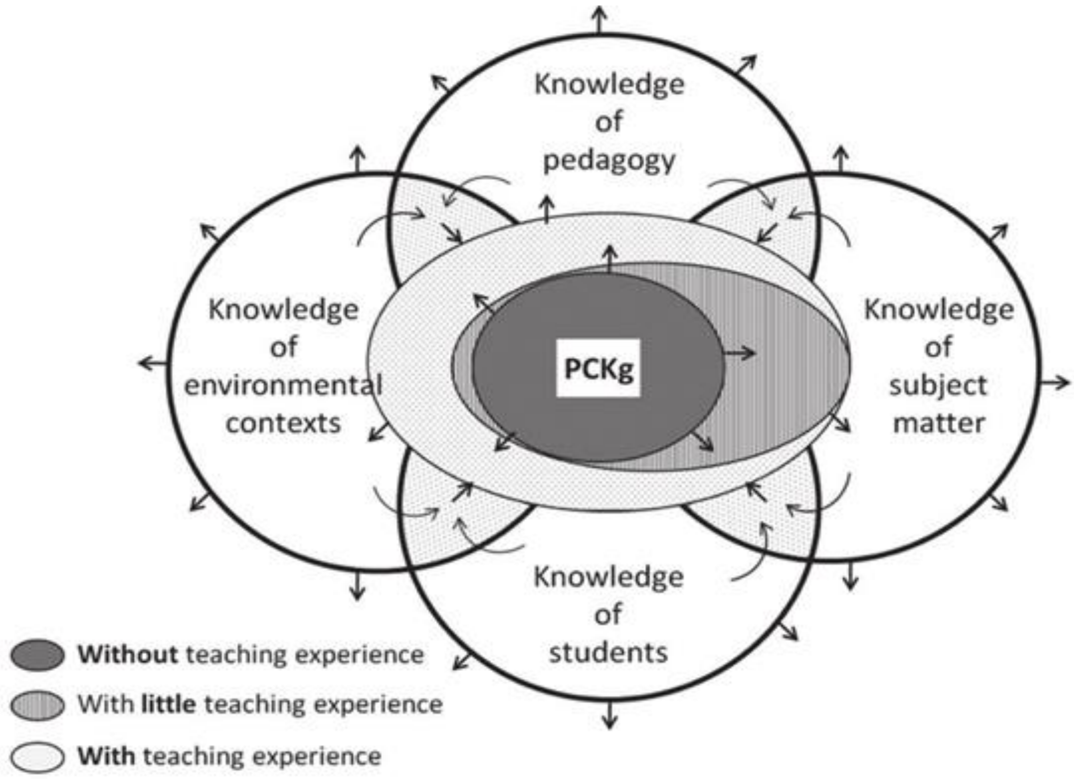

Figure 2.2. Cochran et al. (1993)'s PCKg Model (p. 238)

In separate study, Veal and Makinster (1999) developed taxonomy for pedagogical content knowledge. For them, PCK demonstrated eight attributes that are as follows: context, environment, nature of science, assessment, pedagogy, curriculum, socio-culturalism, classroom management, knowledge of students, content knowledge. Due to hierarchical structure of the taxonomy (Figure 2.3), for a teacher to develop a thriving PCK, content knowledge, knowledge of students, and PCK attributes are essential and fundamental. However, this PCK development does not indicate a linear progression. Rather, the researchers acknowledged that those elements are interdependent. In other words, Veal and Makinster's (1999) taxonomy proved PCK to be a continuous journey in addition to showing that growth in one component has an impact in the overall PCK.

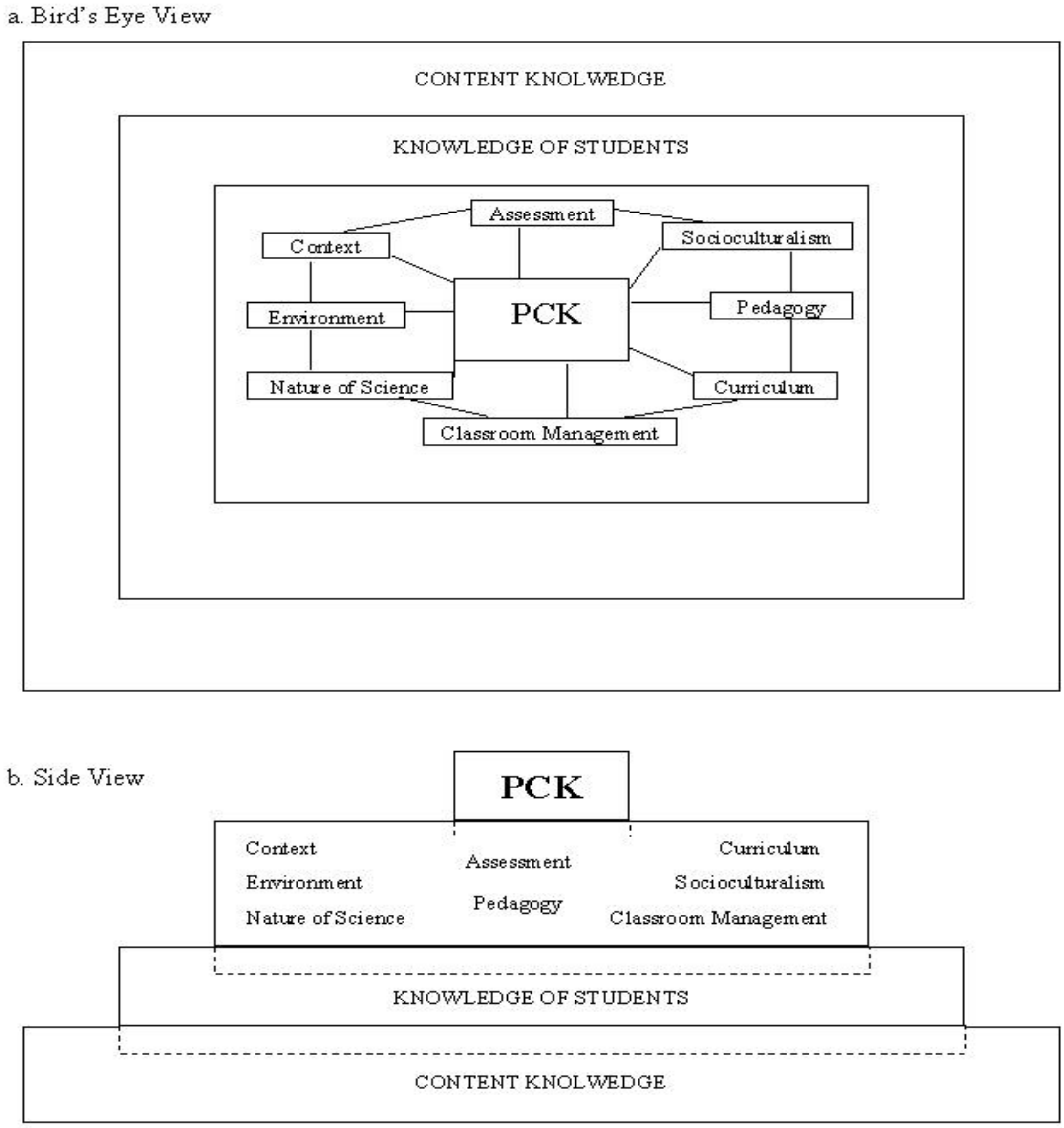

Figure 2.3. Veal & Makinster (1999)'s Hierarchical Model of PCK (p. 11)

Moreover, Veal and Makinster (1999) critized the idea of direct transformation of pedagogical content knowledge. They argued that since PCK was based on contextual settings, it could not be directly transformed; could only adapted to other contexts. PCK, in their definition, is to explain the content to students with the use of varied strategies of instruction. To further exemplify this description, Veal and MaKinster (1999) likened the PCK process to the translation of one language to another. In other words, teacher should be able to translate one language (PCK) to convey the message (content) to people speaking a different language (students).

In their recent work, Park and Oliver (2008) worked on and developed Magnusson et al. (1990)'s model. Their work introduced a sixth component which they called "teacher efficacy". The authors named this model of PCK construction as Hexagonal Model (Figure 2.4). Not only the introduction of the concept of teacher efficacy but also the emphasis on reflection, students' role, and distinctive teaching characteristics distinguishes Park and Oliver's (2008) work from others in this field.

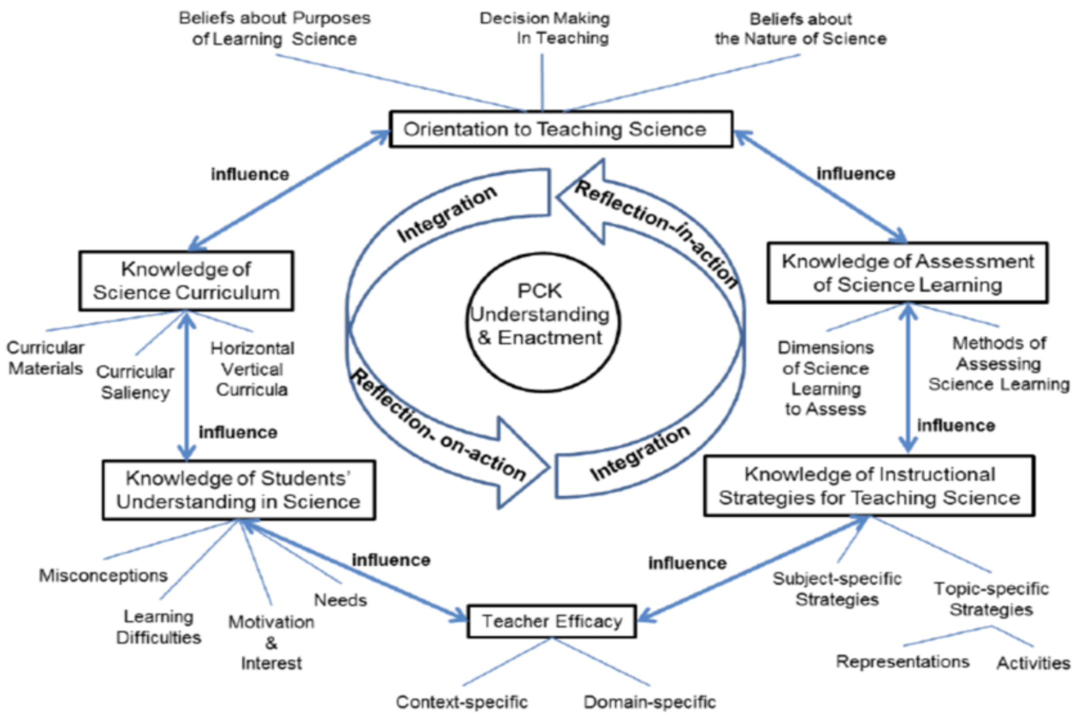

Figure 2.4. Park & Oliver (2008)'s Hexagonal Model of PCK (p. 279)

When we look at the Hexagonal model, we see that the authors referred to two levels of PCK: *understanding* and *enactment.* Within the context of this model, understanding means that the teacher recognizes the challenges, students' needs or learning difficulties, and the instruction strategies needed to explain a specific topic. Enactment, on the other hand, refers to the application of teachers' understanding during a real teaching situation. Furthermore, placing reflection (both in and on action) at the heart of the model illustrates its significance within PCK. Finally, the model developed by Park and Oliver (2008) puts a special emphasis on the idiosyncrasy of PCK which is related to several factors such as distinctive characteristics of teachers in teaching, students' traits, and teachers' experience.

Rollnick, Bennett, Rhemtula, Dharsey and Ndlovu (2008) produced their model of PCK (Figure 2.5) as a mixture of four domains of teacher knowledge. These are content knowledge, context knowledge, knowledge of students, and general pedagogical knowledge. According to the researchers, during practice, these domains trigger the development of four other domains called "products of education" which are content representations, instructional strategies specific for a content, curriculum saliency, and assessment.

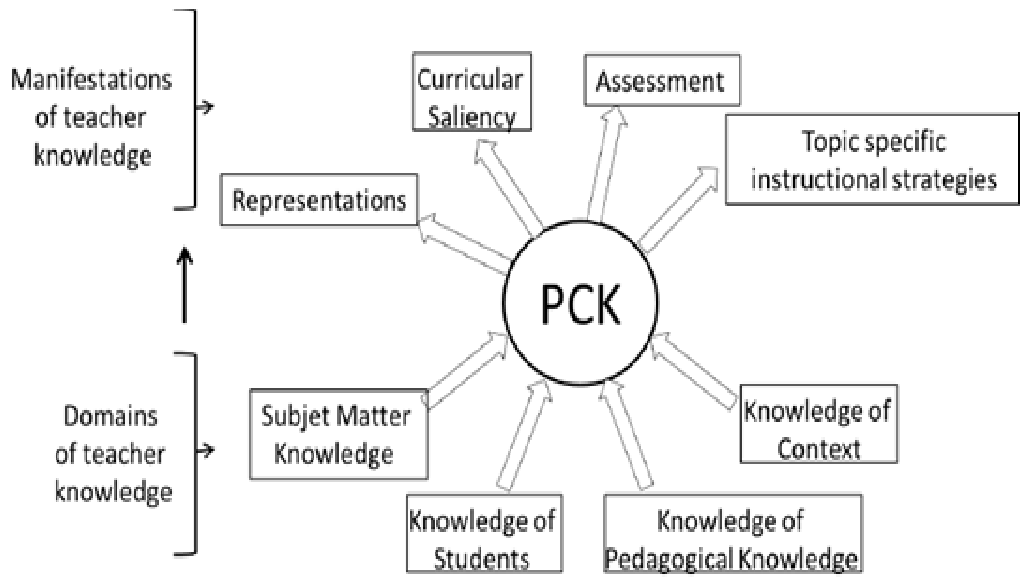

Figure 2.5. Rollnick et al. (2008)'s Tailored PCK Model (p. 1381)

Influenced by Cochran, DeRuiter and King (1993)'s teacher knowledge bases, they placed PCK at the interface between knowledge and practice. In this model, they also concluded that PCK had influence on manifestations in the classroom. Then, Davidowitz and Rollnick (2011) modified this model by including teachers' beliefs. According to this new model (Figure 2.6), there is a reciprocal relationship between teachers' beliefs and teacher knowledge domains.

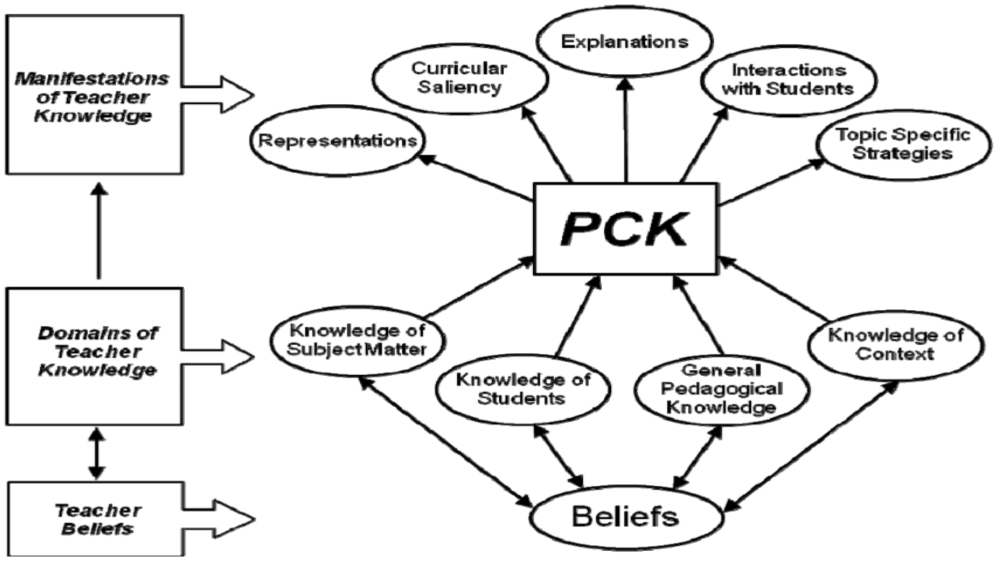

Figure 2.6. Modified Tailored PCK Model (Davidowitz & Rollnick, 2011, p.10)

Finally, the latest PCK model (Gess-Newsome, 2015) was developed as a result of a conference held in 2012, with the aspiration to adopt a common definition of pedagogical content knowledge. In this PCK Summit model (Figure 2.7), there are five professional knowledge bases: 1) knowledge of assessment, 2) pedagogical knowledge, 3) content knowledge, 4) knowledge of students, and 5) curricular knowledge. There is a bivious interaction between these types of knowledge and topic-specific professional knowledge. Having professional knowledge means being knowledgeable about and proficient in instruction methods and strategies, content representation. In addition to these, the teacher is expected to know about students' potential misconceptions and challenges, dispositions as well as scientific methods and applications. On the other hand, teachers' beliefs, the context of education, and teaching orientation all act as filters in shaping teacher's professional knowledge. Only then this specific knowledge can be reconstructed to achieve a personal PCK through classroom context during the practice. The process of developing knowledge continues after it is applied in classroom context where it is subjected to students' beliefs, behavior, and existing knowledge about the topic. Student outcomes can be used to evaluate teacher's professional knowledge on the topic since they affect teachers' personal PCK achieved through practice in the classroom and the topic-specific professional knowledge.

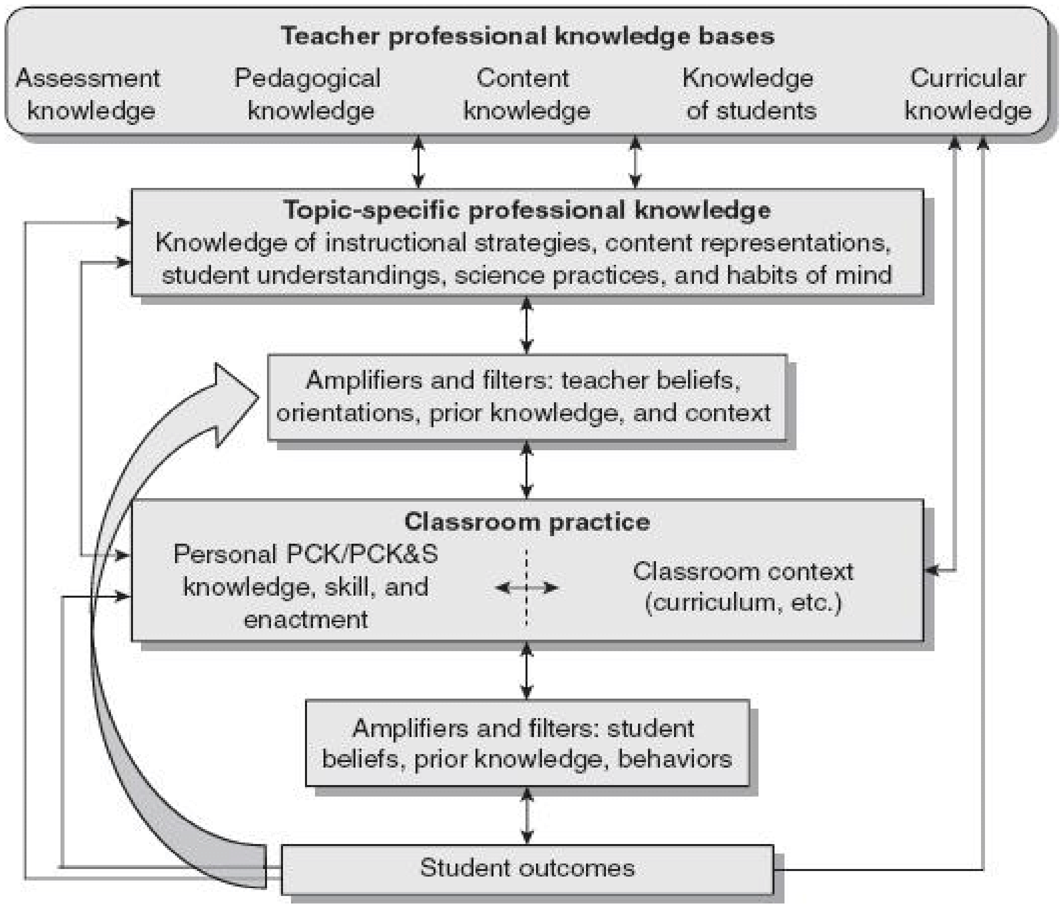

Figure 2.7. Consensus Model of PCK (Gess-Newsome, 2015)

As can be seen, in PCK literature, there are many definitions and models of pedagogical content knowledge. Gess-Newsome (1999) examined PCK in two categories as *integrative* and *transformative* (Figure 2.8). In integrative understanding of PCK, it is viewed as a combination of different factors as pedagogical knowledge and subject matter knowledge in addition to context knowledge. In other words, PCK is not a new or separate domain of knowledge in integrative model. This model is also adopted by Cochran et al. (1993) and Veal and MaKinster (1999). Kind (2009) concluded that due to the lack of interaction among the components, integrative models did not have explanatory power. On the other hand, the transformative model (Figure 2.10) indicates that PCK is the blend of pedagogical knowledge, subject matter knowledge, and context knowledge. Unlike the integrative model, PCK construct here is regarded a special type of knowledge. According to Kind (2009), transformative models have an important mechanism showing the influence of SMK on PCK for teaching particular topics. Models developed by Magnusson et al. (1999), Grossman (1990), and Shulman (1986, 1987) are as well transformative models.

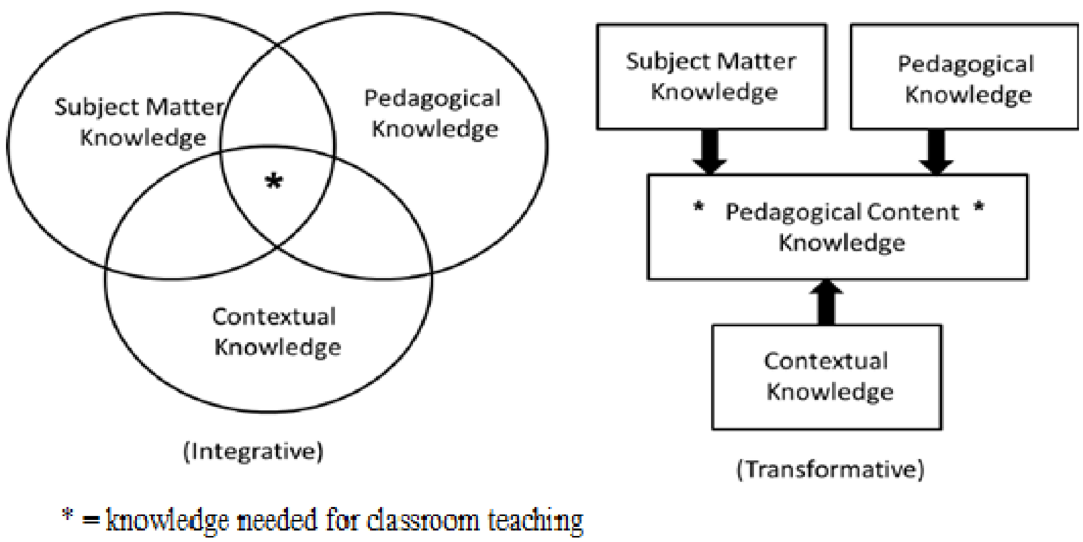

Figure 2.8. Integrative and Transformative Models of PCK (Gess-Newsome, 1999, p. 12)

After examining the PCK development literature, it is observed that the process of teaching is complex, fuzzy and difficult to understand. Hence, most of educational researches have tried to bring forth different solutions in order to clarify the concept of teaching. With an aim to increase the quality of teaching, the researchers, therefore, proposed distinct PCK models having different views of PCK. However, among models of PCK, there are some common components such as pedagogical knowledge, subject matter knowledge, and context knowledge. Additionally, there was a consensus regarding the teacher's knowledge about representations as well as difficulties and challenges experienced by students (Van Driel et al., 1998). Furthermore, studies on PCK suggest that there is still a need for more research the components of PCK so as to clarify the interaction between such.

As a result, even though the definition of PCK has fuzzy meaning, and proposed models have missing pieces in PCK paradigm, PCK construct is an effective tool for understanding the nature of teaching and teacher knowledge (Gess-Newsome, 1999).

2.1.2. Studies on PCK of Science Teachers

In PCK literature, there has been various studies focusing on the disciplines of chemistry (Aydeniz & Kırbulut, 2014; Aydin, 2012; Clermont et, al., 1993; Drechsler & van Driel, 2008; Geddis et al., 1993; Hanuscin et al., 2018; Hume, 2010; Özden, 2008; Padilla et al., 2008; Rollnick et al., 2008; Usak, Ozden & Eilks, 2011; van Driel et al., 1998) and physics (Berg & Brouwer, 1991; Halim & Meerah, 2002; Juhler, 2016; Karal & Alev, 2016; Magnusson et al., 1994; Magnusson et al., 1999; Melo, Cañada & Mellado, 2017; Nurmatin & Rustaman, 2016) in the different contexts. However, as the scope of the study was science teachers' pedagogical content knowledge and subject matter knowledge in the field of biogeochemical cycles, both foreign and national PCK studies conducted with either biology teachers or science teachers teaching biological topics were mostly reviewed in this section.

2.1.2.1. Studies on Science Teachers' PCK on Biology Topics

Researchers explored the construction and development of PCK in teaching biology topics using two different approaches (Mthethwa-Kunene, Onwu & Villiers, 2015). The first approach included longitudinal studies with an aim to increase teachers' knowledge by employing certain experimental interventions as part of professional development programs such as training courses or workshops (Arzi & White, 2008; Brown et al., 2013; Friedrichsen et al., 2007; Gess-Newsome et al., 2017; Henze et al., 2008; Lee & Luft, 2008). The second approach focused on investigating what teachers know about teaching particular topics. This approach applied qualitative methods to gather data (Mthethwa-Kunene, Onwu & Villiers, 2015; Friedrichsen & Dana, 2005; Kapyla, Heikkenen & Asunta, 2009; Lankford, 2010). By focusing on the nature of topic-specific PCK, the components of PCK and PCK development in biology topics, this section explores in detail such PCK studies which were conducted with science teachers.

Brown, Friedrichsen and Abell (2013) conducted an analysis on 4 pre-service biology teachers by using a longitudinal approach to study their level of pedagogical content knowledge. Throughout the analysis, their main focus was on orientation toward science, knowledge of instructional sequence, and knowledge of student. By making use of a teacher certification program, researchers analyzed the development in the pre-service biology teachers' knowledge as they gained experience over time. Data sources for the research included written account of interviews with teachers, teachers' lesson plans, their field notes as well as the materials they produced for in-class use. The study showed K-16 experience and educational background to be the two factors having an impact on the orientations of future teachers' science teaching. The research also demonstrated these orientations to be remarkably resistant to change over time. The teachers were found to believe that teaching is conveying the information to the student and in return, the student is expected to just listen to the teacher. On the other hand, teachers' knowledge of learner developed to some extent over time. To illustrate this finding, teachers had little awareness and knowledge as to the students' challenges at the beginning; however, their understanding increased throughout the certification program. Lastly, the teachers began with conveying information as they believed students would not be able to grasp the knowledge without the help of teachers. As a result, teachers couldn't follow the 5E learning cycle step by step. Yet, using different activities and instructional strategies, they demonstrated transformation in that regard as they gained more experience. To sum up, the research revealed that prospective biology teachers developed their knowledge on instructional strategies and learner to a certain degree, and in parallel to each other. Resulting from their willingness to respond to students' expectations and facilitate learning process, teachers improved themselves in terms of instructional strategy. The science teaching orientation of pre-service teachers was found to be in harmony with the other two components as well as having an impact on those.

There was another study by Friedrichsen, Lankford, Brown , Pareja, Volkmann and Abell (2007). The researchers benefited from an alternative certification program (ACP) to examine the differences between teacher with and without teaching experience. The participants of the ACP consisted of four biology teachers and two of them did not have experience in teaching while the other two worked as biology teachers for two years. For data collection purposes, researchers made use of Lesson Preparation Method. The participants were requested to write their own lesson plans for the teaching of the concept of heritable variation. Participants' lesson plans were used as primary data sources in addition to transcription of follow-up interviews. As a result, it was seen that both experienced and inexperienced teachers' orientation to teaching was didactic and they prepared identical lesson plans. Not possessing pedagogical content knowledge in the field of heritable variation, all participants relied on and benefited from their general pedagogical knowledge. To sum up, it can be said that teaching experience does not make a considerable difference but it facilitates the synthesis of pedagogical components.

Concerning the implementation of new curriculum, in their longitudinal study, Henze et al. (2008) investigated PCK of nine science teachers who had teaching experience. The teachers were expected to teach about solar system and the universe (two models). While they had teaching experience, the application of the recent science curriculum was somehow new to them. The teachers worked on development of PCK with an emphasis on instruction methods and strategies, understanding of students, assessment methods, goals and objectives of the subject within the new curriculum. Data were collected through semi-structured interviews for three consecutive years. Upon the analysis of collected data, it was seen that those teachers had two different PCK forms: 1) type A PCK where the focus was on the content of the topic; and 2) type B PCK was interested in the content of the topic in addition to developing models in science. At the core of type A PCK was the knowledge about instruction methods and strategies while the periphery consisted of knowledge about understanding of students, assessment methods, goals and objectives of the subject. There were some similarities between type A and B PCK. It was observed that knowledge about goals and instruction methods was in harmony with each other. In both types, knowledge about goals and objectives did not show any sign of change. It is also worth noting that when teachers were more aware of students' challenges and knowledgeable about the subject matter, they developed and used instruction strategies in a more effective way. The teachers benefited from exam papers to renew their understanding of and knowledge about their students as they provided an up-to-date report of students' difficulties, misunderstandings, and challenges. Therefore, it can be said that there was a correspondence between knowledge of students and assessment. Lastly, there was a relation among knowledge of assessment and instruction methods as the teachers had the opportunity to assess the student in the exams after teaching them the content of subject matter. However, considering the development of PCK, type A and B PCKs have their own characteristics, and their subcomponents interact with each other in their own way. At this point, it should be noted that authors believed that pedagogical knowledge as well as teachers' belief have an impact in shaping PCK. For example, it can be argued that if a teacher lacks SMK and has a positivist approach to the models of universe and solar system, they may develop type A PCK. On the other hand, teachers with sufficient SMK and a relativist approach to the models may develop type B PCK. The last thing to note is the unsynchronized development of subcomponents of PCK. While there was a considerable improvement in one component, there was little in another.

Arzi and White (2007)'s longitudinal study was a long-term research to investigate how teacher's subject matter knowledge evolved over the years as they gained teaching experience. The study was conducted with secondary school science teachers for 17 years in Australia. The research employed one-to-one interviews with teachers with the use of concept profiles method to examine any change in subject matter knowledge. It was detected that although the general knowledge is kept in memory, the details fade away if not used or revised. Teachers demonstrated a progress in their understanding of structure. It was observed that what teachers know about and how interested they are in their field of study makes a critical contribution to their development. On the contrary, they are more likely to have shortcomings in other topics. Within the scope of this research, the curriculum presented to the teachers works as the sole most important factor that is used to measure knowledge of teachers. As a result of this study, the researchers suggested a model which shows the growth of teacher's content knowledge in three stages. These stages are 1) academic details acquisition, 2) curricular aggregation, and 3) intra- and inter-disciplinary linking and pattern construction.

Orientation to science teaching has pivotal position when growth in teachers' pedagogical content knowledge is considered. To examine this further, Friedrichsen

& Dana (2005) conducted a research with four experienced and respected biology teachers. The collection of data was made through card-sorting method, interviews, and observation in classroom environment. The study demonstrated the complex character of teacher orientation through the use of various central and peripheral goals. Within the frame of the research, central goals were defined as main factors controlling teachers' teaching as well as their decisions about teaching act. Peripheral goals, on the other hand, are less influencing on teaching act. The research revealed that teachers' orientations were different for each individual course. The goals within the scope of this study were categorized as affective, schooling, and subject matter goals. Developing a positive stance to science and being curious or self-confident were included within affective goals which meant that these were of priority and concern for teachers. Schooling goals were preparing students for college or life. When subject matter goals were concerned, the researchers found that they were always present; however, they were not the sole and key goals for teachers. As a result, it was emphasized that the character of teachers' orientations is dynamic and time-bound. Finally, Friedrichsen and Dana (2005) stated that due to their complex character, teachers' orientations should not and cannot be constrained to a single orientation.

In order to examine biology teachers' pedagogical content knowledge, Lankford (2010) carried out a research with six biology teachers who had experience in teaching. The subjects selected for the scope of the study were diffusion and osmosis. It was observed that five teachers held a constructivist orientation which acknowledges the importance of students' active participation in the process of learning and knowledge construction. On the other hand, one of the teachers had knowledge transmission orientation in which teachers see themselves as conveyor of the knowledge to students. Analyzing the factors that have an impact on teachers' orientations, Lankford (2010) discovered that teachers' teaching experience, participation in professional development activities and interaction with their colleagues were among the influencers. The teachers who had constructivist orientation implicitly followed 5E instructional model to teach the selected topics. In terms of sequence in teaching, all teachers taught first diffusion and then osmosis. When they had to use images to teach, it was observed that all teachers began with simple images and then moved on to more complex ones. Teachers identified possible challenges for students in using topic-specific terminology, understanding the images for the molecular level activities, and knowing the direction of water during osmosis. Being able to identify students' challenges and misconceptions helped teachers in determining which instruction method to use. With regards to assessment, teachers asked questions to get their ideas and opinions about the topic and this contributed to teachers' knowledge about their students. So knowing not only their challenges but also their primary knowledge further supported teachers in choosing their teaching strategies. For example, teachers used analogies and animated videos about the topic (i.e. diffusion and osmosis) to facilitate students' learning. It was observed that sometimes teachers shared extra information although the teaching goals and objectives were defined by the state. Lastly, the researcher found that teachers referred to previous subjects to make the current topic more understandable to the students.

With an aim to compare teachers who had different levels of content knowledge, Kapyla, Heikkenen and Asunta (2009) explored two different groups of teachers' content knowledge and pedagogical content knowledge and their relationship with each other. The first group was pre-service biology teachers while the second was pre-service primary school teachers. The concerned topics within this study were photosynthesis and plant growth. The experts in this topic were pre-service biology teachers whereas pre-service primary school teachers were considered beginners. The main elements addressed in this study were knowledge of instruction strategies, knowledge of students (conceptual challenges), knowledge of curriculum, and teachers' orientation to science teaching. The research was performed in Finland (Jyvaskyla) with 10 teachers in each group. Lesson plans, interviews with teachers, and surveys were used to collect data. Upon the analysis of the data, pre-service biology teachers had more awareness about their students' challenges and misconceptions regarding the selected topics while pre-service primary school teachers had no awareness. The researchers found pre-service biology teachers to be more informed about the topics while insufficiency in knowledge about the selected topics was discovered in pre-service primary school teachers. Related to their knowledge of curriculum, pre-service biology teachers were able to differentiate which concept was more important. In terms of instruction strategies, pre-service primary school teachers benefited from activities that need the students to be more creative in their thinking while pre-service biology teachers used activities focusing directly on the teaching of the topic itself. It was observed that each group needed to improve themselves regarding experiments. The researchers argued the two groups of teacher both lacked knowledge of instruction strategies so there may be no relation between knowledge about content and instruction strategies. Therefore, they suggested that PCK should be included in all training programs for teachers. Regarding teachers' orientation to science teaching, there was a difference between the two groups of teachers. Pre-service primary school teachers put students at the center of the lesson while pre-service biology teachers were teacher-centered and held didactic lessons as in Magnusson et. al. (1999)'s model of PCK. As a result, the researchers discovered that possessing better knowledge of content brings better knowledge of students and curriculum. Yet, those teachers with better knowledge of content hold teacher-centered approach to their lessons and convey the information in a didactic way. According to the researchers, this demonstrates that the teachers' knowledge about instruction strategies as well as the orientations to science teaching is inadequate. To sum up, it can be said that the findings of this research partly is in support of the argument that the level of knowledge of content directly affects the level of pedagogical content knowledge.

Again, in their qualitative study, Mthethwa-Kunene, Onwu and de Villiers (2015) explored the pedagogical content knowledge (PCK) and its development of four experienced biology teachers (Grade 11-12) in the context of teaching school genetics. The study used a qualitative research approach within an interpretive paradigm involving multiple-case study method. The researchers used knowledge of content, knowledge of students, and pedagogical knowledge to define PCK. This qualitative research used as data sources the concept maps prepared by teachers, interviews with teachers before and after lessons, video records of the lessons, surveys for teachers after lessons, students' work samples as well as journals written by teachers. The study revealed that the teachers had the required content knowledge in genetics. They applied diverse instructional strategies specific to the relevant topic. The topic-spesific strategies included analogies, illustrations, and peer teaching. The teachers did not, however, implement strategies to support students to visualize or internalize the topic. Lastly, the study demonstrated that the participants were unaware of their students' misconceptions or challenges regarding genetics.

Area of expertise was another element explored in PCK studies. Comparative studies on biology teachers' PCK in both their major and non-major topics were conducted by researchers. Sanders, Borko, and Lockard (1993) examined three science teachers in terms of their planning, teaching and reflecting in their major and non-major fields. The teachers had three to eight years of experience in their major field while in their non-major, they had one or two times experience. When teaching in their major area, their teaching experience constituted the primary source with extra and repetitive revisions every school year. It was observed that they possessed a solid knowledge of students and the learning environment (i.e. classroom). On the other hand, the researchers discovered a disparity between planning, teaching and reflection. The teachers expressed that in their major area they found it easy to adjust the sequence of lesson considering the challenges or demands of students. There was also a difference in applying the instruction methods in their major and non-major fields. While in their major fields the teachers possessed a large number of materials and activities and they were good at planning for their lesson, they needed improvement in planning in their non-major area. The teachers faced challenges in identifying key concepts to teach, the appropriate activities for the lesson, the instruction method, and learning goals when they had deficiencies in SMK. The teachers lacked adequate pedagogical knowledge in teaching in their non-specialization area. An example of this was the failure to estimate the length of an activity which caused them to prepare unnecessary activities. When PCK was considered, the participants were insufficient in knowledge of students as well as instruction strategies in their non-major fields. Another difference was observed when their way of teaching was examined. They were unable to adopt a student-centered approach while teaching in their non-major field. They were challenged to focus on questions from students in their non-major area. They did not feel comfortable to make their own definitions for the terms they need to explain in their non-major area; instead, they focused on delivering the descriptions from written sources. Another finding of the study was the poor ability of the teachers to manage the classroom during lessons in their non-major field. The researchers observed differences in reflection as well. Whereas the teachers were concerned about students' understanding and their challenges in the major field, teaching process was their main focus in the non-major field. As a result of the study, the researchers argue that planning and teaching were facilitated by mainly pedagogical knowledge if the teacher's content knowledge is insufficient in the beginning; and then, over time they improve and internalize content knowledge.

Another study on science teachers' PCK in planning for their major and non-major fields was conducted by Ingber (2009). Six teachers participated in the study which, in particular, examined how they planned for the lesson, what resources they used, and which instruction methods they employed. Questionnaires and think-aloud method were data collection tools for this study. The researcher found the participants to be more qualified in using the terminology within their field of expertise while planning. Additionally, they were able to describe more concepts. In terms of resources, when planning for their major area, they demonstrated a better knowledge on what to use for better teaching and increased SMK. Surprisingly, the results of this study did not show a significant relation between area of expertise and use of instruction methods. Ingber (2009) declared that the latter was teacher-specific.

Chan and Yung (2018) also studied the impact of teaching experience on the development of PCK. They explored the approach to teaching a new concept (polymerase chain reaction) and development of PCK in planning, teaching, and reflection steps. Two high school biology teachers with teaching experience participated in the study. The researchers benefited from semi-structured interviews with teachers, field notes, and in-class observations. The results of the study showed that prior teaching experience affected the planning for the new concept but it did not necessarily facilitate the development of PCK. Therefore, the researchers argued that there are two categories of teachers with experience. The first group of teachers is able to benefit from their prior experience for the purpose of new PCK development. The second group, however, fails to do the same. The difference between the groups results from their inclination to have the mentality to make use of the current SMK for the purpose of new PCK development. Chan and Yung (2018) suggest that training programs for teachers should support them in developing this inclination.

In the abovementioned studies, teachers' PCK were always analyzed through qualitative approaches. There are also quantitative studies exploring teachers' SMK and PCK in biology topics. An example of such is a study conducted by Park, Jang, Chen, and Jung (2011). Carried out with the participation of seven biology teachers, the study aimed to examine their PCK and application of reforms in the topics of photosynthesis and heredity. The researchers developed a PCK rubric for the assessment of teachers' PCK (2008, as cited in Park et al., 2011). The rubric included knowledge of students and instruction methods. In order to evaluate the teachers' application of reforms, the researchers employed the Reformed Teaching Observation Protocol (RTOP) which was created by Sawada, Piburn, Turley, Falconer, Bloom, et al., (2000, as cited in Park et al., 2011). Apart from these data collection tools, in-class observations during lessons and interviews before and after the lessons were used as sources. The findings revealed that having a strong PCK supports teachers to integrate reforms in their teaching. It was also observed that when teachers have a profound content knowledge, they are inclined to focus more on reforms. Despite the constraints of the study due to the use of correlational research method, this study contributed to the literature with its results.

Furthermore, Jüttner, Boone, Park and Neuhaus (2013) underlined that the last 20 years saw a growth in the number of studies exploring teachers' professionalism and professional development. With an aim to contribute to the literature with a comparable research, they investigated the development and utilization of tools that would help in assessing content knowledge and pedagogical content knowledge of biology teachers. The study suggests a theoretical model for the development of such tools through benefiting from empirical data gathered from students. In addition, the researchers inquired if it was possible to assess CK and PCK separately with a paper-pen test. The results obtained from the Rasch analysis applied for 158 biology teachers show that the tools managed to objectively and reliably assess the CK and PCK of teachers. In other words, it is possible to develop and use new tools together with in-class observations during lessons for the measurement of teacher performance.

The researchers in the literature argued that there is a possibility for an interaction between separate PCK components. To further study this argument, Park and Chen (2012) examined high school biology teachers. The results of the study revealed a strong interaction between knowledge of students and instructional strategies. They also argued that these components also interacted with other PCK components. The authors stated that teachers' orientation to science teaching can either constrain or facilitate the interaction between PCK components. For example, acting as a conveyor of knowledge (i.e. adopting a didactic approach) can isolate the knowledge of instructional strategies from other components. On the other hand, when a student-centered approach to teaching is adopted, there occurs an interaction between knowledge of students and knowledge of instruction strategies. Knowledge of curriculum was observed to have a little impact on (therefore a basic interaction with) other PCK components. Lastly, while knowledge of assessment did not incorporated into other components of PCK, it did have an interaction with knowledge of instruction strategies and students. In other words, the development of knowledge of assessment may strengthen the interaction among PCK components.

When the literature was reviewed, it is seen that there are many PCK studies carried out with pre-service and in-service science and biology teachers abroad. However, the number of such studies is limited in the Turkish educational context. The following section examines the studies conducted in Turkey with the participation of pre-service and in-service science teachers.

Firstly, some PCK studies were conducted to examine Turkish in-service science teachers' PCK in biology topics. Recently, Şen, Öztekin & Demirdöğen (2018) explored the influence of content knowledge on pedagogical content knowledge through a study with the participation of three experienced science teachers. The topic selected for the scope of the study was cell division. The researchers collected data through interviews with teachers, in-class observation during lessons as well as teacher documents such as exam papers. The study employed inductive method to analyze the teachers' CK and within-case method for the analysis of PCK. To understand how PCK is influenced by CK, cross-case analysis was utilized. The results of the data analysis demonstrated a possible influence of CK on the knowledge of instruction strategies and students. On the other hand, it was found that teachers' orientation to teaching science may not be influenced by CK at all. Lastly, CK was found to have an impact on knowledge of curriculum as well as knowledge of assessment while it seemed quite complicated.

Aydemir, Çakıroğlu and Tekkaya (2012) studied science teachers' knowledge of students through examining five experienced elementary science teachers in teaching genetics. Knowledge of students, within the scope of this study, was explored in two different categories: students' needs while learning about genetics and their challenges regarding this topic. The researchers observed the participants during lessons and they also held interviews with them. It was found that due to its abstract character, genetics was difficult to be understood by elementary school students. The authors also stated that sequence of knowledge is significant in biology which means learners should first be taught about other topics to lay the basis for more complex and abstract ones. Within the scope of this study, for example, they can understand genetics after they learn about cell, cell division, and fertilization.

Using the PCK model by Magnusson et al. (1999), Karakulak and Tekkaya (2010) investigated PCK of two new teachers in the field of ecology. The researchers collected data through semi-structured interviews with teachers, observations, lesson plans, concept maps, and field notes. It was discovered that new teachers faced challenges and possessed misconceptions in understanding ecosystem, habitat, decomposers, biodiversity, food web, and energy flow within ecosystem. While having general knowledge about ecology, they were challenged to link the learning objectives with their knowledge. The research also revealed that they needed improvement in their knowledge of instructional strategies in ecology. Lastly, it was found that the teachers lacked sufficient knowledge about the challenges and misconceptions that the students faced regarding ecology.

In the Turkish PCK literature, there are also some studies examined pre-service and prospective science teachers' biology-specific PCK. For example, Kaya (2009) examined the interaction between the components of PCK in pre-service science teachers by focusing on the topic of ozone layer depletion. Firstly, the author conducted an open-ended questionnaire with the participation of 216 pre-service teachers in their last year at the faculty. The aim of the questionnaire was to measure their level of knowledge about the topic (ozone layer depletion). The results of the questionnaire helped the researcher to categorize the pre-service teachers as high, average, and low ability groups. Interviews with 25 randomly selected participants from every ability groups were organized to explore their PCK and the interactions between and within the PCK components of pre-service science teachers in teaching the selected topic. It was found that PCK and knowledge of subject matter were in interaction with each other. Moreover, the researcher discovered an important interaction within the components of PCK (apart from knowledge of assessment). Finally, PCK of pre-service science teachers differed according to their subject matter knowledge. The results from different data collection methods supported each other.

Again, the aim of Uşak (2009)'s study is to explain prospective science and technology teachers' pedagogical content knowledge (PCK) about the cell. The researcher interviewed the pre-service teachers, gathered their lesson and laboratory plans, and benefited from concept maps prepared by the pre-service teachers. Carried out with six pre-service science and technology teachers in Pamukkale University (Turkey), the study showed that the participants had insufficient knowledge of instruction methods. On the other hand, they demonstrated sufficient content knowledge. It was also discovered that they adopted a teacher-centered approach in teaching although some of them preferred activities for students which would enable them to actively take part in learning process.

A distinct study in the Turkish literature is the collaborative work of Graf, Tekkaya, Kılıç and Özcan (2011). This study is distinct as it is a comparative study involving two Turkish and two German pre-service science teachers. It aimed to explore the participants' PCK on evolution. Similar to the other mentioned studies, this research collected data through semi-structured interviews with teachers, lesson plans prepared by the participants, and their concept maps. The authors found the knowledge of curriculum to be inadequate in both Turkish and German pre-service science teachers. They were not aware of the place and content of the topic in the curriculum. They also didn't know about the grade the concerned topic is explained and the content of the textbooks regarding evolution. Both group of teachers showed lack of knowledge when it came to instruction strategies. Turkish teachers stated that due to their inadequate content knowledge, it was difficult to rectify the misconceptions identified among students. They declared that the method of questioning might be utilized while teaching evolution. Unlike their Turkish colleagues, German teachers opted for more student-centered strategies such as station method cooperative learning. They also made use of representations to help the students understand this abstract topic. When their knowledge of students was examined, Turkish pre-service teachers believed natural selection and variation to be easy-to-learn. The abstract nature of the topic of evolution was one of the reasons behind students' struggle to comprehend it. Another reason was the difficulty to relate it to everyday life. German teachers, however, found the process of evolution and origin of life to be challenging for their students. Teachers identified religious beliefs, families, and non-scientific books as the causes of misconceptions among their students. According to both Turkish and German teachers, the most common misconception among students regarding evolution was the idea that human is descendant of monkeys. To evaluate their students, Turkish teachers used written assessments such as gap-filling or true/false at the end of their lesson. In terms of timing of the assessment, German teachers were different, and they conducted evaluations before, during, and after the lesson so as to follow the development and change in their knowledge. Again, unlike their Turkish colleagues, German teachers preferred essay type, open-ended, and two-tier questions. To sum up, both groups of teachers couldn't demonstrate a rich PCK in evolution. They lacked knowledge of curriculum. They also did not have sufficient knowledge in terms of instruction strategies (i.e. what to use and how). However, there was a difference in terms of their approaches to teach. While in the Turkish context, teacher-centered approach was adopted, German pre-service teachers stayed student-centered one. Lastly, Turkish teachers were not able to use special assessment methods for the topic of evolution.

Applying qualitative methods of research, Bektaş (2015) also carried out a comparative study to examine PCK of pre-service science teachers in varied topics within biology, physics, and chemistry. Physical and chemical changes, reproduction, growth, and evolution, light and sound were selected topics. Open-ended questions were data sources for this study which was conducted with the participation of 33 pre-service science teachers. Descriptive analysis method was employed to analyze the gathered data. The research showed that knowledge of students in the selected topics was enough for some teachers. Ten teachers reported misconceptions among students about light and sound while 17 of them revealed misconceptions about physical and chemical changes. For biology themes, however, the number of teachers reporting misconceptions was seven. It was found that some pre-service teachers lacked adequate knowledge of assessment and instruction methods. Regarding how to identify and then tackle misconceptions, many of the teachers expressed that they benefit from open-ended questions and traditional instruction methods, respectively.

Influenced by Park and Chen's (2012) study, Soysal (2018) performed a research to identify PCK components of an elementary science teacher with nine years of experience as well as to show the inferred relationships the PCK components have. Semi-structured interview method was used to collect qualitative data. The interview with detailed questions was conducted by the researcher at the school where the participant of the study worked. The interview questions were categorized into five groups with 20 primary questions and several related questions. The gathered data was analyzed both qualitatively and quantitatively in order to have a thorough understanding of the participant's PCK. The research revealed that there was a strong and direct interaction among knowledge of curriculum, knowledge of instruction strategies, and knowledge of students. However, restricted level of interaction was identified between knowledge of assessment and orientation to science teaching and the other PCK components.

2.1.2.2. Studies on Science Teachers' PCK for NOS

Considering the literature on learning and teaching science, it is obvious that the most studied and explored concepts are characteristics of the knowledge required in teaching science to elementary and the ways it is developed. Recently, there has been a tendency on a global scale towards incorporating scientific literacy within curriculum. To be able to respond to such changes in curriculum, teachers are expected to have two separate subject matter knowledge. The first one is knowledge of science, and the second is knowledge about science. The difference between these two is that knowledge of science means the information we have as a result of scientific efforts. Knowledge about science, however, can also be worded as "nature of science" (NOS), and it represents the "how" of science, i.e. rules and methods on how we obtain scientific information and it becomes an accepted concept/fact/theme etc. (Shulman, 1986; 1987). Additionally, teachers should also have adequate pedagogical content knowledge to perform well while teaching the mentioned subject matter knowledge. It can be said that supporting teachers in teaching NOS still remains a great source of difficulty in teacher education. Although science education literature presents few studies with teachers who are able to teach NOS adequately, there is still a need for more in-depth research on PCK of teachers in regard to NOS.

Nargund-Joshi, Rogers and Akerson (2011) conducted a study focusing on how teachers' NOS beliefs affect their teaching. With an aim to fill a gap in the PCK literature and to explore teachers' orientation to teaching science in Eastern societies, the researchers selected two Indian secondary teachers. Teachers' orientation was also examined in terms of its adjustment to the educational reform in India. Semi-structured interviews with teachers, in-class observations as well as materials about the educational reform were used as data collection tools. The results of this research revealed teachers' orientations to be not in harmony with their teaching in real life. It was observed that there were discrepancies about the definition of science, the methods to teach science, and the assessment tools/instruments. Interestingly, during their lessons, the participants were not able to show science as being imaginative while they held this belief in theory. For example, laboratory activities which could have provided a space for the students to be creative were employed as a means to verify the theoretical knowledge they learn. While teachers stated the importance of student-centered approach in the interviews, in actual classroom situations they were found to be implementing rather traditional methods (e.g. following the textbook to teach, holding content-intense lessons). In terms of assessment, in the classroom the teachers were expecting to hear right answers although they acknowledged the students' need for sufficient time to fully and correctly comprehend what their teachers explain to them. In the Indian context, teachers' high expectations from students were linked to the importance of exams their students should take. Therefore, the researchers argued that the requirement to prepare students for exams affected teachers and caused a disparity between their ideas about teaching and their practice in real classroom situations. The authors, therefore, concluded that educational reforms should be prepared by considering teacher orientations to teaching; otherwise, success rate aimed through reforms will not be reached. Apart from exams, the study discovered other elements which have an impact on teachers' orientation, such as classroom management, required period of time to assess students' work, teachers' low self-assessment about their subject matter knowledge, and small number of materials for in-class use. In conclusion, the authors proposed that culture- and context-specific elements should be given consideration in studies examining teachers' orientations as they may have an influence on such.

Looking at different factors related to NOS, Wahbeh and Abd-El-Khalick (2014) aimed to explore how a course on NOS affects understanding of in-service secondary school science teachers and retention of such understanding as well as their planning and teaching. The researchers also investigated which elements enable teachers to apply their understanding of NOS in classroom. The 6-week NOS course they took was an explicit-reflective nature applied with the use of learning-as-conceptual-change frame. The course benefited from metacognitive methods as well as written documents about NOS in order to increase the impact. 19 in-service secondary school science teachers were participants of the NOS course. After they were trained, the teachers were asked to prepare their plans to teach NOS. Upon the analysis of data to determine the level of improvement in the concerned area, six teachers were chosen since they showed remarkable improvement. Following the selection of 6 teachers, the researchers observed them while they applied what they planned at the end of the course. In order to analyze the impact of the NOS course, the authors used teachers' instruction plans, in-class observations, interviews, and other materials prepared by teachers as data collection sources. The results of the research showed that the intense and integrated NOS course improved teachers' understanding of NOS and helped them retain that for five months. While planning for their teaching of NOS, they faced difficulties but also succeeded. In teaching phase, their conception of NOS was shaped by their new understanding of NOS, and since it was only applied to science themes, the teachers were restricted in terms of using their new understanding in new contents.

Using Magnusson, Krajcik, and Borko's (1999) framework, Hanuscin et al. (2011) studied the pedagogical content knowledge for three elementary school teachers'

NOS. The teachers were selected from among those who managed to increase the understanding of NOS in students. The data sources used included surveys, interviews, observations during lessons, and documents and materials gathered from the classrooms for three years to determine their PCK. The results demonstrated that teachers possessed solid knowledge of instruction methods to teach NOS. On the other hand, they did not have sufficient knowledge of assessment which would contribute to and facilitate progress in their teaching and knowledge of students. Therefore, the authors pointed to the necessity to focus on professional development that would improve PCK for NOS. For example, teachers may be supplied with appropriate materials to ensure continuous progress in their PCK for NOS in teaching.

Another study in this field was conducted by Faikhamta (2013) to examine NOS understanding and orientation of in-service science teachers. The researcher employed a PCK-based NOS course designed with Hanuscin et al. (2011)'s NOS model which was adapted from Magnusson et al. (1999)'s model. By means of different reflective methods such as mystery cube and collision theories, the course aimed to uncover teachers' understanding of NOS in detail. Covering every PCK components which are students, orientations, instruction methods, curriculum, and assessment, the NOS course was highly comprehensive. The results of the study revealed that about various elements of NOS, the participants had prior knowledge, both informed and uninformed, yet they demonstrated growth in their understandings. The author focused on teachers' orientations with regard to PCK. It was found that project-based learning approach was mostly adopted among teachers prior to the course while this tended to change towards inquiry-based learning methods which encourage the students to be more active in the learning process. This research did not focus on other components of PCK or the relationship among them.

Among the longitudinal studies, again, one of the recent PCK for NOS researches is Bravo and Cofre (2016)'s research which questioned how biology teachers develop PCK in the field of human evolution. Two biology teachers attended a professional development program (PDP) which had components on recent content, joint lesson planning as well as application of planning. Upon completion of the course, the participants applied their planned lessons during which they were video-recorded. These records were then used to determine teachers' methods, classroom activities, and students' difficulties and misconceptions on evolution. The data collection was achieved through pre-interviews to learn about the participants' prior content representation, a group interview following their lessons, and individual stimulated recall interviews to help them reflect on their own teaching (final content representation). The collected data was analyzed by not only the authors but also the teachers with an aim to give them an opportunity to reflect on changes if any and the underlying causes for their instruction strategies and methods. The analysis revealed change in teachers' knowledge as well as beliefs about the methods to employ while teaching evolution and about their students' challenges and needs in the said topic. Teachers stated that reflecting on their teaching practice contributes to development and growth in their PCK. Results also showed that both teachers demonstrated a poor understanding of the NOS and of evolution at the beginning of the PDP. However, at the end of the first part of the PDP (at the university), both teachers reached a very good level of knowledge regarding evolution, as well as the NOS, which was determined by valid and reliable instruments.

In the Turkish context, PCK for NOS is one of the important research areas of interest for educators although the number of researches is limited. Demirdöğen, Hanuscin, Uzuntiryaki-Kondakci and Köseoğlu (2016) 's study, for example, aimed to investigate the complex nature of early development of orientations, knowledge of instructional strategies, knowledge of students, and knowledge of assessment. The participants of the study were 30 pre-service chemistry teachers who registered in a Research in Science Education course which was intended to improve their PCK for NOS. Data collection methods included open-ended surveys, classroom observations, and materials prepared by teachers (e.g. lesson plans) in addition to interviews. The data was examined with the use of in-depth analysis of explicit PCK together with constant comparative method. Upon analysis of the data, it was found that sufficient understanding and beliefs are required in order to teach NOS. Secondly, the NOS course provided a developmental progress in PCK for NOS and this was observed in their application of the newly acquired knowledge during their lessons. Thirdly, the majority of teachers did not include in their lessons the NOS aspects about which they did not have sufficient knowledge. This result indicated that teachers should feel confident in their understanding of NOS so that they can better teach NOS. Lastly, teachers with well-integrated PCK for NOS hold more successful lessons to teach NOS.

Similarly, Demirdöğen (2016) conducted a PCK for NOS study to explore the interaction between teaching orientations and PCK components through deductive approach. The participants of the study were eight pre-service science teachers. Semi-structured interviews, open-ended survey, and content representation were used to collect data for the study. Regarding the interaction between teaching orientations and PCK components, the study showed that the underlying purpose behind teaching science imposes the components of PCK with which it interacts. It was also discovered that there is no direct interaction between beliefs of teacher (about NOS) and the components of PCK on the condition that such beliefs are not linked to the purposes for teaching science. Lastly, the author detected an interaction among teacher's beliefs about teaching and learning science and knowledge of instruction methods.

Bilican, Tekkaya & Çakıroğlu (2012) conducted a study on PCK only for planning to teach NOS. The research participants were three pre-service science teachers who, within the scope of the research, received an NOS course. Upon completion of the course, the participants were requested to prepare a lesson plan to teach NOS by applying their newly acquired understanding of NOS. The results of the study exposed their continuing inability to explicitly include NOS in their lesson plan and to find suitable assessment methods to evaluate their students' understanding of NOS. In conclusion, the authors suggested that student assessment methods for NOS and different ways to integrate NOS while teaching science should be among the objectives of attempts to support the improvement of PCK among pre-service science teachers.

2.1.2.3. Studies on Science Teachers' PCK for SD

Education for Sustainable Development (ESD) is recently introduced to the world of education as a new area. With its own content, ESD necessitates a holistic approach and reforms in educational structures. Not only novice teachers but also experienced ones face difficulties while teaching in that field. Teachers who will implement ESD should be trained on concepts of sustainable development. They also should be able to comprehend the links and relations between ESD and systemic thinking, values education, and interdisciplinary approach. Teacher education in ESD should enable teachers to incorporate ESD in their teaching, and it should adopt teaching strategies in harmony with ESD methods. In light of these requirements, this section summarizes studies on science teachers' PCK for SD and ESD.

Firstly, Birdsall (2015) examined the application of teachers' understanding of sustainability to pedagogy and its impacts on students' learning in her dissertation. Two teachers participated in the study; and interviews with teachers as well as documents were used to collect data. For the analysis of data, the author benefited from two frameworks: 1) description of sustainability and 2) pedagogical context knowledge (PCxK) with four components. The results revealed an intricate interaction among three PCxK components and little involvement of the fourth when application of sustainability was considered. It was discovered that some students understood sustainability although only two of them managed to associate their understanding with the scientific ideas. Lastly, the author argued that although the PCxK model demonstrated a certain level of accuracy, further studies should be conducted in order to have more reliable data on its ability to elucidate PCK of teachers.

"Systems thinking" has gained significance in both ESD and daily life. Therefore, teachers should know about systems and their behavior (content knowledge) in order to efficiently demonstrate a topic to their students. In other words, knowing, for example, diffusion and osmosis in biology may not be enough for effective teaching. Teachers should also recognize the strategies to promote systems thinking in students. However, currently there is not sufficient data on the development of professional knowledge when it comes to teaching systems thinking. Rosenkränzer, Hörsch, Schuler and Riess (2017) conducted a study to examine teaching systems thinking. The participants of the study were student teachers. The researchers focused the impact of three types of courses (technical, didactic and mixed course) on the PCK for teaching systems thinking. It was found out that teacher education can be used to promote PCK for teaching systems thinking. The results also showed that technical courses on their own are not efficient enough in promoting PCK for teaching systems thinking. The findings of this study can be considered to improve teacher education in terms of promoting systems thinking

Another study aiming to respond to the need for professional development in ESD was conducted by Kadji-Beltran, Zachariou, Liarakou and Flogaitis (2014). The researchers implemented a mentoring program for both experienced and novice teachers through which they received support in planning and implementing ESD. The study also intended to examine the possibility of introducing mentoring as a means to train them for ESD. The results of the study demonstrated that mentoring is significant in training teacher for ESD because it basically consists of all necessary aspects of ESD both experientially and practically. It was also worth noting that it increased interaction among teachers and enabled them to start groups to learn about ESD together. Lastly, mentoring helped teachers improve their PCK for ESD.

CHAPTER 3

RESEARCH METHODOLOGY

The main purpose of the study is to investigate experienced science teachers' subject matter knowledge and pedagogical content knowledge in the topic of biogeochemical cycles regarding education for sustainable development. In order to reader to understand how the researcher addressed the research questions, this chapter discussed the methodology employed in this study. Thus, the following research questions were put forward to guide the study:

1. What is the science teachers' subject matter knowledge for teaching biogeochemical cycles in the context of sustainable development?
   1.1. What is the science teachers' substantive knowledge regarding biogeochemical cycles?
   1.2. What is the science teachers' syntactic knowledge regarding nature of science?
   1.3. What are the science teachers' understanding of SD regarding biogeochemical cycles?
2. What is the science teachers' pedagogical content knowledge for teaching biogeochemical cycles?
   2.1. What are the science teachers' orientations to teaching science?
   2.2. What is the science teachers' knowledge of curriculum for teaching biogeochemical cycles?
   2.3. What is the science teachers' knowledge of instructional strategies for teaching biogeochemical cycles?
   2.4. What is the science teachers' knowledge of students for teaching biogeochemical cycles?
   2.5. What is the science teachers' knowledge of assessment for teaching biogeochemical cycles?

In the next section of the chapter, the researcher would like to explain the interpretive research paradigm considering the focus of the study. Then, this was followed by the section on the qualitative research approach implemented to support methodological perspective and findings of the study. The rest of the chapter addressed the research design, the sampling and participants, data collection tools, and data analysis. Finally, the chapter represented how the trustworthiness and ethical considerations of the current study were addressed.

3.1. Interpretive Research Paradigm

Researchers have different views of what constitutes the truth and knowledge (Denzin & Lincoln, 2008). These views guide the researchers' thinking, beliefs, or assumptions about society involved (Lincoln & Guba, 1990). They frame how the researchers understand the world and influence the researchers' approaches to do research but there is a set of beliefs to guide these views named as research paradigm (Creswell, 2009). Thomas Kuhn (1962) used the term paradigm firstly to denote a conceptual framework shared by a community of scientists. Kuhn defines the paradigm as a research culture with a set of beliefs, values, and assumptions that researchers make a consensus as far as the nature and conduct of research concerned (Kuhn, 1962). A paradigm is as a way of describing a world view that is informed by philosophical assumptions about the nature of social reality, the ways of knowing, and ethics and value systems. It thus leads researcher to ask certain questions and use appropriate approaches to systematic inquiry (Patton, 2002).

Researchers become interested in different theoretical research paradigms based upon their own philosophical assumptions. Therefore, these research paradigms have differences in the assumptions of reality and knowledge which provide a basis for their particular research approach (Scotland, 2012). Knowledge and reality are constructed in and out of interaction between humans, and developed in a social and cultural context (Crotty, 1989). Interpretive research paradigm approaches the reality from subjects, typically from people who own their experiences, views and backgrounds. It aims to understand the phenomenon from an individual's perspective; investigating interactive relations among individuals in their natural settings (Creswell, 2009). This means that the interpretive paradigm emphasizes on the process of understanding the situation in which the research is done (Connole, 1998).

The researcher would like to understand and interpret experienced teachers' subject matter knowledge and pedagogical knowledge in the context of EfSD. Because the focus of the study was to examine teachers' understanding, views and experiences in their natural teaching settings, an interpretive research paradigm has been adopted.

3.2. Qualitative Research Approach

Willis (2007) asserts that researchers using interpretive paradigm tend to favor qualitative research approach (Thomas, 2003, p.6). He emphasized that qualitative methods often give rich information that are necessary for interpretivist researchers to fully understand the context. In this point of view, there is a tight connection between interpretive paradigm and qualitative approach. Researchers using interpretive paradigm and qualitative approach often seek experiences, understandings and perceptions of individuals for their data to uncover reality rather than rely on numbers of statistics. Following the above points, Creswell (2009) states that "qualitative research is a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (p.4). Hence, in educational research, if researcher seeks understandings and experiences of a group of students or teachers, qualitative methods are likely to be the best-suited methods (Patton, 2002; Tahnh & Tahnh, 2015). In the light of this view, qualitative research approaches were used in order to obtain intensive and detailed description of experienced teachers' SMK and PCK on the topic of biogeochemical cycles for the current study. To gather in-depth information about the teachers, the various qualitative data collection methods (interviews, video-recording/observations, documents) and data analysis strategies (inductive and deductive analysis) were implemented.

3.3. Case Study Design

One of the most widespread used designs in qualitative research is case studies (Flick, 1996). Taylor, Sinha and Ghoshal (2006) present case studies as common and attractive methods of qualitative research. Case study is important context for in-depth description and analysis of what is being studied (Merriam, 2009). Yin (2003) also defines case study as an empirical study that explores a contemporary phenomenon within its natural settings. As the name suggests, case study is the investigation of a case; it can be an individual person, a group or organizations that are studied in their context (Robson, 2007). The purpose is to generate in-depth, detailed and intensive description and knowledge of well-defined phenomenon or context (Burton, Brundrett & Jones, 2014; Taylor, Sinha & Ghoshal, 2006).

In this study, multiple case studies design was chosen considering the purpose and nature of the research questions being addressed. The cases of this study were experienced science teachers from different schools. Basically, the researcher is interested in the nature of the subject matter knowledge and pedagogical content knowledge of experienced science teachers. Thus, how participant science teachers generate their pedagogical content knowledge during their experienced years directed the researcher to focus on the case for experienced science teachers. As a result, three experienced science teachers were the three cases of the current study. Moreover, their subject matter knowledge and pedagogical content knowledge were two units of analysis in the study. Figure 3.1 summarizes methodology and the data collection procedures of the current study.

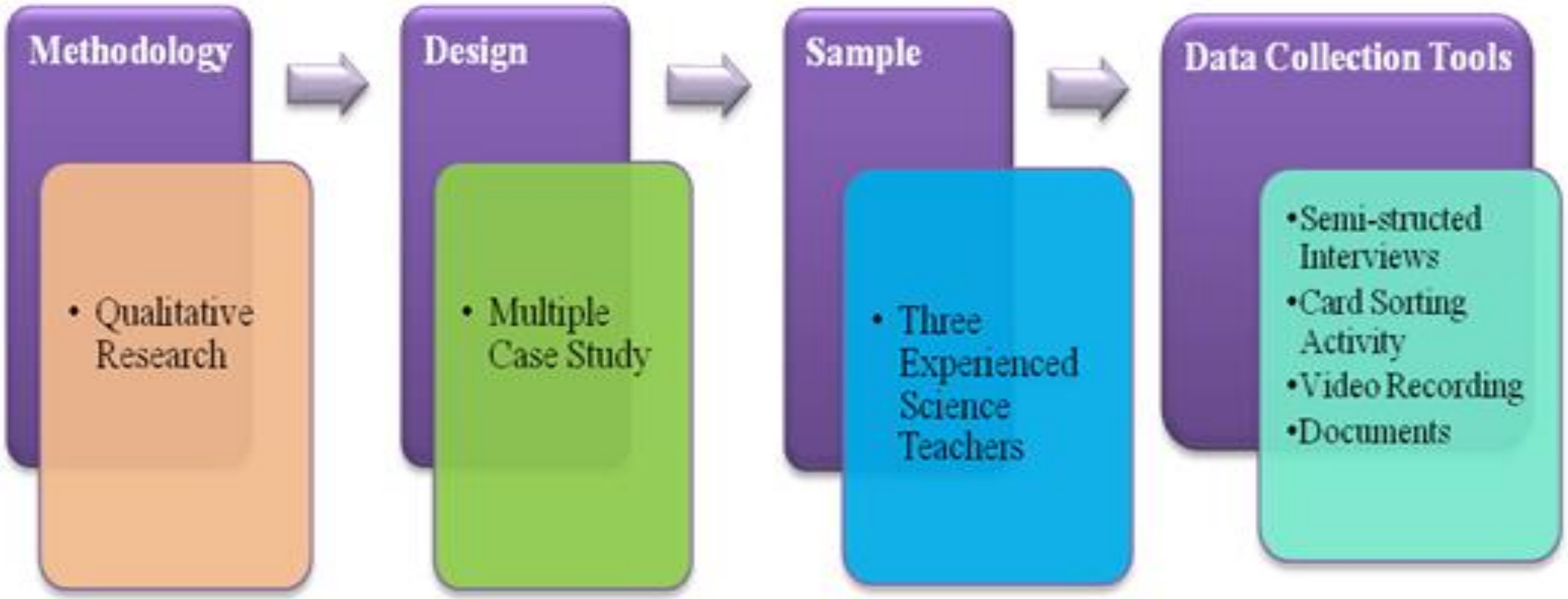

Figure 3.1. The Procedure of The Study

3.4. Data Collection Procedures

This section included detailed information about sampling, participants and data collection tools of the current study. Furthermore, the analysis procedures of the data which had been collected during spring semester in 2013-2014 academic year were presented in depth.

3.4.1. Sampling of the Study

A qualitative study does not aim to generalization similar to a quantitative study (Merriam, 2009). Thus, rather than using the quantitative approach, selecting a sample from a large group of in-service teachers, purposive sampling was selected. The selection of the information-rich cases is the most important aspect of purposive sampling. The aim of the study was to get detailed information about experienced science teachers' SMK and PCK, therefore teachers who had a potential to provide rich data were selected (Patton, 2002). Thus, the important task is to determine the selection criteria for the interest of the study (Merriam, 2009). In the following, criteria to select the participant of the current study were presented with their reasons.

- First of all, eco-schools were selected to conduct this study as science teachers' SMK and PCK regarding biogeochemical cycles in the context of SD. The concept of SD had not been integrated into the science curriculum implemented in 2013-2014 academic year when the data collected, so this study was conducted in middle schools where the Eco-Schools program were applied. As Eco-schools program offers a guiding program that aims to provide environmental education, environmental management and sustainable development education in preschool and primary and middle schools, it is expected that the science teachers in these schools have higher knowledge and awareness of SD than the ones in non-eco schools. To be able to select the participants which more detailed data can be collected, the researcher joined the annual meeting of Eco-schools program performed by TURCEV (Turkish Environmental Education Foundation). Thus, the researcher had a chance to specify science teachers who were willingness to participate to the study. Among the science teachers the researcher specified, three teachers whose weekly schedules were appropriate for the classroom observations were selected.

- Secondly, the context in which the participants worked was the another criterion. Literature including the studies of PCK emphasized that teachers working in the same or similar context should be selected due to the fact that the context influences how teachers teach (Berliner, 2001; Henze et al., 2008; Loughran et al., 2008; Park & Oliver 2008). For this reason, three teachers from the three public middle schools having similar contexts in Cankaya Province were picked as participants to eliminate the context's manipulation on teachers' practice. Additionally, as private schools did not give permission to record the classroom settings with the video-taped, the researcher were lead to conduct the study with public schools because of the missing important points of the teaching in the real classroom environment. Hence, selected public schools had similar context participating the Eco-schools program with the 30-40 students in each classroom.
- The third criterion was being experienced teachers. Because, PCK develops with experience (Abell, 2008) and teaching experience in real classroom context is one of the vital sources for PCK development (Grossman, 1990). Because of this, experienced science teachers' were selected to conduct this study.
- Having all of the other criteria did not guarantee of being the participant of the current study. The last criterion was the place of the selected topic in the Science Curriculum (MoNE, 2005), recently known as Science Curriculum. The topic of biogeochemical cycles is placed in 8th-grade level in the curriculum. Thus, in-service science teachers who taught at the 8th-grade level were selected to obtain in-depth information for the current research.

In addition to the selection of the information-rich cases, the researcher make decisions on some issues such as location, time, topic, money, respondents regarding the participants (Marshall & Roseman, 2016). In this manner, the researcher preferred to use the convenient sampling. When compared with other types of purposive sampling, convenient sampling may cause to getting poorer information from the phenomena studied. Nevertheless, the researcher was forced to use this sampling technique due to the number of the criteria and the unwillingness attitudes of the teachers in the schools.

3.4.2. Participants of the Study

In light of the criteria predetermined, four experienced science teachers were selected at first. However one of participating teachers dropped out during the study because of the administrative reasons. Ultimately, three experienced science teachers, having at least 5-year or more teaching experience, participated to the current study. The participant teachers have different characteristics; therefore, these differences gave opportunity to clarify the patterns for the cases of the study, separately. The researcher used pseudonym for the participant teachers as Kemal for Participant 1, Hale for Participant 2 and Selda for Participant 3. Some demographic information about the participants was summarized in Table 3.1.

Table 3.1. Participant Teachers' Demographic Information

Participant	**Teaching Experience**	**Graduation**	**Bachelor's Degree**	**Master/PhD Degree**
Kemal	38 Years	Education Institute Arts and Science Faculty	Science Teacher Physics	-
Hale	26 years	Arts and Science Faculty	Biology	Master & PhD in Molecular Biology
Selda	21 years	Arts and Science Faculty	Biology	-

3.4.3. Data Collection Tools

In qualitative studies, interviews, documents and observations were three basic data collection tools in order to offer the detailed description of the phenomena studied (Merriam, 2009). Taking into consideration this notion, the researcher used interviews, card-sorting activity, video recording and observations and documents as multiple source of information to get insight about participant teachers' SMK and PCK components in the current study. Table 3.2 presented the data collection tools and related SMK and PCK components in detail.

Table 3.2. Data Collection Tools

Data Collection Tools	**SMK and PCK Components**
Interviews Questions on Biogeochemical Cycles Embedded VNOS-C Questionnaire Content Representation (CoRe)	 Substantive Knowledge & SD Understanding Syntactic Knowledge Knowledge of Curriculum Knowledge of Instructional Strategies Knowledge of Students Knowledge of Assessment
Card-sorting Activity	Orientations to Science Teaching
Video Recording / Classroom Observation	Knowledge of Curriculum Knowledge of Instructional Strategies Knowledge of Students Knowledge of Assessment
Documents Teachers' Drawings Teachers' Exam Papers	 Substantive Knowledge Knowledge of Assessment

3.4.3.1. Interviews

Patton (2002) stated that interviews are valuable information about the participants' point of view that is not observable to the researcher. For the case studies, interview is the best technique (Merriam 2009) and serves as a vital source of information (Yin,

2003) to get detailed understanding of the phenomena studied. Based on the nature of the research, the researcher needs ask additional important questions different from the prepared ones to get specific answers from participants during the interviews. In such a time, semi-structured interviews are invaluable data collection tools to enable participants to reflect their ideas. In the light of these, both semi-structured and structured interviews are used as the primary data sources to gather participant teachers' content knowledge and pedagogical content knowledge in the current study. All interviews were audio-taped with the permission of the participants.

3.4.3.1.1. Questions on Biogeochemical Cycles

The researcher based on the 8th grade objectives of Science Curriculum stated in 2005 and the science textbook approved by Ministry of National Education in 2014 prepared seven semi-structured interview questions to unveil both teachers' substantive knowledge and SD understanding on biogeochemical cycles (See Appendix A). The first three questions are used to obtain detail information about the teachers' conceptual knowledge on biogeochemical cycles. In addition, the researcher expected participating teachers to draw the figure of each matter cycle to gather detailed information about their conceptual knowledge. Moreover, last four questions are prepared to grasp in depth information on how participated teachers connect the SD issues and biogeochemical cycles. Each interview was conducted to participant teachers at their available times in the schools in one meeting and spanned around 45 minutes.

Table 3.3. The Details of Interview Questions on Biogeochemical Cycles

Data Source	Purpose	Time / Length
Questions on biogeochemical cycles	To get detailed information about participant teachers' conceptual and SD understanding	Two weeks before the teaching / About 45 minutes

3.4.3.1.2. Embedded Views of Nature of Science Questionnaire

Participant teachers' understanding on nature of science was corresponded to their syntactic knowledge entitled SMK. In order to determine participant teachers' NOS views, revised Views of Nature of Science Questionnaire, form C (VNOS-C) was conducted in conjunction with semi-structured interviews (Table 3.4). Lederman, Abd-El-Khalick, Bell, and Schwartz (2002) developed the original version of questionnaire that is translated and adapted in Turkish by Doğan, Çakıroğlu, Çavuş, Bilican, and Arslan (2011).

Table 3.4. The Details of the Embedded VNOS-C Questionnaire

Data Source	**Purpose**	**Time & Length**
Embedded VNOS-C Questionnaire	To gather comprehensive information about participant teachers' syntactic knowledge	At the beginning of the study & About 40 minutes

In the VNOS-C questionnaire, ten open-ended questions were conducted to get participants views on NOS aspects. namely empirical nature of science, subjective nature of science, tentative nature of science, role of creativity and imagination in nature of science, inferential nature of science, socio-cultural embeddedness of scientific knowledge, and the function of laws and theories. These questions of the questionnaire were modified by adapting to the topic studied in order to give participants teachers an opportunity to express their ideas easily. The VNOS-C questionnaire previously used and validated in lots of research was utilized in current study and provided in Appendix B. The instrument was administered to participant teachers in one meeting at their available times in schools and lasted approximately in 40 minutes. The participant teachers' voice was recorded.

3.4.3.1.3. Content Representation (CoRe)

Loughran et al. (2004) devised Content Representations (CoRes) to make the links between the experts' knowledge of content, teaching and learning about a particular topic more explicit to others. CoRe was handled for getting understanding how teachers constructed the topic that was taught (Loughran, Berry, & Mulhall, 2006). It is an important data collection tool in order to portray holistic overviews of expert teachers' topic-specific nature of PCK (Loughran et al. 2006, Rollnick et al., 2008).

One of the most important difficulties in PCK studies was the terminology in this field might not be understood by teachers (Aydin, 2012). Due to this reason, Loughran et al., (2004) and Aydin (2012) suggested to use an understandable language in studying with CoRes. Additionally, Aydin and Boz (2012) asserted that all the major components of PCK are related to the themes of CoRe. Therefore, the researcher conducted CoRe, whose original format was a table, as an interview tool that she can get a clear understanding of the participant teachers' PCK on the topic of biogeochemical cycles (See Appendix D). Some additional sub-questions allied to the main questions were used to get deeply information. The CoRe interview were conducted to the teachers at their available times in the schools in one meeting and spanned around 50 minutes. The voices of the participants were recorded during the CoRe interview.

Table 3.5. The Details of the Content Representation (CoRe) Interview

Data Source	**Purpose**	**Time & Length**
CoRe Interview	To get detailed information about participant teachers' PCK components on the topic of biogeochemical cycles	One week before the teaching of the topic & About 50 minutes

3.4.3.2. Card-Sorting Activity

In the current study, the researcher has adopted the PCK model developed by Magnusson et al., (1999). However, Friedrichsen and Dana (2005) and Friedrichsen et al. (2011) stated that Magnusson and her colleagues did not approached to teachers' orientations to science teaching in detail. Herewith, in the process of the forming the card-sorting activity, the researcher considered the realities of the Turkish educational system, Science and Technology curriculum, and the literature related to teachers' orientations. As Aydin (2012) emphasized, the realities of the educational system and the curriculum has an important influence on orientations to teaching science. In Turkey, High School Entrance Exam (TEOG) was given extremely importance by both teachers and students. In the light of such considerations three scenarios were added to take these realities into account. Furthermore, one ESD orientation was written considering that the study was intended to explore teachers' SMK and PCK in the context of ESD. Friedrichsen et al. (2005) also discussed that teachers may have more than one orientation which their goals for science teaching are incompatible. Thus, they emphasized that the science teaching orientations mainly formed by the basis on teachers' beliefs about the goals and purposes of teaching science. Lastly, based on the emphasis on the teachers' beliefs about goals of teaching science (Friedrichsen & Dana, 2005; Volkmann et al., 2005) and the ESD context of the study, the additional questions were asked during the card sorting activity. Thereby, the card sorting activity was got through the thirteen scenarios and six questions in total.

In the card-sorting activity (Friedrichsen & Dana, 2003; 2005), cards including scenarios were utilized to determine participant teachers' orientations and goals for teaching science at 8th grade level in middle schools. In the activity, participants teachers were expected to sort the cards into three groups: first group including cards that are parallel to their teaching, second group including cards that are different from their teaching and third group including cards that teachers are unsure to teach in that way. Afterwards, teachers requested to clarify the common characteristics of the selected cards in the groups and to explain the main similarities and differences between the scenarios and their teaching. Then, the researcher asked in what ways the scenarios and their goals and purposes for teaching science were related. Card-sorting activity was implemented to participant teachers at their available times in the schools. The instrument was conducted in two meetings and spanned around 90 minutes in total. All scenarios and questions were provided in Appendix C with the versions of Turkish. All of the process of the card-sorting activity was audio-taped with the permission of the participants.

Table 3.6. The Details of the Card-Sorting Activity

Data Source	**Purpose**	**Time & Length**
Card-Sorting Activity	To collect in-depth information about participant teachers' orientations to teaching science	At the beginning of the study & About 60 minutes

3.4.3.3. Video Recording

Video-recording involves the collection of 'naturally occurring data' using video cameras (Goldman & McDermott, 2009; Knoblauch, Schnettler, Raab & Soeffner, 2006). Naturally occurring data includes the ongoing interaction of people in a specific context and all aspects of the environment that structure the interactions recorded (Jewitt, 2012). In this study, video-recording was used to obtain naturally occurring data to understand how participant teachers transform their subject matter knowledge to PCK for teaching the biogeochemical cycles. In their real classroom settings, the progress of teachers' teaching was recorded at the back desk of the class. Researcher's position is important during video-recording procedures (Merriam, 2009). Researcher did not interfere with any activity, and only recorded the environment of the class and how teacher performed his/her teaching about the topic of biogeochemical cycles. Video-records lasted in eleven course hours in total. While Kemal's and Hale's teachings lasted in four hours, Selda thought the topic in three hours. All records were transcribed verbatim in order to analyze in detail.

An essential advantage of videotaping is that most potentially useful interaction and behavior can be captured (Patton, 2002). The advantage in terms of the credibility is that the researcher is able to review the same situations again and again. Videotaped materials are rich and provide several possibilities for analyzing the data. In the studies that this method was used, data triangulation enabled the researchers to reduce personal influence on the results (Merriam, 2009).

Table 3.7. The Details of Video-Recording

Data Source	Purpose	Time & Length
Video Recording/ Classroom Observation	To collect comprehensive information about participant teachers' PCK components on the topic of biogeochemical cycles	8th grade class hours from the beginning to the end of the topic

3.4.3.4. Documents

Documents refer to a wide range of written, visual, digital, and physical material relevant to study. Researchers categorize documents in different ways. The two common types of documents used in qualitative research are public and personal documents (Merriam, 2009). Bogdan and Biklen (2007) refer the popular culture document as a third type. There are visual documents which include films, videos, and photography as fourth type. Moreover, documents can be generated by the researcher for the purpose of the investigation (Merriam, 2009). In this study, personal documents and researcher-generated documents were used to obtain in-depth information about experienced teachers' SMK and PCK components in the context of ESD.

3.4.3.4.1. Personal Documents

Bogdan and Biklen (2007) define personal documents as first-person narratives that describe an individual's actions, experiences, and beliefs. Such documents help to researcher to understand the inner meaning of the participant's personal perspective (Merriam, 2009). In order to gather rich data about teachers' knowledge of assessment, teachers' exam papers were used as personal documents in this study. These documents were shared to the researcher during the data collection process.

3.4.3.4.2. Researcher-Generated Documents

When documents are used in a study, they are referred as public records, personal documents or visual/physical material already present in the research setting. These documents are existing and ready-made source of data because they have not been produced for the research purpose (Merriam, 2009). On the other hand, researcher - generated documents were prepared based on the research purpose. This type of documents is prepared by the researcher or for the researcher by participants after the study has begun. The specific purpose of research-generated document is to grasp more information about the situation, person, or event being investigated. In this study, science teachers' drawingss were used as research-generated documents. These drawings were used to obtain more information about the teachers' substantive knowledge on biogeochemical cycles. Participant teachers requested to explain their understanding on each cycle through drawing. Teachers were not interfered with the researcher while they were drawing. In results chapter, based on teachers' orijinal drawings (See in Appendix E), the researcher redrawn the drawings of teachers to ease them become clear. Also the researcher used English versions of the Turkish terms in the participants' drawings to be understandable for the reader whose native language is not Turkish.

3.5. Data Analysis

In qualitative studies, the data analysis provides an intensive and holistic description of the data (Merriam, 1998; Yin, 2009). In data analysis process, researcher tries to understand what the data tell (Bogdan & Biklen, 2007; Merriam, 2009). In addition to the interpretation of the findings, the researcher makes sense of the data through both data analysis and data collection processes. In qualitative research, the data collection and data analysis are inseparable procedures (Bogdan & Biklen, 2007; Merriam, 2009). During the data collection of the present study, the researcher got insights how the teachers use PCK components and had an idea about how to analyze the collected data. The obtained data in this study was analyzed according to the nature of the data and the aim of the data collection tools. In the following parts, the details of the data analysis for the teachers' SMK and PCK were explained.

3.5.1. Data Analysis of Subject Matter Knowledge

In this study, Shulman's view of SMK was used to explain the teachers' content knowledge on the topic of biogeochemical cycles. This view of Shulman was derived from the study of Schwab (1964) and consisted of two types of SMK: substantive and syntactic (Abell, 2007). Specifically for this study, the researcher also wondered the participant teachers' SD understanding regarding biogeochemical cycles. Therefore, the teachers' SMK and PCK were explained in the context of SD. In the following titles, the data analysis procedures of participants' subject matter knowledge regarding biogeochemical cycles as substantive, syntactic and SD understanding are specified respectively.

3.5.1.1. Substantive Knowledge

The organization of concepts, facts, principles, and theories of a discipline is defined as the substantive content knowledge (Abell, 2007, p.1107). In this study, substantive knowledge refers to participant teachers' conceptual understanding (basic concepts & processes) related to biogeochemical cycles.

The teachers' substantive knowledge of biogeochemical cycles was investigated with the help of the three open-ended interview questions. In parallel with these questions, teachers were requested to explain the each cycle through drawings. Both the interviews, drawings and classroom observations were used to understand participant teachers' substantive knowledge related to the components and processes within the biogeochemical cycles. To analyze the participants' responses to the questions, the researcher prepared a rubric consisted of the scientific definitions of the concepts and processes of the biogeochemical cycles (Table 3.8).

Table 3.8. The Scientific Explanations of the Processes in the Biogeochemical Cycles

Concept	Definition/Explanation	Reference
Matter Cycle	The sun supplies ecosystems with a continual influx of energy. Matter, the material of which living things are composed, cycles from living world to the abiotic environment & back again. Biogeochemical cycles include biotic components, abiotic components, and abiotic reservoirs, where chemicals accumulate or are stockpiled outside of living organisms. Chemicals are cycled between abiotic reservoirs and communities. Biogeochemical cycles are important to organisms because they involve materials used to make the chemical components of cells. The chemical materials that organisms use cannot be lost; they are reused and often recycled both within and among ecosystems. Natural cycles, therefore, balance and regulate Earth and its atmosphere.	Audesirk, Audesirk, & Byers (2014) Enger, Ross, Bailey (2012) Reece, Taylor, Simon, Dickey, & Hogan (2015) Sadava, Heller, Orians, Purves, & Hillis (2011) Solomon, Berg, & Martin (2008)

Table 3.8 (Continued)

Concept	Definition/Explanation	Reference
Carbon Cycle	All living things are made of carbon. Carbon, the major ingredient of all organic molecules. Carbon atoms form the framework of all essential organic molecules such as proteins, nucleic acids, lipids, and carbohydrates. It has an atmospheric reservoir and cycles globally. Carbon found as biomass in land plants. Carbon also resides in fossil fuels and sedimentary rocks, such as limestone ($CaCO_3$), and as dissolved carbon compounds in the oceans. The processes of photosynthesis and cellular respiration are mainly responsible for the cycling of carbon between the biotic and abiotic worlds. 1) During photosynthesis, producers (plants, algae, and cyanobacteria) remove CO_2 from the atmosphere and incorporate it into complex organic molecules. 2) These organic compounds of producers passed along the food chain by consumers. 3) And these compounds are used as fuel for cellular respiration by producers, by consumers or by decomposers. The process of cellular respiration returns CO_2 to the atmosphere. 4) Decomposers break down the carbon compounds in dead organisms (detritus); that carbon is eventually released as CO_2. 5) The process of burning or combustion may return the carbon in coal, oil, natural gas and wood to the atmosphere. In combustion, organic molecules are oxidized and converted to CO_2 and water. The increased burning of fossil fuels by humans raises the level of CO_2 in the atmosphere (large amount of C is stored in wood of tree)	Audesirk, Audesirk, & Byers (2014) Enger, Ross, Bailey (2012) Reece, Taylor, Simon, Dickey, & Hogan (2015) Solomon, Berg, & Martin (2008)

Table 3.8 (Continued)

Concept	Definition/Explanation	Reference
Hydrologic Cycle	Water cycle is a complex system having dynamic relationships that exist between the earth's spheres (biosphere, geosphere, atmosphere, & hydrosphere systems) on the globe. It is powered by energy from the sun and gravity. The major water reservoirs are the oceans. Alternatively water may flow in rivers and streams to coastal runoff. Water molecules are the most common molecules in living things. Because all the metabolic reactions take place in a watery environment, within cells or body parts, water is essential to life. Climatic factors (solar radiation, temperature, wind, humidity, atmospheric pressure, cold & warm ocean current) influence the each process of water cycle. 1) Water evaporates from the oceans' surface, streams, lakes, rivers and from soil (Evaporation). 2) Transpiration, the loss of water vapor from land plants, adds a considerable amount of water vapor to the atmosphere (Transpiration) 3) Water vapors eventually condense and form clouds in the atmosphere (Condensation). 4) Water moves from the atmosphere to the land and ocean in the form of rain, snow, hail, or sleet (Precipitation). 5) Precipitation that flows overland to surface streams, rivers, lakes and oceans where it evaporates and back into the atmosphere (Surface Flows). 6) Water also percolates downward in the soil to become groundwater (Penetration).	Enger, Ross, Bailey (2012) Sadava, Heller, Orians, Purves, & Hillis (2011) Solomon, Berg, & Martin (2008)

Table 3.8 (Continued)

Concept	Definition/Explanation	Reference
Nitrogen Cycle	Nitrogen is essential to the formation of proteins, ATP, nucleic acids, DNA and RNA. It is crucial and often limiting plant nutrient. Nitrogen has two abiotic reservoirs: the atmosphere, and the soil. The atmosphere contains about 78%-80% nitrogen gas (N_2), but plants and most other producers cannot absorb nitrogen in this form. They require either ammonia or nitrate. 1) The first step in the nitrogen cycle, nitrogen fixation, a few types of bacteria, called nitrogen-fixing bacteria (free-living bacteria in soil and cyanobacteria in water) converts N_2 into ammonia (NH_3) which dissolves rapidly in water to produce ammonium NH_4. Legumes such as alfalfa, soybeans, clover and peas release excess ammonia produced by the bacteria (Rhizobium) on their roots (Nitrogen Fixation). 2) The second step of the nitrogen cycle is the conversion of ammonia (NH_3) or ammonium (NH_4^+) to nitrate (NO_3^-). Soil bacteria are responsible for this process (Nitrification). 3) Ammonia, ammonium or nitrate are absorbed by producers and incorporated into biological molecules such as proteins, nucleic acids and chlorophyll. When herbivores consume plant tissues, they assimilate nitrogen by taking in plant nitrogen compounds and converting them to animal nitrogen compounds (N-Assimilation).	Audesirk, Audesirk, & Byers (2014) Reece, Taylor, Simon, Dickey, & Hogan (2015) Solomon, Berg, & Martin (2008)

Table 3.8 (Continued)

Concept	Definition/Explanation	Reference
Nitrogen Cycle	4) The fourth step is the conversion of organic compounds into ammonia and ammonium ions. Nitrogen-containing wastes such as urea in urine and uric acid, and nitrogen compounds in dead organisms are converted to ammonia by decomposers. Most available nitrogen in the soil derives from the recycling organic nitrogen (Decomposition). 5) The last step is the reduction of nitrate to nitrogen gas. Denitrifying bacteria in wet soil, swamps and estuaries strip the oxygens from NO_3^- and release N_2 back into the atmosphere (Denitrification). 6) Also, during electrical storms, the energy of lightning combines nitrogen and oxygen gases to form nitrogen oxide compounds. These nitrogen oxides fall to the ground dissolved in rain and converted to nitrate.	Audesirk, Audesirk, & Byers (2014) Reece, Taylor, Simon, Dickey, & Hogan (2015) Solomon, Berg, & Martin (2008)

Table 3.9. The Components and Processes within the Biogeochemical Cycles

Cycle	Components of cycle		Processes in the cycle
	Abiotic Components	Biotic Components	
Carbon	Sun Carbon Reservoirs Soil Water	Producers Consumers Decomposers	• Generate organic carbon (Photosynthesis), • Transform organic carbon (biosynthesis, digestion, food webs, carbon sequestration), • Oxidize organic carbon (Cellular respiration, Combustion) • Decomposition • Aquatic carbon cycle
Hydrological	Sun Gravity Water Reservoirs (Oceans, Lakes, Glaciers, Underground Waters) Soil Climatic factors	Producers Consumers	• Evaporation • Transpiration • Condensation • Precipitation • Infiltration (Penetration) • Surface Flows
Nitrogen	Sun Nitrogen Reservoirs Soil Water	Producers Consumers Decomposers Nitrogen-fixing bacteria Nitrifiers and Denitrifiers Cynobacteria in aquatic systems	• Nitrogen fixation • Nitrification • Denitrification • N-assimilation • Lightning

Using the related literature, the researcher also prepared an overall rubric presented in Table 3.9 including all components and processes within the biogeochemical cycles. The rubrics enabled to categorize the participant teachers' substantive understanding on biogeochemical cycles. By adopting Simpson and Marek (1988)'s categorization levels, participant teachers' responses were put under three levels of understanding as sound understanding, partial understanding, and naïve understanding. In the following, the explanations of the categories were presented in Table 3.10.

Table 3.10. The Explanations of Categories of Participant Teachers' Substantive Knowledge

Category	**Explanation**
Sound	Participant teachers' understanding including all components and processes of the cycle being evaluated. The teachers' statements should be consisted with the scientific explanations.
Partial	Participant teachers' understanding including lack of knowledge on both components and processes within the cycle being evaluated. The teachers' responses were demonstrated as partial, if the statements: • did not include at least one component and/or process of the cycle being evaluated, • included inadequate explanations when compared to the scientific explanations.
Naïve	Participant teachers' understanding including unscientific explanations and misconceptions related to the components and processes of the cycle being evaluated.

3.5.1.2. Syntactic Knowledge

The syntactic structures of a discipline refer to the rules of evidence and proof used to generate and justify knowledge claims (Abell, 2007, p.1107). Abd-El-Khalick and Boujaoude (1997) emphasized that Nature of Science knowledge is referred as the syntactic knowledge of the science discipline. Therefore, to gather participant teachers' syntactic knowledge, VNOS-C was conducted. The researcher utilized the rubric that serve as a basis for evaluation of VNOS responses (Abd-El-Khalick, 1998; Lederman, Schwartz, Abd-El-Khalick & Bell, 2001). This rubric (See in Appendix F) shown in helped the research enable the determination of the teachers' informed views of NOS.

3.5.1.3. SD Understanding

Participant teachers' understanding on sustainable development issues were examined as a knowledge type under subject matter knowledge regarding the topic of biogeochemical cycles. In order to examine participant teachers' conceptions of SD in terms of biogeochemical cycles, four questions were asked (See in Appendix A). To be able to determine the science teachers' conceptions on the relations between biogeochemical cycles and SD issues, the thematic connections between biogeochemical cycles and sustainable development developed by Koutalidi and Scoullos (2016, p.14) were mainly used (Table 3.11). Additionally, the researcher added some issues and phenomena through the related literature. After that, the researcher used seven categories of SD developed by Kilinc and Aydin (2013, p.741) in order to identify the teachers' main conceptions of SD. Some existing codes were revised and also additional codes (in italic) were derived from the data of the current study. These seven categories and also codes formed under them can be seen in Table 3.12.

Table 3.11. The Thematic Connections between Biogeochemical Cycles and SD Related Issues

Cycle	**Phenomena**	**SD Related Issues**
Carbon	Greenhouse effect; Global warming; Climate change; Atmospheric pollution; Ocean acidification	Unsustainable modes of production and consumption Scarcity of energy resources Geopolitical implications Poverty Renewable energy Non-carbon economy
Hydrological	Water Pollution Soil/Water Salinization through salt water intrusion; Desertification Glaciation	Water scarcity Floods/Droughts Trans-border water conflict Health impacts through water pollution Non-conventional water resources Water resource management The impact of agricultural activities
Nitrogen	Eutrophication; Acid rains Soil pollution Greenhouse effect of nitrogenous gases	Health impacts through water and soil pollution Sewage treatment Alternative agriculture practices Role and use of fertilizers Food safety

Table 3.12. Categories and Codes Used to Identify Participant Teachers' SD Understanding (Kilinc & Aydin, 2013, p. 741)

Categories	Codes
Environment	• Sustaining the natural balance • Finding permanent solutions • *Interdependecy of living things* • Damaging the environment
Society	• Future generations • Improving the living standards of the society • Sustainable lifestyles • *Awared/Educated society* • *Health of the society* • *Shared responsibility*
Economy	• Creating new job opportunities • Sustainable production • *Production-based development* • *Sustainable investments* • *Industrial development* • *Dependency on foreign trades*
Energy	• Using renewable energy sources • *Scarcity of energy*
Politics	• Having strong government and catching up with developed countries • Developments in every area • *Developin policies* • *International treaties*
Technology	• Developing technologies
Education	• Developments in education

3.5.2. Data Analysis of Pedagogical Content Knowledge

In order to analyze experienced science teachers' PCK, the model developed by Magnusson, Krajcik and Borko (1999) was used in the current study. The model consists of five components which are orientations to science teaching, knowledge of curriculum, knowledge of instructional strategies, knowledge of students' understanding of science, and knowledge of assessment. All components were used in order to analyze participant teachers' PCK on the topic of biogeochemical cycles. The details of the components and subcomponents of the model are shown in Table 3.13.

Table 3.13. The Components and Subcomponents of the PCK model used in the current study

Components	Subcomponents
Orientations to Science teaching	Central Goals
	Peripheral Goals
Knowledge of Curriculum	Goals and Objectives
	Curriculum Materials
Knowledge of Instructional Strategies	Subject-Specific Strategies
	Topic-Specific Strategies
Knowledge of Students' Understanding	Students' Requirements for Learning
	Areas of Student Difficulty
Knowledge of Assessment	Dimensions of Science Learning to Assess
	Methods of Assessment

3.5.2.1. Orientations to Science Teaching

Magnusson et al. (1999) defines this component of PCK as teachers' knowledge and beliefs about the goals of science teaching at a specific grade level. The orientations as an overarching component of PCK play a central role and guide teachers to decide the planning of instructional strategies, the content of the student assignments, the use of curricular materials and textbooks and the evaluation of students' understanding (Borko & Putnam, 1996, Magnusson et al., 1999). In the literature, there are nine different orientations discussed by the science researchers respectively, process, academic rigor, didactic, conceptual change, activity driven, discovery, project-based science, inquiry and guided inquiry. The details of the orientations are shown in Table 3.14. In this study, teachers' orientations to science teaching were uncovered by the help of the card-sorting activity explained in data collection tools in detail. In card sorting activity, teachers' orientations were gathered by both the questions about the teachers' beliefs about goals of teaching science and the thirteen scenarios including the nine orientations mentioned below. The obtained data were categorized in two dimensions which are central goals and peripheral goals proposed by Friedrichsen and Dana (2005) to explain teachers' beliefs about goals of teaching science.

Table 3.14. The Goals of Different Orientations to Teaching Science (Magnusson et al., 1999)

Orientations	Goal of Teaching Science
Process (Magnusson et al., 1999)	Help student develop science process skills
Academic Rigor (Lantz&Kass, 1987)	Represent a particular body of knowledge
Didactic (Magnusson et al., 1999)	Transmit the facts of science
Conceptual Change (Roth, Anderson, & Smith, 1987)	Facilitate the development of scientific knowledge by confronting students with contexts to explain that challenge their naïve conceptions.
Activity Driven(Anderson & Smith, 1987)	Have students be active with materials; hands-on experiences
Discovery (Karplus, 1963)	Provide opportunities for students on their own to discover targeted science concepts
Project-based Science (Ruopp et al, 1993; Marx et al., 1994)	Involve students in investigating solutions to authentic problems
Inquiry (Tarnir, 1983)	Represent science as inquiry
Guided Inquiry (Magnusson & Palinesar, 1995)	Constitute a community of learners

3.5.2.2. Knowledge of Curriculum

This component of PCK consists of two categories namely, knowledge of goals and objectives, and knowledge of specific curricular programs and materials (Magnusson et al., 1999). In this study, knowledge of specific curricular programs was not examined because of the national curriculum in Turkey. This curriculum is offered by Ministry of National Education and pursued in all elementary schools in the country. Participant teachers' knowledge of curriculum was obtained by the help of the CoRe interview questions and their teaching practices recorded by video camera. Codes both generated based on the gathered data and PCK literature were used to analyze participant teachers' knowledge of goals and objectives, and knowledge of materials.

Table 3.15. The Categories and Codes of Knowledge of Curriculum

Categories	Codes
Knowledge of Goals and Objectives	Objectives of the topic Horizontal relations Vertical relations The violation/modification of the curriculum
Knowledge of Materials	Dependence on curricular materials Sources that teacher use Aim of using source

3.5.2.3. Knowledge of Instructional Strategies

In the PCK model of Magnusson et al. (1999), knowledge of instructional strategies component is constituted of two categories: knowledge of subject-specific strategies and knowledge of topic-specific strategies. Subject-specific strategies means teachers' overall approaches specific for science teaching. The strategies in this category represent the general approaches to enacting science instruction (Magnusson et al., 1999). In this study, teacher centered strategies (for example; Lecturing, Questioning etc.) and student centered strategies (for example; 5E Learning Cycle, Conceptual Change Approach, Guided Inquiry etc.) that participant teachers' handled to teach the biogeochemical cycles topic was used to analyze teachers' knowledge of subject specific strategies. Topic-specific strategies refer to teachers' knowledge of strategies to facilitate student learning of specific science concepts. Representations and activities are two categories of this type of strategies (Magnusson et al., 1999). In order to analyze the participant teachers' knowledge of topic specific strategies, the categories shown in Table 3.16 were used. Participant teachers' knowledge of instructional strategies was obtained by the help of the CoRe interview questions and their teaching practices recorded by video camera.

Table 3.16. The Categories of Knowledge of Topic-Specific Strategies

Category	Type of Category
Knowledge of Representations	Illustrations (Photos, Videos, Figures, Drawings) Examples Models Analogies, Metaphors Simulations
Knowledge of Activities	Demonstrations Investigations Experiments Problems

3.5.2.4. Knowledge of Students' Understanding

This type of knowledge means teacher knowledge that helps student to develop specific scientific knowledge. It consists of two categories: requirements for learning and the areas of students' difficulties (Magnusson et al., 1999). Knowledge of requirements for learning refers the knowledge about prerequisite knowledge for learning specific science concepts (Magnusson et al., 1999). Knowledge of areas of students' difficulties means that teachers' knowledge about the science concepts or areas that student learning is difficult. There are several reasons why students find difficult to learn science concepts. Thus, teachers should be having enough knowledge about the difficulties that specific for each science topic (Magnusson et al., 1999). In this study, the categories and codes used for analysis of the participant teachers' knowledge of students' understanding on biogeochemical cycles topic were presented in Table 3.17. Participant teachers' knowledge of students' understanding was obtained by the help of the CoRe interview questions and their teaching practices recorded by video camera.

Table 3.17. The Categories and Codes of Knowledge of Students' Understanding

Categories	Codes
Requirements of Learning	Prerequisite knowledge on biogeochemical cycles topic Abilities and skills that students need to learn the topic Students' learning styles
Areas of Students' Difficulties	Abstract structure of the concepts Misconceptions about the topic The existence of terminology

3.5.2.5. Knowledge of Assessment

This component of PCK model used in this study refers to teachers' knowledge about the ways what and how students learn. There are two categories to underlay this type of teacher knowledge: knowledge of dimensions of science learning and knowledge of methods (Magnusson et al., 1999; Tamir, 1988). The category of dimensions of science learning includes the aspects of students' learning which are important to assess in the teaching of a particular topic. In the literature, the dimensions of science learning to assess were identified as conceptual understanding, interdisciplinary themes, nature of science, and science process skills (Champagne, 1989). Based on the context of the study, these dimensions were adopted as conceptual knowledge, syntactic knowledge (NOS understanding) and SD understanding of participant teachers. The other category of knowledge of assessment is the knowledge of methods of assessment. This knowledge refers to the methods that teachers employed to assess students' specific dimensions of science learning (Magnusson et al., 1999).

In this study, teachers knowledge of methods of assessment is categorized as formative and summative mentioned in the literature (Earle, 2015). Formative assessment is the evaluation during the learning process to provide ongoing feedback to improve students' learning whereas summative assessment is implemented to understand how well students have learned at the end of the unit

(Sadler, 1998). In formative assessment, the purpose is to monitor students' learning process. However, summative assessment is interested in the students overall achievements and products (Black et al., 2003). Moreover, the ways of assessment were labeled as formal and informal with parallel to methods of assessment.

Table 3.18. Categories and Codes for Knowledge of Assessment

Categories	Codes
Knowledge of dimensions of science learning to assess	Conceptual understanding SD Understanding Nature of science Science process & ESD skills
Knowledge of Methods of Assessment	The type of assessment *Formative & Summative*
	The way of assessment *Formal & Informal*

3.6. Trustworthiness of the Study

The aim of trustworthiness in a qualitative research is to support the argument that the research's findings are "worth paying attention to" (Lincoln & Guba, 1985). This statement is completely related to validity and reliability issues. The terms 'reliability' and 'validity' are not used by many proponents of qualitative design. Lincoln and Guba (1985) prefer the terms *credibility, transferability, dependability* and *confirmability*, because they felt that these terms better reflect the underlying assumptions involved in qualitative research (Trochim, 2006). Table 3.19 shows the proposed terms in qualitative research and the "analogous" quantitative criteria.

Table 3.19.Proposed Criteria and Analogous Quantitative Criteria (Trochim, 2006)

Traditional criteria for quantitative research	Alternative criteria for qualitative research
• Internal validity	• Credibility
• External validity (generalization)	• Transferability
• Reliability	• Dependability
• Objectivity	• Confirmability

3.6.1. Credibility

Credibility means that how results of a study coincide with reality (Merraim, 2009). To establish trustworthiness in a qualitative research, confirmation of credibility is most important factor (Lincoln & Guba, 1985). There are different strategies to increase credibility; making triangulation, prolonged engagement, external check by peer review, clarifying researcher position and member check (Creswell, 2007; Merriam, 2009). In this study, triangulation, peer review, prolonged engagement in the classroom settings and clarifying research position was included to address credibility in the designing the research procedure.

Firstly, the researcher used data triangulation to provide a richer, more multilayered and more credible data set from the participants. Using multiple data collection methods such as interviews, video-records, and documents strengthened the criteria of credibility. Also, multiple data sources were used to provide more credible information. Researcher examined the transcriptions of data gathered both interviews and video-recordings to compare and contrast teachers' perceptions. Moreover, teachers' exam papers and drawings helped researcher to obtain the consistent results.

Secondly, external check of peer review strategy was used to address the credibility of the study. Two colleague experienced in qualitative research were asked to advise the data collection and analysis methods of the study. Furthermore, a researcher familiar with science education and PCK checked and analyzed some portion of the data to increase the credibility of the study. In the light of these reviews, different interpretations and any disagreements were examined and resolved through the discussions and negotiations. In addition to these, the researcher's advisor and co-advisor also gave feedbacks throughout the research. These feedbacks based on advisors' perceptions, experiences and comments helped researcher to recognize her own biases and widen her vision about the progress of the current research.

Thirdly, prolonged engagement in the teaching environment of the participants gave more credible information about the teachers' perceptions and PCK. The researcher spent time with the participants at their schools in regular intervals throughout the one semester (five months) to obtain more credible data. Also, the researcher visited the participant before the study to explain the purpose of the study and what she wanted them to do. Meanwhile, the researcher had chance to observe the participants' in their natural settings. During these meetings, researcher and participants became familiar talking about teaching, students, context of the school and science curriculum. These meetings and conversations were beneficial to obtain more detailed and thicker description of the current study.

Lastly, clarifying the researcher bias was another important issue to ensure the credibility of the research findings. In qualitative studies, researcher position is important factor (Merriam, 2009). The researcher's experiences, expectations, values and training affects the results of the study (Merriam, 2009; Patton, 2002) because the researcher is the instrument in qualitative studies (Lincoln & Guba, 1985). The researcher took a qualitative research course before the research was conducted. This does not mean that the researcher became expert in doing qualitative research but the course helped researcher to get a wider perspective on the nature of the qualitative research approach. Moreover, the researcher had an opportunity to examine several qualitative studies and three main qualitative books throughout the course so she provided necessary underpinnings of the qualitative approach. In addition, the researcher had experienced with pre-service teachers in practice teaching course since 2011 so she could advanced her knowledge about how PCK develops. Furthermore, the pilot study helped the researcher to make revisions for providing more detailed and credible data. As a result, all evidences mentioned above provided the credibility of the researcher bias.

3.6.2. Transferability

Transferability means the degree to which the results of qualitative studies can be generalized or transferred to different situations (Merriam, 2009). Although it is difficult to generalize the qualitative results from one context to another, transferability can be increased by thick description of the research context and paper trail (Lincoln & Guba, 2009). In this study, these strategies were used to increase the transferability of the research. The researcher described the context of the study; participants; the data collection procedures and findings in detail. Moreover, several of the data collection and analysis documents were included in an appendix part. The complete set of data collection and analysis documents are on file and available upon request. Thus, intensive description and access to the research's "paper trail" gave other researchers the ability to transfer the conclusions of this study to other contexts.

3.6.3. Dependability

Dependability in qualitative study refers to reliability in quantitative research. To address dependability, the research findings and collected data should be consistent and could be repeated (Merriam, 2009; Patton, 2002). In this study, triangulation, peer review and clarifying the researcher bias to ensure both the dependability of the research results. These efforts were explained in credibility part of this section. This means that the strategies to increase credibility help to ensure dependability.

Yin (2009) states the purpose of dependability is to prevent the errors and bias in the study. The case study protocol describing the detail description of the data collection, data analysis, the decisions throughout the research provided dependability of a study (Merriam, 2009; Yin, 2009). In the current study, this protocol was explained in the previous sections of this methodology chapter.

Moreover, a science education researcher also analyzed some parts of the data to provide agreements with the findings of the study. The results compared and inconsistencies were discussed to arrive at a consensus.

3.6.4. Confirmability

Confirmability means the degree to neutrality of researcher while the study was implementing and the results were interpreting (Linccoln & Guba, 1985). It is a researcher effort to ensure that the findings of the study are not affected by the characteristics and ideas of the researcher (Merriam, 2009). There are a number of strategies to ensure confirmability in qualitative research (Trochim, 2006). Triangulation, identifying researcher position, detailed description of the context and methods are some of these strategies. All of these strategies was also used to enhance the credibility and dependability of the research and detailed in previous parts.

3.7. Ethical Issues

Protection of the participants from harm, deception of the participants, and confidentiality of data are three important points related to the ethics in research (Frankel & Wallen, 2006). Under these considerations, first, Institutional Review Board (IRB) approval was taken from METU Human Subjects Ethics Committe (Appendix F) in order to be able to conduct the study. IRB approved that the current study has no potential to harm both participant teachers and the students in the classes. The researcher took an additional permisson from Ministry of National Education (Appendix G) to carry out the study in the public middle schools. Besides, anonymity of participants and the school were assured. For all participants, pseudonyms were used. Besides, participants of the study were not deceived. They all accepted to participate to the study voluntarily. Participants were informed about the purpose of the study. The researcher also explained that whenever they want, they could quit the study and the results of the study could be shared with them if they want. Finally, except the researcher, her advisor, and additional coders, nobody had access the data collected for the study. Considering the important points above mentioned, the ethics in the current research was guaranteed.

3.8. Assumptions of the Study

For this study, the following assumptions were made:

1. The rubrics prepared in order to analyze the teachers' understandings are well-developed tools consistent with the focus of the study.

2. The participants may have some prior knowledge about the issues in the study. They took the related courses so they had a background in these issues and they are able to give some information scientifically on the questions being addressed.
3. The participants' actions are not affected by the presence of the audio and video recorder in the study.

3.9. Limitations of the Study

The following limitations originating from the nature of the qualitative study were explained for this study.

- Firstly, generalizability of the study is one of the limitations of this study. The number of participants is limited to three in-service science teachers. Therefore, results of the study may only be generalized to individuals and contexts whose characteristics and descriptions are similar to those studied in this study.
- Secondly, the data collection tools of the current study were prepared based on the science and technology curriculum revised in 2005. After the study began, the curriculum was changed two times in 2013 and 2018. These changes were not taken into consideration throughout the analysis and interpretation of the data.
- Thirdly, participant teachers' native language was Turkish. Therefore all data collection tools and procedures were implemented in Turkish. All quotations and codes derived from Turkish data were translated into English so the terminology of the translated data may have some problems. To reduce the limitation of this issue, the suggestions of the advisor were valuable for the quality of the translations.
- In the beginning of the study, the researcher planned to investigate three topics, namely biogeochemical cycles, energy sources and recycling to determine teachers' SMK and PCK in the context of ESD. Therefore, the duration of interviews of each participant's SMK and PCK sometimes could

take very long time than expected. When necessary, in order to minimize the risk of being bored, the researcher occasionally used structured interview questions rather than semi-structured ones.

- There can be some limitations concerning the use of video-recording method. The most essential limitations are mechanical problems and the influence of videotaping on behavior.
- There can be some limitations in terms of the orientations used in the study. Although, considering the aim of the study, four orientations were added; the researcher adhered to the nine orientations shown in Table 3.15. Some current orientations (e.g. argumentation, STEM) were not considered. Moreover, Magnusson et al. (1999) stated that teachers can identify multiple orientations depending on the topic or the grade level. However, all orientations which participant teachers identify for characterizing both their belief systems and purpose for teaching science at 8th grade could not be observed. Regarding the topic of biogeochemical cycles, the researcher could only report one or two dominant orientations.
- The post-interviews related to either participated teachers' SMK or PCK could not be conducted.

CHAPTER 4

FINDINGS

This chapter presents the findings of the study. Results are detailed for each participant for content knowledge and pedagogical content knowledge in two parts. In the first part of each case, teacher's content knowledge is reported. Hereby, based on the data collected through interviews and drawings, participant's substantive, syntactic and SD understanding regarding biogechemical cycles are analyzed and presented under the heading of content knowledge. In the second part of the each case, detailed results are presented for teacher's PCK components namely, orientation to science teaching, knowledge of curriculum, knowledge of instructional strategies, knowledge of students' understanding and knowledge of assessment. For each case, teacher's statements taken from data based on interviews, video-recordings (classroom observations) and documents are reported for the description of teacher's use of each component of PCK. At the end of the chapter, the findings of the teachers' both content knowledge and pedagogical content knowledge are summarized.

4.1. CASE 1: Kemal's Subject Matter Knowledge and Pedagogical Content Knowledge on Biogeochemical Cycles

In this study, the researcher used the pseudonym for the participant teachers and Kemal was called as Case 1. Kemal is male and sixty years old. He was graduated from Education Institute in 1977. He had worked in a high school for five years in different branch of study. In 1982, he was graduated from physics department in Faculty of Arts and Science of a public university. He had taught physics lessons in high schools for twenty-five years. Kemal has already been working in Eco-schools project implemented by TÜRÇEV (Turkish Foundation of Environmental

Education) for four years in his current middle school. Currently, he has been teaching science for eight years in a public middle school as a science teacher. Kemal has taught 5, 7 and 8^{th} grades during 2013-2014 education year and has twenty course hours as work load per week. There were thirty-six students in his classroom. In this section, Kemal's results of subject matter knowledge and pedagogical content knowledge were presented.

4.1.1. Kemal's Subject Matter Knowledge

4.1.1.1. Kemal's Substantive Knowledge

The results of Kemal's substantive knowledge regarding biogeochemical cycles are presented under three subheadings, respectively the carbon, hydrological and nitrogen cycle.

Kemal first was requested to answer the question what the biogeochemical cycle is. He started to the definition by explaining that the amount of the materials needs to be balanced. In the continuation of his explanation, Kemal defined the biogeochemical cycle as 'the materials such as carbon, nitrogen, oxygen, phosphorus and, water which are the building blocks of the earth are used by the living things and returned to the earth''. Although Kemal referred the biotic components of the cycles mentioning the living organisms such as plants, animals, he did not specifically touch upon abiotic components (i.e. the sun and the soil) and reservoirs of chemicals in his definition. As a result, his understanding of the cycle was considered as partial according to the scientific definition.

> **Researcher (R)**: How can you define biogeochemical cycle?
> **Kemal (K):** …There are some materials such as carbon, nitrogen, oxygen, phosphorus and water whose amounts needs to be balanced…These materials are the building blocks of the organic compounds in living things. The living things are plants, animals etc. They are used by the living things and returned to the earth…

4.1.1.1.1. Kemal's Knowledge about Carbon Cycle

To reveal Kemal's understanding of carbon cycle, he was requested to draw and explain the carbon cycle. Considering his statements in both his drawing and teaching; Kemal's understanding of carbon cycle was labeled as partial due to the lack of his knowledge. In Table 4.1, Kemal's understanding related to the carbon cycle is summarized.

Table. 4.1. Kemal's Understanding of the Carbon Cycle

	Kemal's Understanding
Components within the cycle	• The plants (Producers) • The animals and humans (Consumers) • Bacteria (Decomposers) • CO_2 in the atmosphere, dissolved carbon compounds in water, fossil fuels, the structure of living things (Carbon Reservoirs) • Sun (Abiotic Component) • Soil (Abiotic Component) • Water (Abiotic Component)
Processes within the cycle	• Photosynthesis • Transformation of carbon from plants to animals through food chain • Respiration of plants and animals • Combustion of fossil fuels • Decomposition

Kemal began his explanation with the importance of carbon cycle. When asked the question of why the carbon cycle is important, he stated that carbon is very important matter because it is the basis of the building blocks of living things such as carbohydrates, proteins, and fats. He also addressed the importance of CO_2 for the plants to make food and produce oxygen through photosynthesis.

R: Why is the carbon cycle important?
K: Carbon is very important matter. It [carbon] constitutes the basic building blocks of living things. It is in the structure of carbohydrates, proteins, and oils. Besides, plants use CO_2 in photosynthesis to produce oxygen and food. In this manner, it is [carbon] very important for life...

Then Kemal began to explain the carbon cycle through drawing (Figure 4.1). He first mentioned the release of carbon to the atmosphere because of combustion of fossil fuels. He included fossil fuels as a source of carbon element in his drawing. Although he did not draw specifically the process of combustion, during explanation phase of his drawing, he verbalized that people consumed the fossil fuels in their daily lives. Then, he continued to his drawing expressing the removal of carbon dioxide from the atmosphere through plants during photosynthesis. Although he also mentioned about the plants in aquatic systems, he did not specifically explain the aquatic carbon cycle. Then, he mentioned that the organic compounds (food) formed in the photosynthesis enter the bodies of composers through food chain. In here, Kemal referred the process of transformation of organic carbon from plants to consumers. Later, he explained that living things such as plants, animals and humans also release carbon dioxide to the atmosphere with respiration. Finally, Kemal emphasized that carbon dioxide returns back to the atmosphere and the soil by the process of decomposition. However, he did not show the decomposition process in his drawing.

> **R:** Could you please explain the carbon cycle by drawing?
> **K**: …[Drawing] One of the most important sources of the carbon is the fossil fuels such as oil, natural gas and coal, which we call non-renewable energy sources. We use those [fossil fuels] in our homes, in our cars; in factories…As we use these fuels, the carbon dioxide gas is released to the atmosphere… Then plants use this carbon dioxide. When they [plants] consume it [carbon dioxide] in photosynthesis, they [plants] produce oxygen and organic compounds… By the way, photosynthesis do not happen just on land. Plants living in the sea also make photosynthesis. This organic compound produced through photosynthesis, in turns, enters the bodies of living things. I mean animals; humans are eating it [plant]. Living things are continously releasing CO_2. Plants, animals and people give out water vapor and carbon dioxide through respiration. This carbon dioxide is released to the atmosphere again ... Finally there are dead bodies of living things. These dead bodies are separated by the decomposers and the carbon dioxide gas return to the atmosphere and the soil.

Although Kemal did not explain the sun as the driving force of the cycle in his drawing, he specifically addressed the sun as the energy source for the photosynthesis in his teaching of carbon cycle.

> **K:…**We know the sun is important for living things. What does the sun provide to the plants? Through its rays, it gives energy to the plants. What does the plant do with this sun energy? They [plants] photosynthesize on their leaves? They produce food…[Classroom Observation]

Kemal also expressed all reservoirs of the carbon in four earth spheres as atmosphere, hydrosphere, lithosphere, and biosphere. However, he did not refer the major source of CO_2 as plants (biomass) and oceans.

> **K**:…First, the carbon is found in the atmosphere as carbon dioxide. The second is in the hydrosphere. I mean that the carbon compounds are dissolved in the water. In the lithosphere, it [carbon] is fossillized. It [carbon] is found in the structure of fossil fuels as oil, coal, natural gas. Finally, in the biosphere, the living things contain carbon compounds such as proteins, carbonhydrates, nucleic acids etc…

Kemal did not draw the oxygen cycle separately. He pointed out the processes of oxygen cycle are reverse of the ones in the carbon cycle. He expressed that the carbon and oxygen cycles are interrelated. Kemal touch upon the oxygen cycle briefly in during his teaching of carbon cycle. He mentioned about the characteristic of oxygen element and referred the importance of O_3 for the living things.

> **K:** There's no need to mention the oxygen cycle. The processes in the carbon cycle also occur in the oxygen cycle. This cycle [O_2] is reverse of the carbon cycle. The oxygen and carbon cycle are interrelated. So, if there is no carbon cycle, there will be no circulation of oxygen…

In conlusion, considering Kemal’s statements in both his teaching and drawing related to the carbon cycle, it can be said that his explanations had lack of the knowledge. First, he stated the sun as the energy source of photosynthesis not a driving force of the cycle. While explaining the photosynthesis, he did not mention the algae and cynobacteria as producers. Furthermore, he did not refer the major source of CO_2 as plants (biomass) and oceans. Additionally he did not touch upon the carbon cycle in aquatic systems. Therefore, Kemal’s understanding of carbon cycle was labeled as partial.

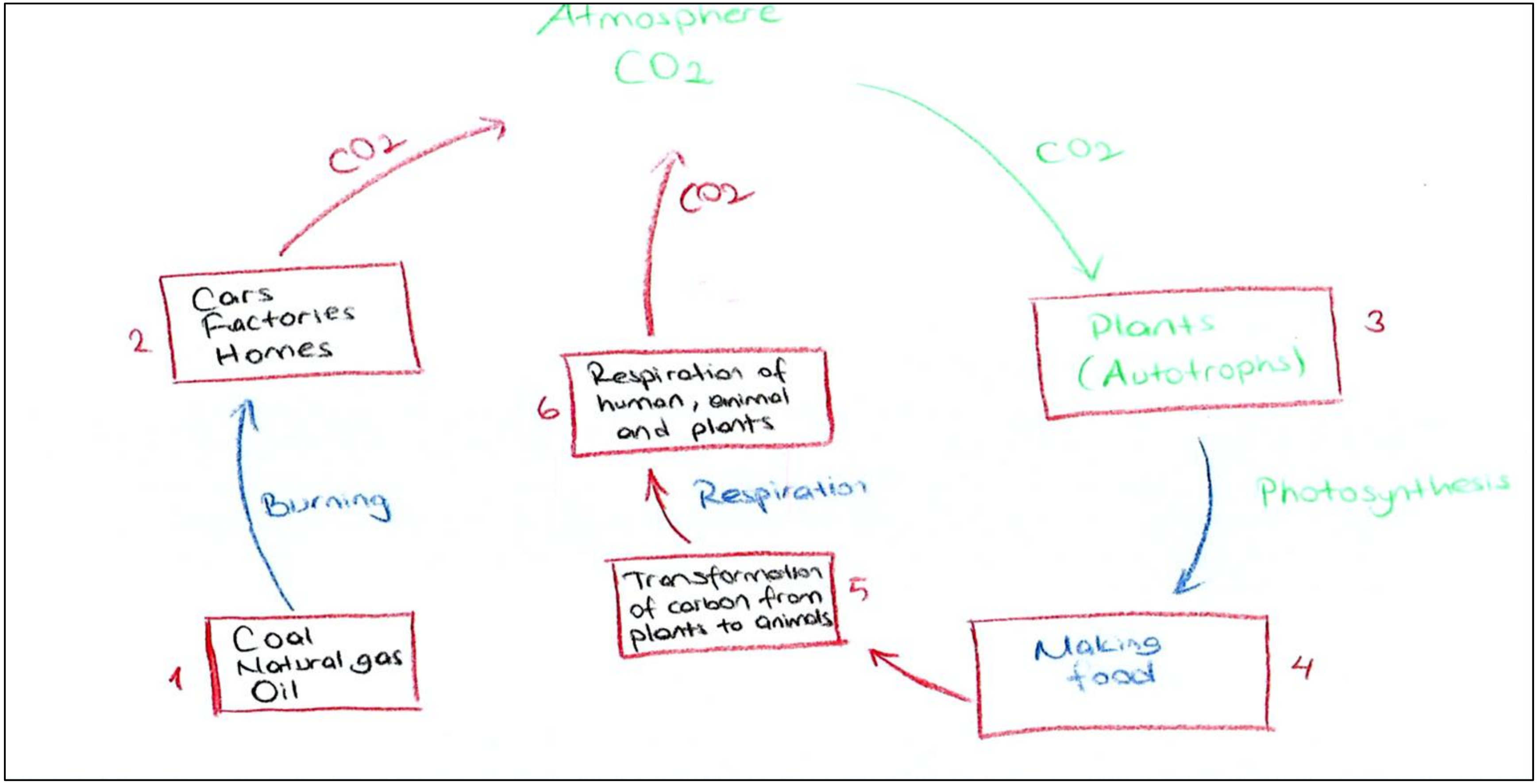

Figure 4.1. Kemal’s Drawing of Carbon Cycle

4.1.1.1.2. Kemal's Knowledge about Hydrologic Cycle

To identify Kemal's understanding of hydrologic cycle, he was requested to draw and explain the hydrological cycle. Considering his statements in both his drawing and teaching; Kemal's understanding of hydrological cycle was labeled as partial. In Table 4.2, Kemal's understanding related to the hydrological cycle is summarized.

Kemal initially define the hydrological cycle as ''the water which evaporates from the water resources is condensed and return to the earth in the form of precipitation''.

Table 4.2. Kemal's Understanding of the Hydrological Cycle

	Kemal's Understanding
Components within the cycle	• The plants (as Producers) • The animals (as Consumers) • Oceans, Lakes, Glaciers, Rivers, Ground Waters (as Water Resources) • Soil(as Abiotic component) • Sun (as Energy source) • Temperature & Wind (Climatic factors)
Processes within the cycle	• Evaporation • Condensation • Precipitation • Transpiration • Surface Flows • Infiltration

Then, he explained all reservoirs of the water as oceans, lakes, glaciers, rivers and underground waters as the abiotic components of the hydrological cycle. Besides, he mentioned the existence of water as a feature that separates the earth from other planets. In addition to this, he underlined the importance of water for living things in his teaching of hydrological cycle.

> **K:** …We know that 3/4 of earth is water. There are oceans, seas, lakes and rivers. There are also glaciers and ground-waters…The most important feature that separates the earth from other planets is its atmosphere and the presence of the water vapor in it [atmosphere]....

> ...So drinking water is very important to us...You have known that the cells of organisms can live only watery environment. So water is very important for plants, for animals, for all living things…[Classroom Observation].

When it comes to his explanations through drawing, Kemal mentioned about the process of evaporation. He stated that the water evaporates due to the heat energy from the sun. Although he stated the rain, snow and hail as the types of precipitation and the process of condensation as the formation of clouds in this explanation, he did not show these processes [precipitation and condensation] in his drawing (Figure 4.2) as well. Moreover, he addressed the plants and animals as the biotic components of the cycle. In here, he explained the presence of water vapor in the atmosphere due to the respiration of animals and plants. He also touched upon the transpiration of plants in the cycle.

> **R:** Could you please explain hydrologic cycle by drawing?
> **K:**…[Drawing] Now let's say we have a lake. Next to this lake, there are plants and animals. There is a water vapor because of the process of respiration in plants and animals. There is a factory and a house near the lake as well. Smoke and water vapor are constantly coming from the factory and house chimneys to the atmosphere… The lake is warming up; water is evaporating due to the heat energy from the sun. Plants are also releasing water vapor through the process of transpiration. These vapors form clouds in the air…From the clouds; water should be fallen back to the earth as a type of precipitation like rain, snow, or hail according to the weather conditions…

Futhermore, Kemal was expected to refer both surface flows and the process of penetration in the hydrological cycle. Although he did not give place these processes [penetration and surface flows] in his explanations through drawing, he explained them during his teaching of hydrological cycle. He also mentioned the short and long water cycle. Lastly, Kemal touched upon some climatic conditions such as temperature and wind as factors affecting water cycle.

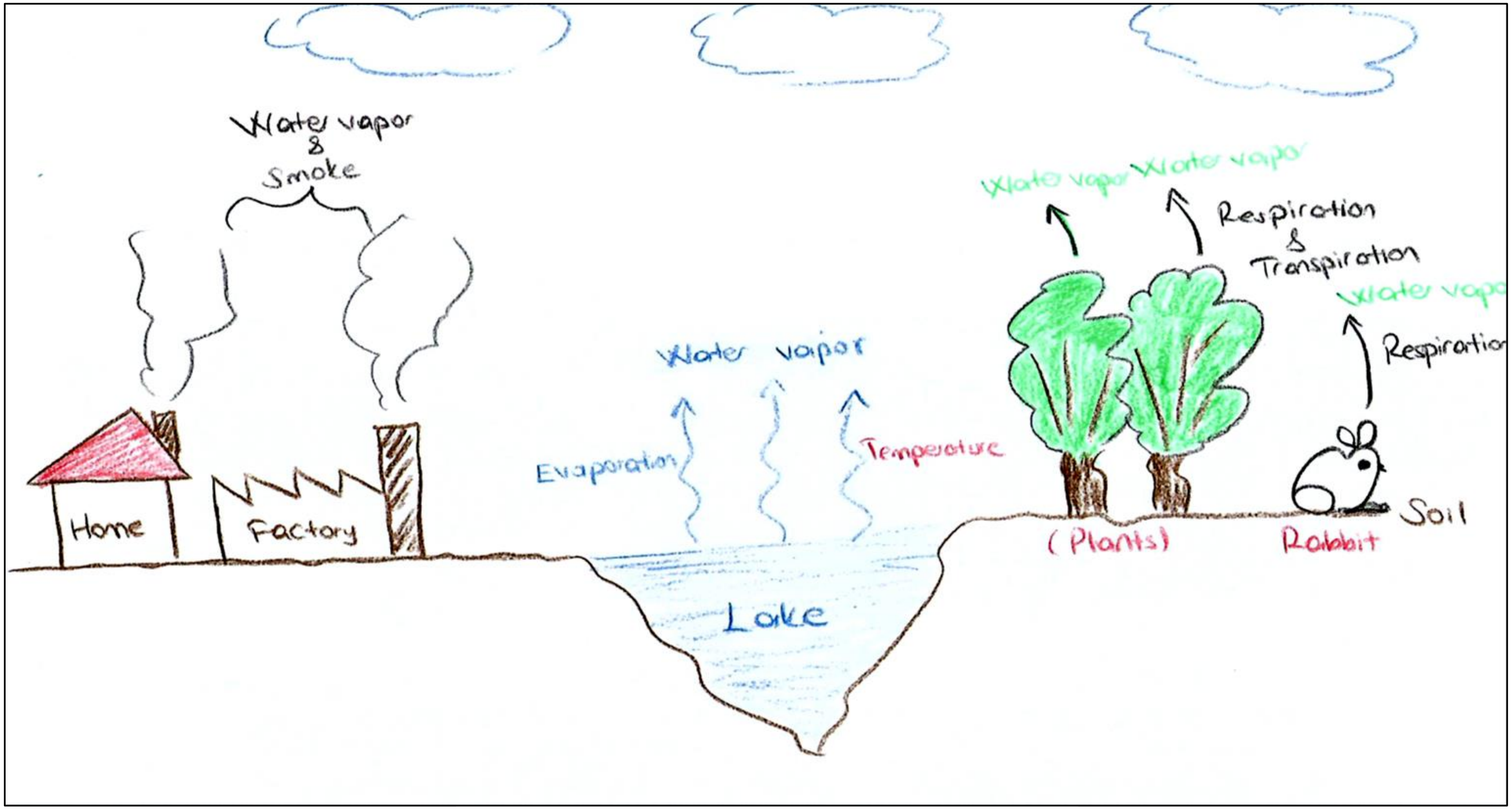

Figure 4.2. Kemal's Drawing of Hydrological Cycle

In conclusion, Kemal's explanations related to all abovementioned processes and components of the hydrological cycle (Table 4.2.) were consistent to the scientific explanations. However, considering the lack of the knowledge regarding the sun and gravity as the driving forces for the cycle, Kemal's understanding of hydrological cycle was labeled as partial.

4.1.1.1.3. Kemal's Knowledge about Nitrogen Cycle

To better grasp Kemal's understanding of nitrogen cycle, he was requested to draw and explain the nitrogen cycle. Considering the statements in both his drawing and teaching; Kemal's understanding of nitrogen cycle was labeled as partial due to the lack of his knowledge. In Table 4.3, Kemal's understanding related to the nitrogen cycle is summarized.

Table 4.3. Kemal's Understanding of the Nitrogen Cycle

	Kemal's Understanding
Components within the cycle	• The plants (Legumes) (as Producers) • The animals and people (as Consumers) • Decomposers • Nitrogen-fixing bacteria • Nitrifying bacteria & Denitrifiers • Atmosphere and the soil (as Nitrogen Reservoirs) • Water (as Abiotic component)
Processes within the cycle	• Nitrogen fixation • Nitrification • Denitrification • Transformation of nitrogen compounds in the plants to animal compounds through food chain (N-Assimilation) • Lightning

Kemal first emphasized that nitrogen is essential material for living things because of the formation of proteins, nucleic acids, ATP, DNA, RNA and vitamins. He addressed the atmosphere as a reservoir contains 78% nitrogen gas. Besides, he pointed out the components of the nitrogen cycle such as soil, plants, animals, decomposers, nitrogen fixing bacteria, nitrifying and denitrifying bacteria. Kemal defined the processes of nitrogen fixation, nitrification and denitrification in the cycle clearly. He referred the nitrogen assimilation through the food chain.

> **R:** Could you please explain the hydrological cycle by drawing?
> **K:**…[Drawing] Nitrogen is a very important element for life. There is 78% nitrogen gas in the atmosphere ... Plants and other living things cannot use this nitrogen directly. Nitrogen in the atmosphere is caught by nitrogen-fixing bacteria in the roots of plants (legumes) and converted to nitrate by nitrification. Already through the plants we can get nitrogen with the food. Then nitrogen compounds in dead organisms are converted to ammonia by decomposers. This ammonia is converted into nitrate by chemosynthetic nitrite and nitrate bacteria in the soil. This nitrate is taken up by plants in order to be used in the synthesis of amino acids, nucleic acids, ATP, vitamins, DNA and RNA... Excess nitrate accumulation in soil is a dangerous situation. Nitrate forms nitric acid when dissolved in water. For this reason, the excess nitrate in the soil is converted into nitrogen gas by the denitrification bacteria and goes back to the atmosphere again.

Kemal referred the lightning in order to capture the nitrogen in the cycle. He emphasized the knowledge that the lightning is the way of fixing nitrate in the soil although the minority of the cycle is based on this process.

> **K:** One way of capturing nitrate in the soil is lightning. This process only connects the nitrogen in the places where it [lightning] falls. This involves a very small fraction of the nitrogen cycle. In true sense, nitrogen is formed by fixing to plant roots with nitrogen-fixing bacteria, its transformation to food. This food is consumed by animals and the nitrogen compounds in the bodies of dead organisms separated by bacteria and they [nitrogen compounds} returned to the atmosphere as nitrogen gas.

In short, Kemal's statements regarding the all abovementioned processes and components of nitrogen cycle (Table 4.3) were consistent to the scientific explanations. However, he did not mention the cynobacteria in aquatic systems as a nitrogenous bacteria and the sun as the energy source of the cycle in both his drawing (Figure 4.3) and teaching. In these considerations, Kemal's understanding of nitrogen cycle was labelled as partial.

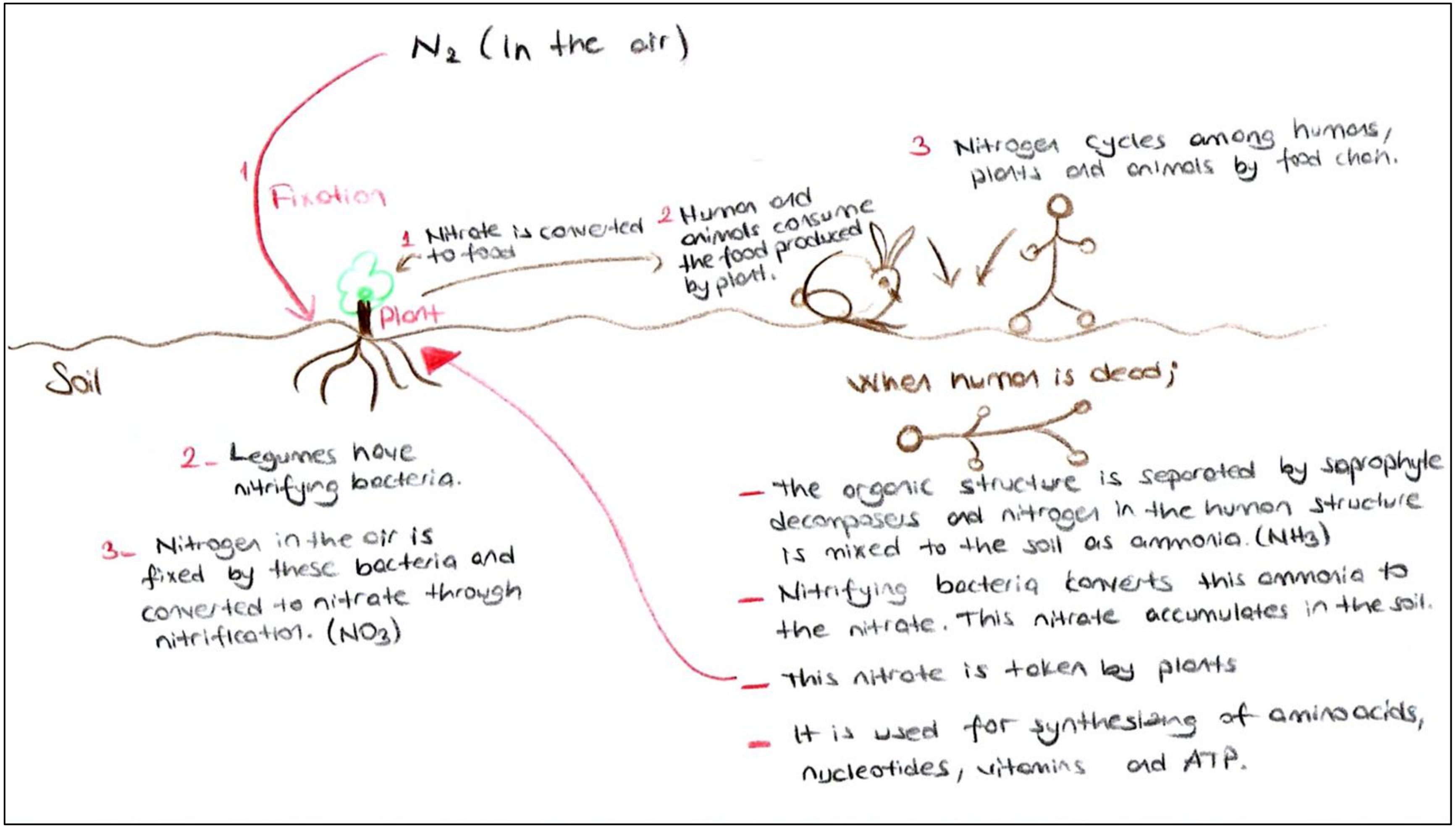

Figure 4.3. Kemal's Drawing of Nitrogen Cycle

To conclude, it can be said that Kemal's substantive knowledge in the topic of biogeochemical cycles was partial considering his responses related to the components and processes of the cycles. In the next section, Kemal's syntactic knowledge regarding his NOS understanding was documented.

4.1.1.2. Kemal's Syntactic Knowledge

In this section, the results of Kemal's syntactic knowledge (NOS view) were presented based on empirical, tentative, inferential, creative and imaginative, subjective, socio-cultural nature of science as well as the distinction between theory and law. Kemal's NOS views were obtained by using the interview questions in embedded VNOS-C questionnaire.

Empirical NOS: When asked the questions of what the science is and what makes science differ from other disciplines, Kemal, first, explained the science as ''All studies conducted to understand the universe and the world we live in''. He expanded his explanation with the definition of scientific knowledge as knowledge gained based on the scientific methods and processes. He accepted science both as a body of knowledge and as a process, yet possessed the misconception that a universal scientific method exists. Moreover, Kemal acknowledged that the most important feature that differ science from other disciplines is its dependence on the data obtained from experiments and observation. Kemal stated that scientists can prove the existence of global warming based on data and observations such as increase in the temperatures, melting of icebergs. Thus, he believed that scientist use observations and experiments to reach definite conclusions and make claims based on these evidences. On the other hand, he failed to understand that experiments and observations are not the only route to scientific knowledge and many scientists have used non-experimental techniques to advance knowledge (Abd-El-Khalick, 2005). Under these circumstances, Kemal's understanding had deficits in terms of empirical NOS (See table 4.4 for sample quotas).

Table 4.4. Kemal's Sample Statements of Empirical NOS

NOS view	Sample Statements
Empirical	…Scientists dealing with positive sciences (physics, chemistry, biology etc.) communicate with each other through clear evidences… In the scientific process, you get results with the experiments. …Let's give a simple example. Torricelli went to a sea shore, took a mercury bowl and a tube in one meter in length. He filled the tube with mercury and it [mercury] becomes stable when it reaches to the height of about 76 cm. He repeated the procedure many times and concluded that because of the air pressure, the mercury in the tube comes to rest at 76 cm, at sea level…If every scientist repeat the experiment as Torricelli did, they reach the same conclusion…In positive sciences, there is something called experiment and there is observation. …Scientists know that Earth temperature has increased 3-4 degrees up to now. At least they [scientists] provide evidences like the melting of glaciers in the poles, the joining of icebergs to the oceans…These are very important data that show the global warming really happens.

Theory & Law: When asked the differences between theory and law, Kemal was not aware of the understanding that theories and laws are different kinds of scientific knowledge. He also ascribed to a hierarchical view of the relationship between scientific theories and laws whereby theories become laws when 'proven true'. He held the common misconception that the theories are the knowledge that needs to be proven. He also detailed his assertion that laws are certain knowledge with the example of Newton's laws of motion. When asked whether greenhouse effect is theory or law, he failed to understand that it is a theory (Ramanathan, 1988; Wilkins, 1993) because of his misconception on the explanatory function of theories. He perceieved the theories as the knowledge needed ''proof''. Therefore, his responses implied that he failed to understand the functions of and differences between theories and laws (See table 4.5 for sample quotas).

Table 4.5. Kemal's Sample Statements of Theory & Law

NOS view	Sample Statements
Theory & Law	…He [scientist] proposes an idea to solve a problem. What we call this idea is hypothesis…Scientists also formulate many hypotheses related to the same problem in different places and later write scientific articles. Then many scientists do an aggrement on these hypotheses. So they become theories if they [hypotheses] are confirmed by all scientists. Theories can sometimes be wrong. But when the theories are proven, we call them as laws in simple sense…The facts that scientists know its certainty called law… …Newton formulated the law of gravity… Based on this law, the pen I throw to the up will fall to the ground. In every time, the pen will fall…If so, the laws always work and they are always true. …The greenhouse effect is an important event that warms the earth. Scientists are sure of the fact that the greenhouse gases such as water vapor, CO_2, methane, etc., which holds the heat reflected from earth, warm up the atmosphere and thus the earth. They [scientists] can also collect data on the changes in the proportions of these gases in the atmosphere. In the line with this knowledge, I perceive the greenhouse effect as a law…

Tentative NOS: When asked whether the theories and laws can be changed, Kemal acknowledged that all scientific knowledge is subject to change. He emphasized that scientific knowledge can be developed in the light of new technologies and by different interpretations of previous knowledge in different way. He expanded his answers by giving examples of the studies in CERN, and the atom models to explain how scientific knowledge changed. When asked whether theories and laws can be changed, he claimed that theories can be changed. However, his explanations indicated that theory change were not associated with a tentative view of science. Rather, he reflected a naive view that theory is an intermediate step in the generation of 'true' scientific knowledge as law (Abd-El-Khalick, 2005). Besides, he had also claimed that laws are certain knowledge. Thus, the results showed that his misconception related to the functions of theories and laws caused her explanations on tentative NOS to be inconsistent and partial (See table 4.6 for sample quotas).

Table 4.6. Kemal’s Sample Statements of Tentative NOS

NOS view	Sample Statements
Tentative	…In science it is necessary to perceive; knowledge as tentative… We cannot ignore Newton's laws of gravity, but it can be improved in the light of the different interpretations [new ways of thinking]. In this sense, I believe that it [law] can change ... For example; The Einstein’s Theory of Relativity questioned to the Newton’s laws… At CERN, an experiment was conducted regarding the formation of the universe…What will be results of this experiment? Will the results disprove the existing laws?... I mean, I do not think science and technology will advance if we see the law as certain knowledge… We know how the atomic theory has changed from Dalton’s view to the present day…Atom was indivisible but it later found to be comprised of sub-particles such as proton, neutron and electron…

Inferential NOS: When asked how scientists are certain about the appearance of the dinosaurs, Kemal’s responses implied that scientists make inferences. He did not mention the term ‘‘inference’’ explicitly but he implied that scientists make interpretations based on evidences. For example, he emphasized that scientists constructed models of dinosaurs depending on the fossil evidences. Thus, Kemal’s understanding on inferential NOS reflected that scientific claims are based on empirical evidences. In other words, it can be said that Kemal’s understanding of inferential NOS were affected by his view of empirical NOS (See table 4.7 for sample quotas).

Table 4.7. Kemal’s Sample Statements of Inferential NOS

NOS view	Sample Statements
Inferential	Science is divided into many branches, for example geologists and biologists worked together and based on fossil evidences, and they concluded that dinosaurs had lived. At the same time, they [scientists] investigated the skeletal systems and bone structures of dinosaurs, and constructed models using technology. Thus, they got an idea of how dinosaurs looked like.

Creative and Imaginative NOS: Kemal recognized the crucial role of imagination and creativity in science. He claimed that scientists' imagination and creativity is essential for the continuation of their investigation. In his example of inferential NOS, he also implied how scientists use their imagination and creativity due to the get an idea of how dinosaurs looked like. Hence, his responses included informed views because of the understanding that scientists' imagination and creativity have an important role in every part of the scientific investigation. Kemal's sample statements can be seen in Table 4.8.

Table 4.8. Kemal's Sample Statements of Creative and Imaginative NOS

NOS view	Sample Statements
Creative and Imaginative	Scientists take advantage of their creativity and imagination, and they do not go a step further unless they did not use them [their imagination and creativity]. If science is based on curiosity, I think it [science] will advance by imagination and creativity. For me, scientist should use them [imagination and creativity] in every stage of their work…No matter which phase he is in. He should progress using his/her creativity and imagination.

Subjective NOS: Kemal possessed naïve understanding of subjective NOS. He claimed that scientist's preconceptions, values; background should not influence their investigations. He held the misconception that science should be objective and value-free. He acknowledged that the reason of scientists' different interpretations is the lack of evidence. For instance, he asserted that there are several different interpretations of the causes of the dinosaurs' extinction because scientists did not have enough evidence to prove why the dinosaurs become extinct. Sample statements can be seen in Table 4.9.

Table 4.9. Kemal’s Sample Statements of Subjective NOS

NOS view	Sample Statements
Subjective	…Scientist should be objective. All scientists, of course, have different perspectives, but they have to come together and create a consortium to produce a common result based on the same data… …Concerning dinosaurs’ extinction, scientists have a lot of different views such as climate change, meteorite hit, separation of continents, volcanic eruptions, depletion of their foods etc. It's been a long time since this [dinosaurs’ extinction] happened and scientists have no chance of going back. They do not have enough evidence to prove it [dinosaurs’ extinction] so they have different interpretations on the causes of the extinction

Socio-Cultural NOS: Kemal indicated naïve understanding of socio-cultural NOS. To hold a naïve understanding of socio-cultural NOS, participant should consider that science is isolated from the norms and values of the society. At this point, Kemal believed that science is universal and it should be independent of the culture. Sample statements can be seen in Table 4.10.

Table 4.10. Kemal’s Sample Statements of Socio-Cultural NOS

NOS view	Sample Statements
Socio-Cultural	Science is universal. It should be independent of the cultural values. I mentioned that science is objective and seeks the true results. If it is so, it should not be influenced by them [socio-cultural values and norms].

To sum up, Kemal’s responses implied that he did not possess informed understanding on all NOS tenets. Specifically, he had naïve understanding on the functions of and differences between theory and law, subjective and socio-cultural NOS. In fact, it can be also said that Kemal’s NOS views were dependent to each other. For example, although Kemal asserted that scientific knowledge can be changed by the new interpretations, he held the naïve idea that the change of laws is difficult because laws are certain knowledge. Specifically, regarding embedded NOS views on theory and law, he had the misunderstanding that the greenhouse effect is a law. Therefore, he hold the misconception about the functions and differences between theory and law. In here, the deficiencies in his understanding of the functions of theories and laws affected his view of tentative NOS. Likewise, his misconception that there is a scientific method universally accepted led his understanding to be naïve in terms of subjective and socio-cultural NOS. On the other hand, Kemal's understanding that scientific claims are based on empirical evidences helped his view of inferential NOS become substantial. Kemal's understanding was more informed on the aspects of creative and inferential NOS. To conclude, Kemal did not have sophisticated views of NOS because he was not deeply informed in all of the NOS tenets. Moreover, it observed that he did not translate any aspects of NOS into his classroom practice of biogeochemical cycles. Next section documented Kemal's SD understanding regarding biogeochemical cycles.

4.1.1.3. Kemal's Understanding of Sustainable Development Regarding Biogeochemical Cycles

In order to reveal Kemal's understanding of sustainable development (SD) regarding biogeochemical cycles, he was asked to state what the causes, consequences and solutions to the disruptions on the cycles. Besides, his teaching of biogeochemical cycles was observed. Therefore, both his practice and responses unveiled how Kemal linked the biogeochemical cycles to the aspects of sustainable development.

Kemal began with the explanation that anthropogenic activities are main causes of many problems related to the biogeochemical cycles. He generally touched upon the unconscious use of natural resources (water, energy, food, soil, etc.) by human beings. Therefore, he attributed the environmental problems to human activities referring the environmental aspect of SD. He especially had the idea that human activities should sustain the balance of nature.

> **Kemal (K):** The factors that cause the deterioration of the cycles are people [behavior]… We [people] have polluted the seas, cut the trees, and released too much greenhouse gases to the atmosphere. We are seriously abusing the balance of the nature. We devastated the earth…

4.1.1.3.1. Kemal's Knowledge on the Connections between Carbon Cycle and Sustainable Development

In respect of the degradation in carbon cycle, Kemal stated that the environmental problems such as the extensive use of fossil fuels and deforestation caused to the increase in emissions of CO_2 and other greenhouses gases to the atmosphere. He specially emphasized the atmospheric pollution because of the activities arising from energy need. In here, Kemal had the idea that population growth caused the unbalanced use of natural resources and consequently, the scarcity of energy resources. As a solution, he suggested the use of renewable energy sources by emphasizing the consequences of the consumption of the non-renewable ones for future generations. In other words, Kemal stressed that the development should be compatible with the balance of nature and the future of generations. Therefore, it can be said that Kemal linked the aspect of energy to the SD aspects of society and environment by implying that the problem of scarcity of energy caused to the damage the natural resources which affects the future generations.

> **K:** …It is said that there are 7 billion people in the world. If we calculate the daily carbon dioxide gas releasing from the factories, cars, houses where those people's activities were carried out, we can realize that there was excessive atmosphere pollution. We have released too much carbon dioxide to the atmosphere. We know the only living thing that assimilates the carbon dioxide from the air is the plants. So, if the air is so much polluted and forests are destroyed, how much the plants can photosynthesize? How will the carbon-oxygen cycle continue?
>
> …For example, we have still suffered from the consequences of the Chernobyl in Black Sea region. I accept that we need energy but I think that the use of non-renewable energy sources such as fossil fuel and nuclear is too dangerous for our future…

Furthermore, it can be seen that Kemal tried to imply the unsustainable modes of production through the industrialization and urbanization. He emphasized that a society could develop its prosperity by the help of the industrialization. He had the idea that production-based development improves the living standards of the society. However, he mentioned that the unplanned industrialization destroy the vegetation from land for construction of roads, bridges, and factories. He, therefore, implied that unplanned development policies could cause to be damaged the environment. In here, it can be obviously seen that Kemal referred four aspects of SD, namely; economy, politics, society and environment by emphasizing the production-based society, development policies, society's prosperity and damaging the nature.

> **K:** If we want to create a society with a high level of prosperity, we need to make production. I mean we need to industrialize. Industrialization means the construction of new factories, new roads, new houses and new cars etc. To build these structures, however, millions of trees are destroyed. For example, 17 million trees were cut [in Istanbul] for construction of second bridge in Bosphorus. [In fact] Not only the trees, but also the entire ecosystem was damaged. While creating a wealthy society, we are destroying nature. Industrialization means construction of more factories with chimneys, so it means more carbon is released to the atmosphere. So what I mean is that industrialization pollutes the world… The desires of the human beings and madness of production and consumption, which came with industrialization, polluted the world.

Kemal also emphasized the SD aspect of politics in preserving the balance of the nature. He especially mentioned that all countries including both developed and developing countries must have the policies to control the CO_2 emissions for the equilibrium of the nature. In here, Kemal also touched upon the social responsibility for development of the society. He believed that both governments and humans should know their own responsibilities to protect the future generations. Kemal also attributed society's level of of prosperity to the developments in education by means of educated and awared generations. Moreover, he touched upon that green technologies needs to be developed in order to decrease CO_2 emissions. He suggested that renewable energy sources should be used. However, he complained that these [renewable] energy sources were not preferred due to the high cost of system setup. Thus, he implied that the permanent solutions for the environmental problems should be found by the help of the develpoment in every area including society, economy, energy, politics, technology and education. Therefore, he stressed the all aspects of SD by underlying the geopolitical and social issues.

K: …We all know that we need to conserve the balance of the nature. It is important to note that the countries which pollute the world mostly are G7 countries. They [G7 countries] have an organization once a year and talk about what to do, which is not enough to save the earth. It is necessary to take action to save the earth. When the balance of the world is overturned, all of the people not only in G7's will all suffer the consequences of this deterioration. The people in all societies are on the same ship…If we raise environmentally conscious generations, we see that societies with a high level of prosperity are formed. All countries should reduce their carbon emissions. Both underdeveloped and developing countries such as Turkey are using the technologies produced by the G7's. Then, the produced technologies need to be greener. Technologies which filter or reduce the carbon emission need to be produced and consumed. Most importantly, renewable energies must be used. Since it is costly to establish and expand facilities, these energy sources are not preferred, unfortunately…

Kemal, again, stressed the aspect of environment implying that sustainaning the natural balance is important. He pointed out the global warming and climate change as the main results of the disruption of the carbon cycle arising from the antropogenic activities. He, therefore, touched upon that human activities should sustain the balance of nature.

K:…If we do not value the protection of nature and the environment, the economic strength will have no meaning. Today, we pay the biggest bill of environmental damage caused by global warming and climate change… We know that greenhouse gases such as water vapor, CO_2 and methane warm up the atmosphere naturally holding the heat reflected from earth and but we have released too much carbon dioxide and other greenhouse gases to the atmosphere. The atmosphere is covered by CO_2 because of the excessive burning of fossil fuels in cars, home, factories…This event causes earth to get warmer seriously. At the end of this warming, climate changes… Drought will begin to occur and our world will be desert…At the same time, because of excessive rains, the excessive floods will occur. Finally, due to the extreme decrease in temperature, the earth will glaciate. These are [all] the consequences of the climate change…

Briefly, when Kemal's responses related to the causes, results and solutions to the degradation of the carbon cycle were examined, it can be seen that he touched upon the important phenomena such as greenhouse effect, global warming, climate change and atmospheric pollution. Additionally, he connected these phenomena with the main issues of sustainable development except the poverty. During his explanations of the connections between the carbon cycle and SD, Kemal also addressed all seven aspects of sustainable development including environment, society, economy, politics, energy, technology and education.

4.1.1.3.2. Kemal's Knowledge on the Connections between Hydrological Cycle and Sustainable Development

Kemal generally showed the understanding that the degradations in carbon cycle affects the hydrological cycle. As can be seen, during he was mentioning the climate change as a result of the disruption of carbon cycle; he touched upon the phenomena of desertification and glaciation as the phenomena which affect the hydrological cycle directly. However, he did not address how these phenomena affected the hydrological cycle. Likewise, although he addressed the droughts and floods as a result of climate change, he could not connect these issues to the degradation of the water cycle.

Kemal also addressed the large amounts of agricultural irrigation as unconscious use of underground waters. In here, he referred the unbalanced use of water resources as the causes of the water scarcity and the depletion of the fertility of the lands used for agriculture. In other words, he again stressed the damage of the natural resources affects the future generations. Therefore, Kemal, ih here, had the idea that balanced use of natural resources is important for development of the generations of the society.

> **K:** As I said, we have polluted the world. I think our children will suffer the consequences of this water pollution. After the 40-50 years, they will not be able to find potable fresh water. We witness to the excessive withdrawing of ground waters where there have been a lot of agricultural activities. In those places, the formation of the pothole increased. For example, there has been a problem of land subsidence in Konya Plain [a plain takes place in the Central Anatolian Region of Turkey] because of extensive irrigation in recent years.

To summarize, when Kemal's responses related to the causes and results of the degradation of the hydrological cycle were examined, it can be seen that he touched upon the SD issues such as floods and droughts, water scarcity and agricultural activities. Moreover, he addressed the water pollution, desertification and glaciation as the phenomena that influence the hydrological cycle. However, he could not explain the connections between these phenomena and related SD issues. Again, he did not touch upon the phenomena such as soil salinization through salt water intrusion and the pollution of water resources through atmospheric pollution. Moreover, he did not address the trans-border conflicts of water, the diseases arising from water pollution or the non-conventional water resources as sustainable issues related to the hydrological cycle. Terefore, regarding hydrological cycle, Kemal's understanding of SD only focused on the aspects of environment and society emphasizing that balanced use of natural resources is important for development of the generations of the society.

4.1.1.3.3. Kemal's Knowledge on the Connections between Nitrogen Cycle and Sustainable Development

When Kemal's responses were examined in terms of the degradation of nitrogen cycle, it can be seen that he addressed that household, industrial and agricultural wastes caused to water pollution. He also emphasized the reduction in variation due to the water pollution. In other words, he implied the interdependency of the cycles. Therefore, he attributed the environmental problems to human activities referring the environmental aspect of SD. He especially had the idea that human activities damaged the sustainable balance of nature.

> **K:** Now let's say we have a lake or a sea or a river. Now this lake is 200 meter in depth. Within these depths, plants, algae, and/or planktons live. But if there is a very intense pollution in the lake due to the household wastes, agricultural activities, industrial wastes from factories, paint wastes from leather and textile industry, the water becomes blurred with time which blocks sunlight. So, photosynthesizing organisms living in this contaminated lake cannot produce oxygen. Due to the lack of oxygen both in the water and atmosphere, this is resulted with a decrease in the number of biodiversity which in turns cause the extinction of the species over time.

Moreover, he did not emphasize the eutrophication due to the excessive nitrates in the soil or water resources. In the same way, he did not address that the greenhouse gases includes nitrogen. Thus, he did not relate the excessive nitrogen in the atmosphere to the acid precipitation. On the other hand, it was observed that Kemal mentioned the acid rains in her teaching of biogeochemical cycles. During his teaching of carbon cycle, he only mentioned that the structure of acid rains includes contains carbon element. However, he did not relate this phenomenon to the nitrogen cycle. To sum up, it can be seen that Kemal only addressed the acid precipitation as a phenomenon and water pollution as an issue of sustainable development in nitrogen cycle. In that case, Kemal's understanding of SD only focused on the aspects of environment emphasizing that human activities should sustain the balance of nature.

Finally, while mentioning the solutions, Kemal especially focused on the SD aspect of education. He emphasized that developments in education could create more sustainable world for the future generations with the help of educated and awared people. Thus, he stressed the society aspects by underlying the future generations.

> **K:**…Sustainable life, sustainable environment, sustainable energy, sustainable nature, sustainable economy. The basis of all these issues lies in education. In such issues, if we do not educate our society, we will disappear. We will struggle with ilnesses, the problmes such as the loss of land, the scarcity of water or energy. But if we are educated in terms of sustainability, I believe that we can cope with all of these problems and make our world a more peaceful, greener, safer home. I mean that education leads to awareness of people and finally people in the society can share the responsibility for the future…

To conclude, When Kemal's explanation related to the results, causes and solutions to the depletion in biogeochemical cycles examined, it can be seen that he mostly underlined the issues and aspects of SD in the carbon cycle. Therefore, it can be said that he failed to connect both nitrogen and hydrological cycles to the related sustainable development aspects although he mentioned some SD issues related to these cycles. Additionally, although Kemal mainly approached to biogeochemical cycles from the environmental aspect, he adressed all aspects of SD in related parts of his explanations. To sum up, Kemal's conceptions of SD regarding biogeochemical cycles can be seen in Figure 4.4.

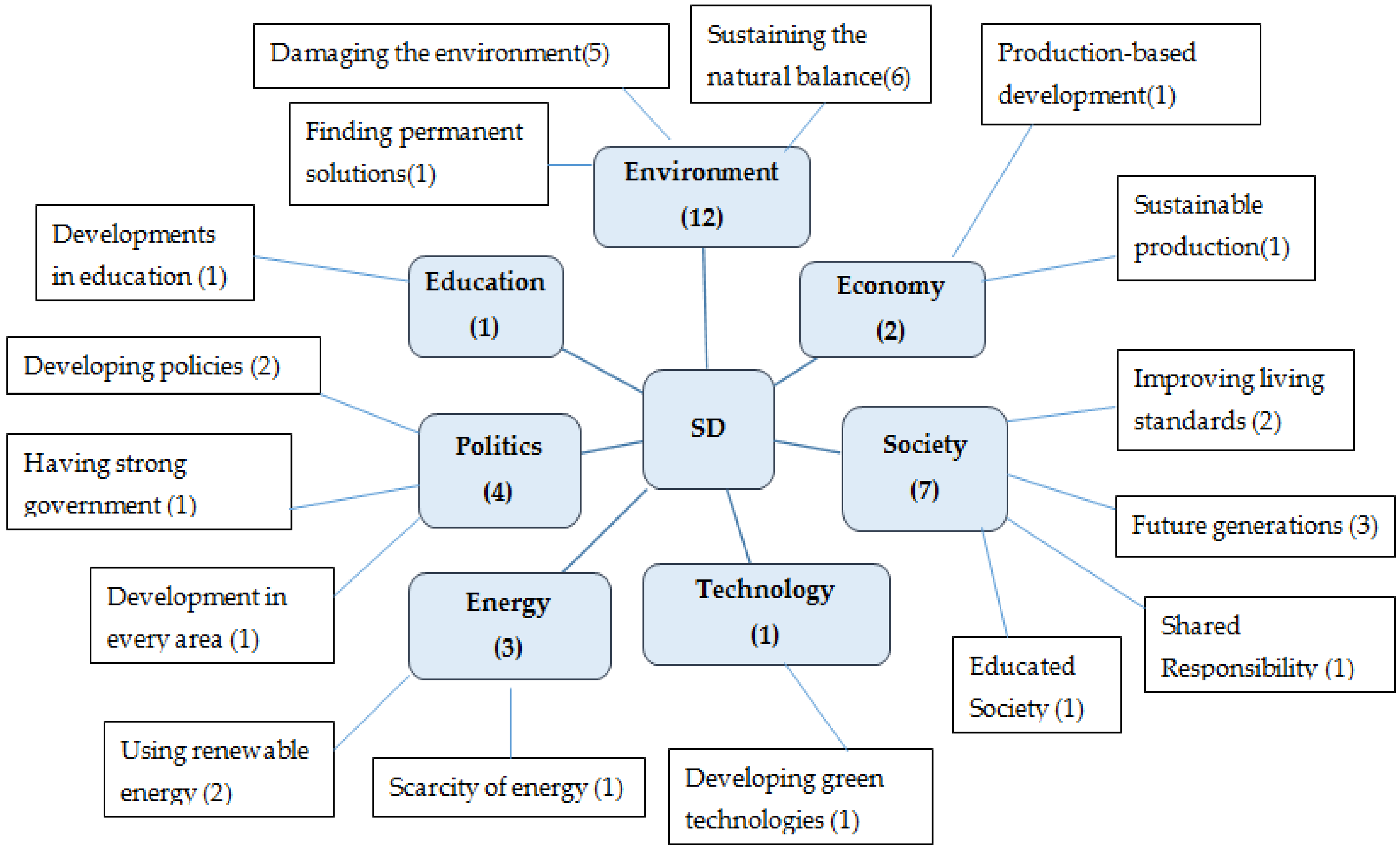

Figure 4.4. Kemal's Conceptions of Sustainable Development

4.1.2. Kemal's Pedagogical Content Knowledge

4.1.2.1. Kemal's Orientation to Science Teaching

In this section, Kemal's beliefs about goals of science teaching at grade 8th were presented based on the analyses of his responses to both the card-sorting scenarios and the interview questions related to the goals of science teaching.

Kemal cited that his beliefs about central purposes for science teaching were generally affected by the national science curriculum and TEOG exam (currently known as LGS). He expressed that his basic goal of science teaching was to transmit the curriculum objectives. Furthermore, he focused on the goal of preparing students to courses taught at high school which are chemistry, physics, and biology. He emphasized that specifically in 8th grade level; the goal of science teaching was to prepare learners to high school exam because of the existence of TEOG (See Table 4.11 for sample quotas).

Table 4.11. Kemal's Sample Statements related to Beliefs about Central Goals for Science Teaching

Central Goals	Sample Statements
To transmit the knowledge required by curriculum	As a science teacher I have no special goal. I present the topics as a curriculum objective at the 8th grade. That is, we present the scientific concepts as curriculum knowledge…
To prepare learners to high school courses	…Science teaching, in my view, is an education given students to prepare them for high school years…That is to say, science education is branched to physics, chemistry, and biology in high school. So science education in middle school basically should given students to prepare them to these courses…
To prepare learners to high school exam	…My main goal at the 8th grade is to prepare students to high school exam. One of the visions of our school is to be successful in high school entrance exam, too. We try to prepare students for a qualified Anatolian or science high school.

When it comes to his peripheral goals for science teaching, Kemal pointed out that one of his goals for science teaching is to connect science and daily life. Moreover, he stated that he tried to help students fulfill their needs in daily life. His responses included that science teaching is necessary to comprehend technological knowledge and development (See Table 4.12 for sample quotas).

Table 4.12. Kemal's Sample Statements related to Beliefs about Peripheral Goals for Science Teaching

Peripheral Goals	Sample Statements
To prepare learners to life	…In a simple sense, preparing children for life is a part of science education…
To help learners to satisfy their needs in daily life	…Science education is a process in which students are given basic knowledge related to their lives or to survive in a rapidly changing world. They need to have this knowledge in order to meet the needs of their daily life (i.e., the need for shelter, nutrition, the energy…)
To help learners to connect science and technology	Technology is inevitable need in today's world. Science teaching is necessary to comprehend the technology. This [science] education helps students learn how to use technology as well.

Kemal's beliefs about the central and peripheral goals of science teaching completely overlapped with the orientations that he chose as parallel to his science teaching. These orientations were based on the scenarios in the card-sorting activity. Kemal stated that the scenarios numbered 1, 4, 5 and 13 corresponded to his teaching. These scenarios were didactic, conceptual change, academic rigor and the reality of Turkish Educational System respectively (Table 4.13 for sample quotas). Although he chose the conceptual change as his orientation to science teaching at 8th grade, it could be obviously seen that his explanation was not appropriate the definition of conceptual change.

First of all, he pointed out that he generally preferred didactic teaching to transmit necessary knowledge to the students in a shorter time in 8^{th} grades.

> **Kemal (K):**…In my science courses, I usually give a general definition of biogeochemical cycles, I try to reinforce this definition with some examples in our daily lives, and transfer the knowledge of biogeochemical cycles to the students. The aim of the students' learning is to answer the questions asked in written exams.

According to Kemal, teachers had to teach the particular body of the curriculum in certain times because of TEOG. Hence he mentioned that the main goal was to prepare students to high school and the entrance exam so he preffered solving different questions related to topics during his courses. Futhermore, he expressed that teachers had both legal obligation and responsibility for obeying the curriculum and they were not free to carry out different activities.

> **K:**…TEOG is a national common examination that 8^{th} grade students in all over the country enter in the same day. It means that if you do not complete to teaching of required topics until certain dates in the first and second semester, you are responsible for any problems arising from the incomplete topics. We [teachers] have a legal obligation and administrative responsibility…We sign on this issue that we will complete the topics... My problem is that we are not free. We are given a curriculum, given a time schedule, and I have to be in accordance with the curriculum.

When he was asked why he selected those scenarios, he stated that because the scenarios shared a common characteristic, which is being teacher-centered. He expressed that there was a limited time to complete the topics because of the national examination (i.e., TEOG) so those scenarios were appropriate for his science teaching in 8^{th} grades.

Table 4.13. Kemal's Sample Statements Related to Orientations Parallel to His Teaching

Orientations	Scenarios	Sample Statements
Didactic	A good way to effectively teach students about biogeochemical cycles is by lecturing to draw the figures of the cycles by using the blackboard and tell the students the differences between the cycles.	We have a limited time so that one of our basic goals is to transmit the related knowledge to the students. To teach biogeochemical cycles, I give daily life examples, draw figures on the board. I have to teach this topic in line with curriculum.
Conceptual Change (*His orientation was not conceptual change*)	A good way to teach students about recycling is to ask questions and/or to use a demonstration that will check on the students' prior knowledge of the topic and then try to eliminate their misconceptions with scientific conception.	Let's say I will teach the electricity in the 8th grade. I ask children "What is electricity? What did you learn about the electricity? What did you learn about the electricity in 5^{th}, 6^{th} and 7^{th} grades?" I check the previous knowledge of students about electricity. If they say something wrong, we correct it in class. I ask if there is anyone who knows [about the topic], a couple of students raise their hands. After that, I repeat the topic by using students' previous knowledge and correct their misconception if any. Then, I continue to teach new topic about the electricity.
Academic Rigor	One way to effectively teach students about renewable and nonrenewable energy source is to solve different and difficult questions (problems).	In 5, 6 and 7^{th} grades, I can do different activities but in 8^{th} grade I generally teach the topic, and then I try to solve different questions…
Reality of Turkish Educational System	As a teacher, you think that the best thing to do for students is to prepare them for high school. Therefore, you teach the topics and then try to solve as many problems/questions as possible.	…Our basic aim is to prepare them [students] for the exam, to prepare children to an Anatolian high school having high quality…

Kemal pointed out that he could not utilize the remaining scenarios, including activity driven, discovery, guided inquiry, project based, inquiry, process, liberation and curriculum goals due to their student-centered nature. He explained that such scenarios required time and not suitable for crowded classrooms. He also mentioned the teachers' and students' anxiety regarding national exam, the overloaded curriculum, and the context of the school were most important factors to be done these activities. Kemal's sample quotas related to these scenarios can be seen in Table 4.14.

Although he varied his teaching with daily-life examples and questions to facilitate students' understanding of the basic concepts, observation data (the teaching of the biogeochemical cycles) revealed that lecturing and questioning were dominated his teaching as well. He did not use any subject-specific strategies (orientations) apart from the direct instruction. His teaching was generally structured, sequenced and led by himself which was line with his orientation.

Table 4.14. Kemal's Sample Statements Related to Reasons of Orientations Not Corresponded with His Teaching

Orientations	Scenarios	Sample Statements
Process-Scientific Skill Development	The best way to teach the carbon cycle is to use data obtained from the research on the topic. Then you ask students to formulate hypothesis, interpret data, analyze the data, and communicate their results with others in the class	Students need adequate time to formulate a hypothesis, interpret and analyze data. The student does not even have more time. Also the students can neither formulate a hypothesis, nor interpret the data. We do not teach them formulating hypothesis, interpretation of data, or analysis of data. Teaching of these processes is not possible in middle school. Theoretically, students will learn these subjects in high school...In fact; none of teachers are knowledgeable with the scientific process. I think that there is limited number of teachers that can address the scientific process in the lessons.
Curriculum Goals	One of the effective ways in order to teach the contributions of researches and developed technologies on renewable energies and technologies to the environment and the country's economy is to ask students to interview experts (engineers and scientists etc.) related to the subject and to present their research results to their classmates. An effective way to educate learners as environmentally responsible citizens is to ask students to investigate how to find solutions to the problem of waste, one of the most important problems of our day as a result of human activities.	In real classrooms, we do not implement such things [interviews with experts/scientists]. At best, two or three students can ask for project homework about these issues [the contributions of researches and developed technologies on renewable energies and technologies to the environment and the country's economy/ solutions to the problem of waste] in one semester. The only thing students can do in the lessons is to download the relevant documents from the internet, prepare a file and present it to me.

Table 4.14 (Continued)

Orientations	Scenarios	Sample Statements
Activity Driven	One way to effectively teach about biogeochemical cycles to use laboratory and/or classroom activities in which will provide the students the best opportunity to learn the topic.	I can not use laboratory activities in general. Especially in chemistry topics I can use laboratory but unfortunately I do not have necessary time to deal with the experiments. I can only teach the topics in the class theoretically.
Inquiry	By separating the students into groups and giving them a scenario from their surroundings, an effective way of teaching environmental problems caused by non-renewable energy sources is to ask students to educe a cause-and-effect relationship with these problems and to assess the validity of the information in order to generate these outcomes	I think these scenarios [inquiry & guided inquiry] are including higher order skills than the ones the students have. If I ask them to do such homeworks, they [students] can submit good assignments because there are thousands of homeworks on the internet on these issues. But, I do not think the methods in these scenarios are useful. Because the students do not prepare the homework, instead their parents do. Therefore, such homeworks are not really students' performance and do not mean anything to me.
Guided Inquiry	One way to effectively teach students about the disruption of biogeochemical cycles is to allow students to design their own experiments using variables they decide upon.	

Table 4.14 (Continued)

Orientations	Scenarios	Sample Statements
Discovery	The best way to teach students about the renewable and nonrenewable energy sources is to ask students plan an investigation/activity that allows them to present the areas of usage of these sources.	We can talk and discuss this issue [renewable and nonrenewable energy source] theoretically in the class. We can do this activity [planning an investigation/activity] in 7th grades but I do not ask students to do such an activity in 8th grades. When I ask them to do an activity, I waste their time.
Project-based	One of the effective ways of teaching recycling is to encourage students to participate in NGOs interested in environmental protection, and to cooperate with these non-governmental organizations in order to provide solutions to waste disposal.	In the ecoschool project, we have just applied such activities very effectively. However, 8th grade students are not interested in such things…On the other hand; the curriculum includes only the definition of recycling. For the teaching of this concept, I do not do such a great activity. I can only teach the recycling by lecturing at about 10-15 minutes in the class.
Liberation	After having studied the concepts related to the subject, one of the effective ways of teaching recycling is to allow students to discuss these concepts clearly and develop their own concepts.	This activity needs to time for students' discussion of the concepts. Furthermore, the discussion causes to the confusion in the class. As I said before, I have limited time for teaching the topics due to the TEOG exam. I can not use this activity in the 8th grades because of the classroom management as well.

4.1.2.2. Kemal's Knowledge of Curriculum

4.1.2.2.1. Kemal's Knowledge of Goals and Objectives

In the Science and Technology curriculum utilized during the study, there was only one objective specific to the topic of biogeochemical cycles, which is *students are able to explain biogeochemical cycles parallel to the energy flow in the food chain* (MoNE, 2005, p.354). The acquisition of this objective is closely related to the understanding of the previous topic which is energy flow in the food chain. Hence, the objectives of previous topic should be considered as a reminder to teach the topic of biogeochemical cycles. While Kemal was teaching the cycles, it was generally observed that he both helped students to recall the previous knowledge and checked whether the students gained the objectives related to photosynthesis, respiration, relationship between producers and consumers, and nutrition and energy flow in the food chain.

When Kemal asked the aim of teaching biogeochemical cycles in CoRe interview, he pointed out that the main aim of teaching this topic was the acquisition of the objectives in the curriculum.

> **Researcher (R):** What is your aim of teaching the topic of biogeochemical cycles?
> **Kemal (K):** As a science teacher I have no special goal. That is, we [teachers] present these topics as curriculum knowledge at 8th grade. While teaching biogeochemical cycles, I try to teach the importance of the cycles and the actions to be taken due to the continuation of the cycles. In other words, we answer the questions such as why carbon cycle, water cycle, nitrogen cycle are so important and what happens if they are disrupted… [CoRe Interview].

Besides, he emphasized that it was not enough to give students only the curriculum objectives to comprehend this topic. He therefore stated that because this topic is a matter of vital importance in human's daily life, he expected his students to gain affective domain objectives, indicated in Table 4.15, apart from the one in the curriculum.

> **K:** When the people interfere in the biogeochemical cycles, many problems come to light...If the industrialization and technology cause so much pollution in the

world; the problems arising from the disruption of the cycles will continue to happen increasingly. The earth is warming day to day; the earth's climate is changing. The forests are destroyed and the variation is decreasing. These problems affect human's life, affecting whole living things' lives. Then we need to solve these problems. So, I aim that students should be aware of the consequences of deterioration of the cycles and at least I try to make them more sensitive to environmental problems as an individual…[CoRe Interview]

Table 4.15. Kemal's Intended Objectives Related to Topic of Biogeochemical Cycles

Intended Objectives
To describe the effects of human on the biogeochemical cycles
To comprehend the consequences of deterioration of the biogeochemical cycles
To recognize what needs to be done for the continuation of the biogeochemical cycles
To raise awareness for environmental problems as an individual

In line with Kemal's CoRE interview, observation data (the teaching of cycles) pointed out that he tried to attract his students' attention to the human effects on the biogeochemical cycles. For example, he exemplified the environmental problems that occur as the consequences of human activities during his teaching of carbon cycle. Especially he associated the problems related to carbon and oxygen cycles to the deforestation (i.e., forest fires and the cutting down the trees).

K: …When people are interfering too much in nature, the balance of nature is destroyed. How people interfere in nature? For example, millions of hectares of the forests are disappearing because of cutting down the trees or forest fires. There are people who cut the trees intentionally and set up new buildings. For whatever the reason is, cutting trees is equivalent to killing people for me. Each tree both feeds us and produces oxygen. So, trees and plants are very important to maintain the cycles of carbon and oxygen...We are the consumers so if we want to contribute to the continuation of the cycles, we can plant a lot of trees and pay attention to our consumption habits…[Classroom Observation].

Moreover, Kemal was aware of both the horizontal and vertical relations to the topic of biogeochemical cycles in the science and technology curriculum. Regarding the horizontal relations, he emphasized that the previous topics of energy flow in food chain, photosynthesis and respiration are very closely related to the topic of the biogeochemical cycles. He pointed out that the learners' comprehension of these previous topics has vital importance in their understanding of the biogeochemical cycles. As Kemal expressed, it was observed that he often recalled the previous topics during his teaching of biogeochemical cycles.

> **K:**... In the previous topic, you learned that living things were transferring the energy to each other. First of all, we mentioned an ecosystem, did not we? We said that there are living things in the ecosystem and they continue their lives by transferring their energy to each other in this ecosystem. We started to energy flow with photosynthesis. We told the green plants have vital importance for the continuation of life by the help of the photosynthesis. They were at the bottom of the food chain....Which organisms consume the plants?
> **Student (Std):** Consumers.
> **K:** Yes, that is herbivors. Herbivors eats the plants and they receive the energy. Then the carnivores eat the herbivors and the energy transfers to the carnivores. While the energy flows among the organisms in this way, living things consume something during their lifetime? What do they consume? For example, plants consume carbon dioxide, animals consume oxygen…If so these inorganic matters should be cycled within the ecosystem due to continuation of the life Therefore, in this topic, we will mention about the biogeochemical cycles… [Classroom Observation].

When the vertical relations were taken in consideration, Kemal emphasized that the biogeochemical cycles are closely related to the topics of the basic building blocks of living things, the properties of elements and compounds, and the chemical bonds included in the learning area of matter and change in the science and technology curriculum at the grades of 6 and 7. In his teaching of biogeochemical cycles, it was observed that he often touched briefly on the required topics related to the each cycle. For example, at the beginning of his teaching of biogeochemical cycles, he leaded in the topic reminding to his students the importance of the building blocks of living things and the elements in these structures. Moreover, he evoked his students the difference between evoparation and boiling during his teaching of hydrological cycles.

> **K:…**You know that living things made up of the molecules of carbohydrates, proteins, fats, vitamins. When we examine the structure of these molecules, we see that they include some elements having vital importance. You had learned these molecules in the 6th grade, and even in the 7th grade. We said that there are carbon, hydrogen and oxygen elements in the structure of the organisms. Also there is nitrogen, phosphorus. They are very important for all living things. So, if these basic elements were not replaced when they were used up, we would

say that after a certain time, life would end. If living things can not use oxygen, they will not be able to breathe. If the carbon did not return to the nature, plants would not photosynthesize…Nitrogen is the basic building block of proteins. Its absence spells out the loss of living things. [CoRe Interview].

When asked the presentation sequence of the cycles in the curriculum, Kemal was aware of the place of the topic and the sequence of the sub-topics. However, he pointed out that he presented the cycles respectively carbon and oxygen cycle, hydrologic cycle and nitrogen cycle. He attributed the reason of the modification of the sequence of the sub-topics to the familiarity to pre-requisite topic and the importance of the problems related to the disruption of the carbon cycle. In other words, he modified the curriculum due to both his students' understanding and his beliefs about the teaching the cycles.

R: How is the sequence of the cycles presented in the curriculum?
K: In the curriculum, the matter cycles topic starts when the topic of energy flow in the food chain ends. First, the water cycle is presented, then carbon cycle and lastly, nitrogen cycle is presented. However, I do not pay attention to the sequence of the cycles…
R: Well, in your opinion, why is the sequence of the cycles presented in the curriculum like this?
K: I do not know why the sequence of cycles is like this in the textbook. The authors of the textbooks know the reason of this presentation sequence but I do not know ...I can only explain why I teach the cycles of carbon and oxygen first. The biggest problems of the world faced with are the ones arising from the disruption of oxygen and carbon cycles. There are too many industrilization, too much air pollution. The ratio of carbon is becoming higher day to day in the atmosphere and we can see that how the climate changes. So I begin with these cycles to the teaching of the topic of biogeochemical cycles. And I also said that the previous topics of photosynthesis and respiration are very familiar with these two cycles... It is easier to teach in this sequence for me…[CoRe Interview].

4.1.2.2.2. Kemal's Knowledge of Materials

In terms of resources used, Kemal explained that he has used the textbook and his own lecture notes to teach the biogeochemical cycles. He stated that he did not use textbook or student exercise book in the classroom actively. He underlined that he only used the textbook to follow the curriculum and that his main source was his own notebook that prepared from the internet sites (Table 4.16).

K: There was a problem with the cycles when I tried to teach depending on the textbook in the previous years. For me, it (textbook) was not enough. I prepared my own notes by the searching of the internet. I constructed a notebook which includes all of the topics in the curriculum in detail. I usually teach in line of these notes. Besides, before I teach, I update my knowledge about the topic from the internet. That is all. [CoRe Interview].

Table 4.16. Kemal's Aim of Using Teaching Sources

Sources that teacher use	Aim of using in teaching
Textbook	To follow the curriculum
Internet	To update the information about the topic
Personal Notebook	To teach the topics by the help of the information in notebook & To aid students take notes of related topic.

During the classroom practice, it was observed that Kemal usually used his notebook to benefit from the information related to the biogeochemical cycles. He took it as reference during both the teaching of the concepts and the drawing of the figure of each cycle. On the other hand, he did not use the textbook and student exercise book as he stated.

4.1.2.3. Kemal's Knowledge of Instructional Strategies

In this section, the knowledge of instructional strategies of participant teachers was reported in two categories namely, knowledge of subject specific strategies and knowledge of topic specific strategies.

4.1.2.3.1. Kemal's Knowledge of Subject Specific Strategies

The strategies handled in this category represent the general approaches to enacting science instruction. Teachers' knowledge of subject-specific strategies is related to the ''orientations to teaching science'' component of PCK (Magnusson, Krajcik & Borko, 1999).

Kemal stated that he mostly used direct instruction and questioning method. He pointed out that he let his students to answer questions and share their ideas about the topic and explained the topic the help of drawings and daily life examples through the lecture.

> **Researcher (R):** How do you teach the topic of biogeochemical cycles? Which instructional strategies do you use in general?
> **Kemal (K):** I draw the relevant figure and picture of the cycle all over the blackboard. I try to draw every thing I say... I finish the topic when I completed the drawing... I try not to teach in a boring way. I expect them [students] to be active in the lessons by using questioning method. [CoRe Interview].

Kemal attributed the main reason of the preffering questioning method to the crowded classrooms. He stated that each student has different characteristic and therefore, he could not use different methods according to their different learning styles. Furthermore, Kemal complained the students' high level readiness because of the national examination prevented employing of different methods.

> **R:** Why do you prefer to use this teaching method?
> **K:** The classrooms are very crowded. There are at least 40 students in each class and every student's perception and characteristic is different. I can not teach according to the learning style of each student. Besides, the students have already known the topic because they are taking extra lessons after school. They are studying for the TEOG exam... They have no difficulty in understanding of these topics…[CoRe Interview].

Kemal pointed out that the time devoted to teach the biogeochemical cycles in the curriculum was adequate. Accordingly, he addressed that he spent less time for teaching the topic than suggested by the curriculum. According to him, it is necessary to employ this method in order to teach the topic in a short period of time.

When Kemal's teaching of biogeochemical cycles was examined, it could be seen that the main characteristic of his teaching was its teacher-centeredness. He generally used questioning and direct instruction to transmit the content knowledge to learners. His teaching was generally based on lecturing. He did not use any student-centered strategies like 5E Learning Cycle, Conceptual Change Approach and Guided Inquiry etc.

4.1.2.3.2. Kemal's Knowledge of Topic Specific Strategies

Knowledge of topic-specific strategies of participant teacher was presented with two sections as; knowledge of representations and knowledge of activities.

4.1.2.3.2.1. Kemal's Knowledge of Representations

Results showed that Kemal used the representations like drawings and examples in order to aid students in developing the understanding of the topic of biogeochemical cycles. Especially, he actively used the blackboard to draw the figures to represent the concepts of carbon (Figure 4.5), hydrological (Figure 4.6), and nitrogen cycle (Figure 4.7). For each cycle, he drew the whole cycle systematically, explaining the concepts throughout the lecture. Sometimes, he invited students to the board and asked them to draw some parts of the cycle.

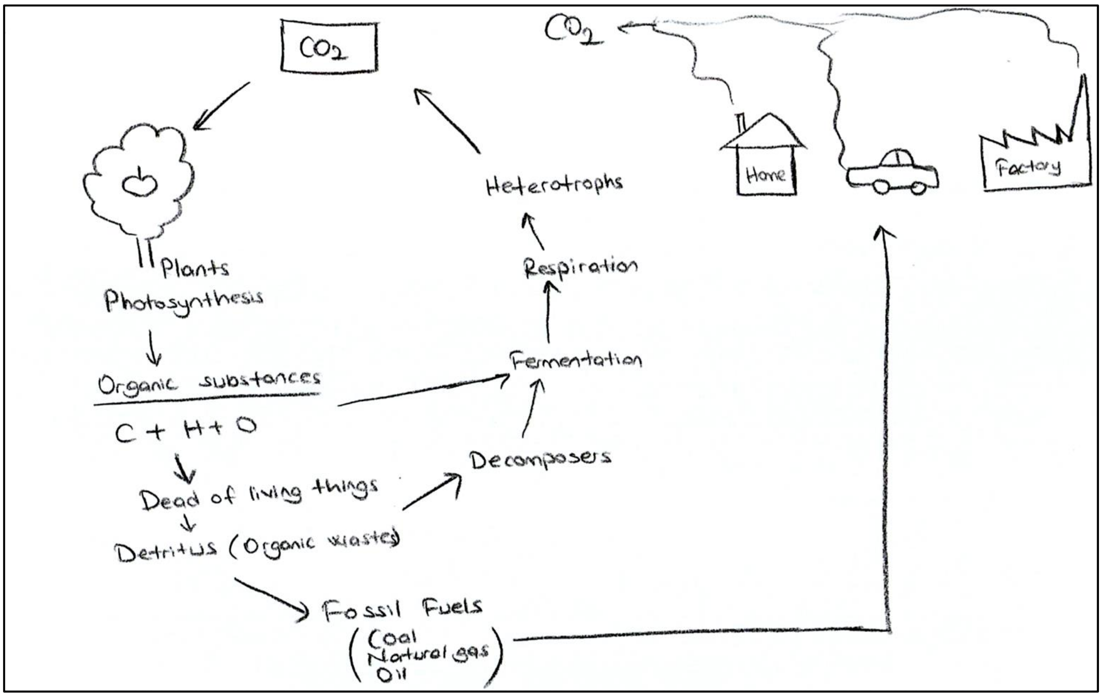

Figure 4.5. Kemal's Drawing Used to Teach the Carbon Cycle

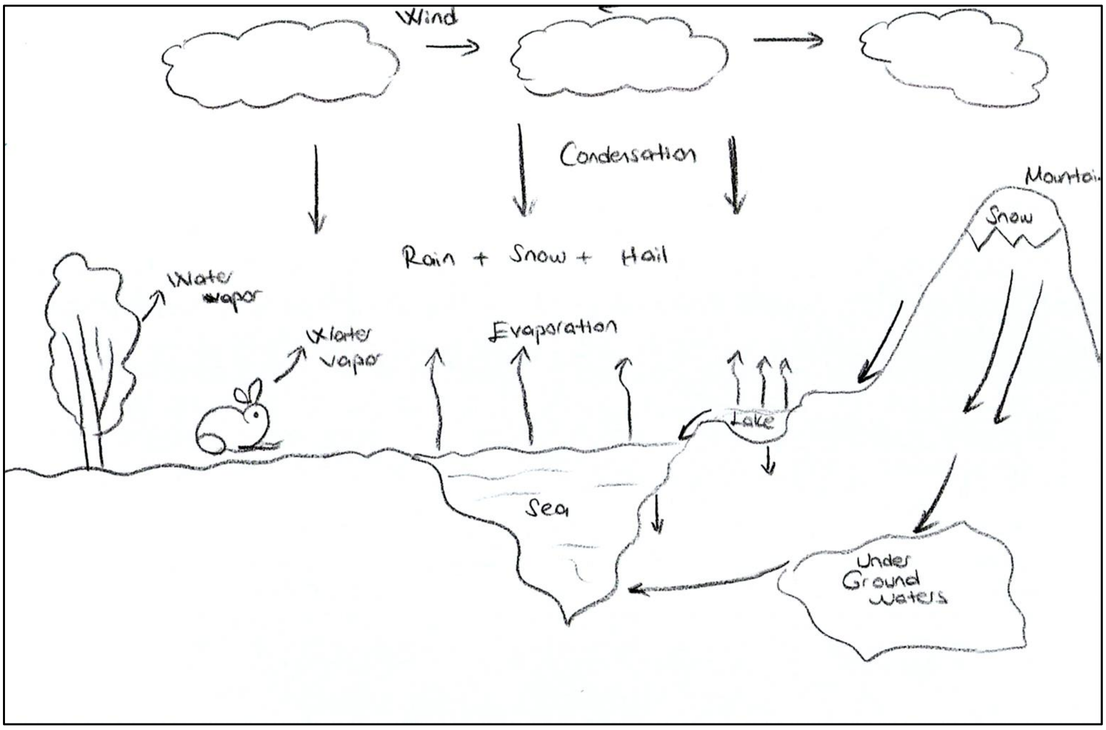

Figure 4.6. Kemal's Drawing Used to Teach the Hydrological Cycle

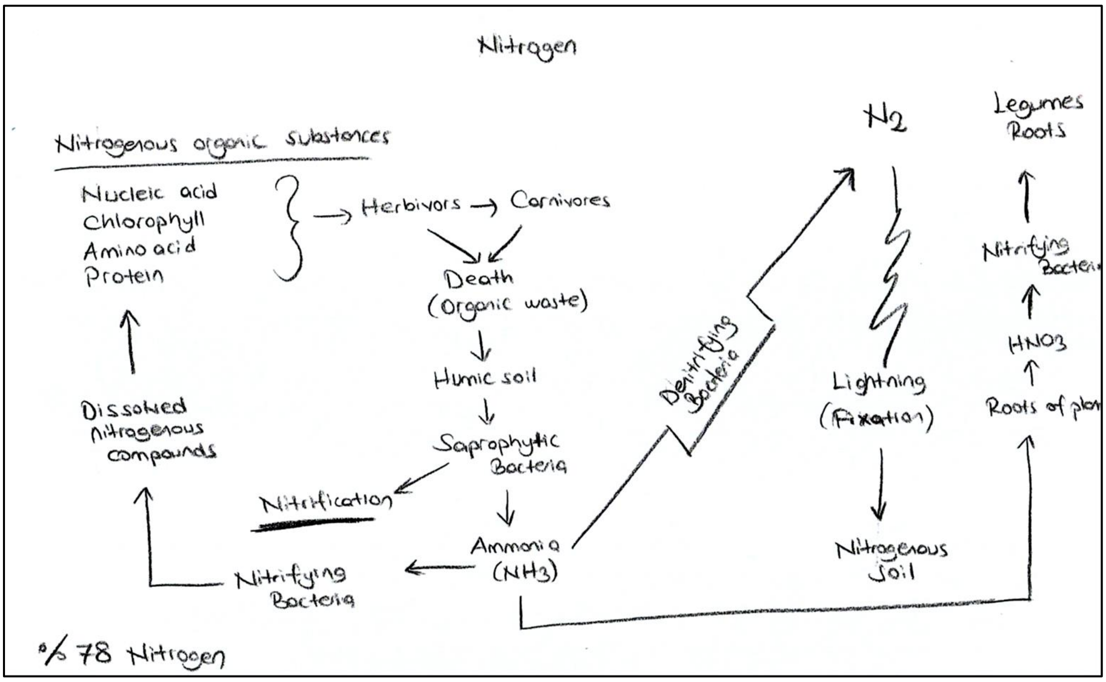

Figure 4.7. Kemal's Drawing Used to Teach the Nitrogen Cycle

Moreover, he gave various daily life examples to support the comprehension of students. At the beginning of the topic of biogeochemical cycles, to attract students' attention to the balanced amounts of matters in nature, he exemplified the consumption of the foods found in the refrigerator from daily life.

> **K:** You go home, you open the refrigerator, and you slice some cheese, and eat it. The next day you go home again, you open the refrigerator again, take some cheese and you eat. You do same things on the 3rd day, and when you go home on the 4th day, will you find cheese in the refrigerator?
> **Std:** I do not. No.
> **K:** Do not? Why?
> **Std:** Because I eat it all.
> **K:** You eat and finished it. What will you eat next time? You will eat olives. After a certain period of time, the olives will finish. So what? If we do not replace the things we have consumed, we will not be able to use them again. The same thing is valid for biogeochemical cycles. The cycle continues as long as the matters are in their reservoirs…[Classroom Observation].

Especially in his teaching of hydrologic cycle, Kemal gave many examples to emphasize the importance of water for living things. He first mentioned the examples of Aral Lake and the civilizations on waterfronts in order to attract students' attention to the conservation of the natural resources. Then, he tried to explain how important the water is by the example of a deer's thirst.

> **K:...** I watched it in a documentary. One scientist says that a lake whose size is five times bigger than Marmara Sea disappeared. A lake called Aral. It is disappearing and its waters are drawn. Such a lake disappears, but nobody cares. But if there was a drop of water from space, it was announced as extraordinary news. These statements cause me to be sorry because we can not preserve our sources. When you examine all civilizations, they were on waterfronts. What was the first civilization established in the Euphrates and Dicle basins? Is Sumerian civilization? Or Anka, Asian civilizations, you will see that they are established on the edge of a water source. The most important part of our life is being sucked into the water. One of our indispensable resources is water. It is essential for all living things…
> **…**
> **K**:… A deer thirsts; a crocodile awaits it in the swamp. The deer knows it, but goes there to drink water. Would you go there?
> **Std**: Yes, I would.
> **K**: You did. Why?

Std: In any case I will die. I would try to drink water. Other wise I will die due to the thurst. For me, being the food of crocodile is better than the thurst.
K: Okay, as you say, the deers go and drink water from there. So drinking water is very important to us...You have known that the cells of organisms can live only watery environment. So water is very important for plants, for animals, for all living things… [Classroom Observation].

4.1.2.3.2.1. Kemal's Knowledge of Activities

Kemal did not include any activities regarding the topic of biogeochemical cycles in his lessons. He used the representations rather than activities. He stated that he could only give examples and draw figures because of his students' high level readiness. He pointed out that since his students have already known the topic, the topic did not attract them anymore. In a result, Kemal expressed that he did not conduct any activities found in the textbook and student exercise book.

4.1.2.4. Kemal's Knowledge of Students' Understanding of Science

This component of PCK focuses on the teachers' knowledge in order to help students develop specific scientific knowledge. There are two subcomponents: requirements for learning and areas of difficulties. In this section, Kemal's knowledge of learners' understanding regarding the topic of biogeochemical cycles was presented.

4.1.2.4.1. Kemal's Knowledge of Requirements for Learning

Kemal was aware of the pre-requisite knowledge needed by students to learn the topic of biogeochemical cycles. He first emphasized that students need to know the structure of the carbon, hydrogen, oxygen, and nitrogen elements, the compounds they formed, and the organic structure of living things.

Researcher (R): What prerequisite knowledge do students have to learn the topic of biogeochemical cycles?
Kemal (K): First of all, it is necessary to for students to know carbon, hydrogen, oxygen, nitrogen elements. As well as their place on the periodic table, and whether metal or not. Students also should describe the properties of these elements. They should describe the chemical structure of the compounds formed. The important thing is to perceive the importance of these elements in our daily

life... Secondly, they need to know the organic molecules that living things consist of. They will learn what happens to these organic structures after living things die. So they will infer that organisms which are producers, consumers and decomposers are very important components of biogeochemical cycles…[CoRe Interview].

Then, he underlined the understanding of the topics of the photosynthesis and respiration; and food chain in the ecosystems as third requirement of the topic.

K:...The processess of photosynthesis and respiration are very important factors especially in the carbon and oxygen cycles. In the photosynthesis, the amount of light, the amount of water and the carbon dioxide is very important elements. In the respiration again, the food produced by plants and the amount of oxygen. And the interactions among the organisms in the food webs are important as well. These components are closely related to the biogeochemical cycles because they are the components and processes which take place in the cycles directly. Therefore it is required that the students should comprehend these topics meaningfully [CoRe Interview].

In his teaching, Kemal generally used the pre-requisite knowledge to aid his students' learning of the new topic of biogeochemical cycles easily. For instance, while teaching the topic of carbon cycle; he recalled the topic of energy flow in the food chain to introduce the relations between organic and inorganic structures in the cycle.

K: Who consume carbon dioxide in the air?
Std: Plants.
A: Plants use the carbondioxide in the air. So, the organisms that can produce their own food use this carbondioxide. What do they produce by using the carbon dioxide?
Std: Food.
K: They produce organic food, do not they? Well, do the plants live forever?
Std: No.
K: They die, do not they? How the plants die?
Std: They get dry.
Std: They turn pale.
K: So, does this plant die when an animal eat it?
Std: No, it does not.
K: Well, what happens in that case?
Std: Gives its energy.

> **K:** Yes, it gives the energy to another organism. So, the plant does not die; it becomes the food and turns into energy for other organisms [Classroom Observation].

On the other hand, Kemal considered his students' neither skills, abilities nor learning styles. He, generally, touched upon his students' requirements for their conceptual understanding.

4.1.2.4.2. Kemal's Knowledge of Areas of Students' Difficulties

Kemal stated that his students did not have any difficulty or any misconception in the topic of biogeochemical cycles. Kemal pointed out that students have concerned about the exam results, not the comprehension of the topic. He complained that his students have neglected the topic of biogeochemical cycles because of the limited number of the questions asked in the TEOG exam. Moreover, he stated that in environmental topics, students could not transform their knowledge to the daily life. He complained that the learners cannot develop an attitude in accordance with their environmental awareness.

> **R:** Do students have learning difficulties that will affect your teaching about biogeochemical cycles? This may be misconception or partial understanding. At what points are students have difficulties?
> **K:** …I do not have any inclusive student in my classes. I have taught in two 8th grades, both are successful. There are no excuses to understand this topic.
> **R:** Do not their prior knowledge have any misconception?
> **K:** Absolutely not. As I said before, their prior knowledge is very good... I have known these students since 5th grade. So, I have known whether the students comprehend the topics or not. Thus I can say that they do not have any difficulties in preliminary knowledge or comprehension of the required topics. However, ecpecially in such topics related to environmental issues, students can not transform their knowledge to their daily life. We can not evaluate whether students gain environmental awareness **[**CoRe Interview].

4.1.2.5. Kemal's Knowledge of Assessment

This category of PCK includes two subcomponents namely; knowledge of dimensions of science learning to assess and knowledge of methods of assessment. Kemal's knowledge of assessment was presented in this section.

4.1.2.5.1. Kemal's Knowledge of Dimensions of Science Learning to Assess

Kemal's knowledge of assessment on students' learning was examined in the dimensions of conceptual understanding, interdisciplinary themes, NOS understanding, science-process skills and/or problem solving skills. Kemal stated that during the lessons, he could only assess the content knowledge that students were supposed to learn in the curriculum.

> **Researcher (R):** Is there any assessment methods do you use in order to evaluate students' learning during the lessons?
> **Kemal:** Due to the national exam, we have a limited time, so we transmit the knowledge of the current topic and pass to new one. We can only assess what and how much students learn according to their grades on the written exams. I can also use the questioning in order to either evaluate their conceptual understanding or recall the knowledge on the previous topic. [CoRe Interview].

Data gathered via observations also revealed that Kemal generally focused on the assessment in order to evaluate his students' conceptual understanding rather than assessing other types of domains such as interdisciplinary themes, NOS understanding, science-process skills and/or problem solving skills. It was also observed that he endeavoured to elicit his students' conceptual knowledge asking several questions to monitor students' learning on previous topic. For example, he used the questioning method to reveal students' prior conceptual knowledge related to photosynthesis and respiration before his teaching on carbon cycle.

> **K:** ….In this topic, we will talk about the biogeochemical cycles. First of all, I want to start with carbon cycle. Why is carbon important? Do you have any idea?
> **Std:** It is important to produce food. Plants need carbon to produce food.
> **K:** Carbon or a compound of carbon?
> **Std**: The compound of carbon.
> **K:** It needs carbon dioxide. Anything else?
> **Std:** Carbon dioxide takes place in respiration. We gave CO_2 to the air.
> **K:** Yes.
> **Std**: Fossil fuels contain carbon.
> **K:** Yes, your friend has mentioned something important.
> **Std:** Acid rains include carbon.
> **K:** Yes, Anyting else?
> **Std:** It takes place in foods and in the atmosphere.
> **K:** Ok, then let's mention about carbon cycle [Classroom Observation].

Some questions that Kemal used to assess his students' learning after the teaching of carbon and oxygen cycle were presented below in Table 4.17.

Table 4.17. Kemal Sample Questions to Assess Student Learning

Questions
How do the plants produce energy?
What are the fossil fuels?
Where are fossil fuels used?

4.1.2.5.2. Kemal's Knowledge of Methods of Assessment

Kemal stated that he preferred to use only traditional assessment methods namely, informal questioning and written exam. He emphasized that he used only written exams which include multiple choice, true/false and open-ended questions to evaluate his students' conceptual understanding. He stated that the open-ended questions were distinctive ones to understand how much students learn. Furthermore he addressed the informal questioning to recall the prior knowledge of students during the lessons. He did mention any alternative assessment methods like concept map, structured grid, peer or self assessment.

> **R:** Are there any specific methods that you generally use to assess students' learning on the topic of biogeochemical cycles? How do you use these methods?
> **K:** Only written exams. Besides, I ask the questions in order to understand whether students learn previous topic before starting to new topic. That's it.
> **R:** Ok, then why do you assess in this way? What are the reasons?
> **K:** The system of TEOG forces us to use such methods. We do not have time to assess students' progress during the lessons. We have to be interested in students' scores on the exams. When a question is asked in the written exam or national exam, how many students can answer this question correctly is more important for me. For example, I asked a question during the lesson and Fatma answered very well. I said ''Fatma, you well done, you learned very well'' but then she took 20 points (out of 100) in the written exam. This result is not good for me. I mean that if the student has meaningful understanding of the topic, he/she should receive high scores in the exams.
> **R**: Which type of questions do you ask in the exams?
> **K:** There are multiple choices. There are the questions that students fill in the blanks. If we want, we ask two open-ended questions. The students get high scores from other questions except the open-ended ones. These are are distinctive in order to evaluate whether students meaningfully understand the topic [Core Interview].

Kemal used the traditional assessment techniques during his teaching of the cycles, too. He preferred generally the close ended questions to monitor his students' learning. He did not use any other assessment technique apart from the questioning to monitor learners' understanding through the topic. As mentioned in his CoRe interview, he did not provide any feedback for additional activities or review the points that learners have difficulties as well. In this regard, Kemal's formative assessment was missing.

> **R:** Do you assess your students' learning during the course? Or do you use any technique to evaluate what the students learn during the lesson?
> **K:** No, I do not. I have no time to assess students' learning during the course. If the classroom size is 20 students, I can use different assessment techniques but in the crowded classroom I generally use questioning to either recall the previous topic or monitor the students' learning. [CoRe Interview].

It was observed that Kemal only focused on the summative assessment at the end of the unit. He held a common written exam including multiple choice items (ten questions), true-false questions (five questions), and short answer (five questions). In the exam, there was only one multiple choice question in order to assess students' conceptual understanding on the carbon cycle. It was also observed that he could not even use the assessment techniques in the textbook and student workbook to assess his students' understanding during and after the teaching the topic. In the light of the explanations above, Kemal's knowledge of assessment was summarized in Table 4.18.

Kemal underlined that teachers had serious problems about the alternative assessment techniques. He stated that Ministry of National Education expected teachers to apply different methods, but they were not informed about these techniques. He asserted that teachers do not know how to assess students' learning.

> **K:** …We have serious problems with the measurement and evaluation. The Ministry of Education writes a lot of things about measurement and evaluation in the curriculum and wants us to use these methods actively. We have no idea about how they are used. The authorities can come and inform through the in-service training. They should train us on how these methods applied in the lessons…[CoRe Interview].

Table 4.18. The Summary of Kemal's Knowledge of Assessment

Method of Assessment	Aim of the Assessment	Type of Assessment	Way of Assessment	What is Assessed	Types of Questions
Questioning	To provide feedback on students' understanding on the related cycle	Formative	Informal	Prior Knowledge & Content (Conceptual Understanding)	Open & Close-ended
Written Exam	To evaluate whether students learn the topic at the end of the unit	Summative	Formal	Content (Conceptual Understanding)	Open-ended, multiple-choice, short answer, true-false.

4.2. CASE 2: Hale's Subject Matter Knowledge and Pedagogical Content Knowledge on Biogeochemical Cycles

In this study, the researcher used the pseudonym for the participant teachers and Hale was called for Case 2. Hale is female and forty-six years old. She was graduated from biology department in Faculty of Arts and Science of a public university in 1988. After graduation, she worked as a biology teacher for one year. Hale had completed her PhD in the department of molecular biology between the years of 2003-2009. She attained trainings on student-centered instructional strategies and alternative assessment techniques. Moreover, she has communicated with their colleagues to share teaching experiences via social media. She is an active participator in TÜRÇEV (Turkish Foundation of Environmental Education)'s activities and annual meetings. Hale has already been working in Eco-schools project implemented by TÜRÇEV for seven years in her current middle school. Currently, she has been teaching science for twenty-five years in public middle schools as a science teacher. Hale has taught 7 and 8^{th} grades during 2013-2014 education year and has twenty course hours as work load per week. There were thirty-three students in her classroom. In this section, Hale's results of subject matter knowledge and pedagogical content knowledge were presented.

4.2.1. Hale's Subject Matter Knowledge

4.2.1.1. Hale's Substantive Knowledge

The results of Hale's substantive knowledge regarding biogeochemical cycles are are presented in three headings, respectively; carbon cycle, hydrologic cycle and nitrogen cycle.

Hale initially was requested to answer the question what the biogeochemical cycle is. She explained the cycle as ''a process in which the amounts of the materials are conserved without being completely consumed''. Hale underlined the balance in the amounts of the chemical materials stating ''nature preserves and balances the amounts of the materials such as water, carbon, oxygen, nitrogen and phosphorus which are necessary for vital activities of living things''. She continued to her explanation mentioning ''plants, animals and other living organisms need to consume these materials [water, carbon, oxygen, nitrogen and phosphorus] and then, the detritus of the organisms are decomposed into inorganic matters under the soil by decomposers''. She added that these inorganic matters are used by living things through food web and returns to the atmosphere again. She detailed the biotic components of the cycles as plants, animals, decomposers, and living organisms in food web. Although she highlighted the soil as abiotic component of the cycles, she did not touch upon the sun as the source of continual influx of energy or driving force in the cycles. She also did not address the reservoirs of chemicals as the abiotic components. In result, Hale's understanding of the cycle was considered as partial.

Researcher (R): How can you define biogeochemical cycle?
Hale (H): Cycle is a process in which the amounts of the materials are protected without being completely consumed. Nature preserves and balances the amounts of these chemical materials which are necessary for vital activities of living things…The materials such as water, carbon, oxygen, nitrogen and phosphorus are used by plants, animals and other living organisms and then, decomposers decompose the detritus and the dead bodies of the organisms to inorganic matters under the soil. These inorganic matters are used by plants and other living things through food web and returns to the atmosphere again…

4.2.1.1.1. Hale's Knowledge about Carbon Cycle

To reveal Hale's understanding of carbon cycle, she was requested to draw and explain the carbon cycle. Hale's understanding of carbon cycle was labeled as partial based on the statements in both her drawing and teaching. In Table 4.19, Hale's understanding related to the carbon cycle is summarized.

When asked the question of why the carbon cycle is important, Hale initially underlined the existence of carbon and oxygen in the structure of living things. She highlighted the functions of carbon and oxygen in the formation of organic compounds such as proteins, carbohydrates, and fats addressing the food requirement of all living things, she emphasized the importance of CO_2 for the photosynthesizing organisms to produce food.

R: Why is the carbon cycle important?
H: Carbon and also oxygen are the main materials of substances that form the structure of the living body including cells. They [carbon and oxygen] are important elements because they constitute the structure of nutrients such as proteins, fats and carbohydrates. Furthermore, every living thing needs food to produce energy for vital activities. We, consumers, do not produce our own food. We can get the food through plants. Plants and other photosynthesizing organisms need carbon dioxide to produce food. For this reason, CO_2 has also vital importance for both the plants and all other living things.

Table 4.19. Hale's Understanding of the Carbon Cycle

	Hale's Understanding
Components within the cycle	• Plants, algae-cyanobacteria (as Producers) • The animals and humans (as Consumers) • Bacteria under the soil (as Decomposers) Organic compounds in the structure of all living things, fossil fuels, atmospheric CO_2 (as Carbon Reservoirs) • Soil (as Abiotic Component) • Water (as Abiotic Component) • Sun (as Energy source)
Processes within the cycle	• Burning of fossil fuels • Photosynthesis of plants, algae, cyanobacteria • Respiration of plants, animals and people • Transferring of carbon element from plants to animals and people by food substances • Decomposition • Carbon cycle in aquatic environment

Then, Hale continued to explain the carbon cycle through drawing (Figure 4.6). She initially underlined the process of combustion stating that the carbon dioxide is released to the atmosphere as a result of burning fossil fuels in human activities. She drew the fossil fuels under the soil as a source of carbon element. Later, she continued to draw the processes of respiration and photosynthesis. She touched upon that carbon dioxide is also released to the atmosphere through the plants, animals and humans during respiration. She detailed that carbon element in the structure of the food is transformed to the animals, people; reacts with the oxygen gas and returns to the atmosphere as carbon dioxide in the process of respiration. In here, Hale also referred the process of transformation of carbon from plants to consumers. Although she merely showed the plants as autotrophs in her drawing, she mentioned that organisms such as plants, algae, and cyanobacteria use the carbon dioxide in the atmosphere to make food during photosynthesis. Lastly, she addressed the process of decomposition in her explanations through drawing (Figure 4.8)

R: Could you please explain the carbon cycle by drawing?
H: …[Drawing] The main processes in the carbon cycle are photosynthesis, respiration and combustion. The carbon dioxide in the atmosphere is released during the processes of respiration and combustion, and used by plants in the process of photosynthesis. First I want to mention about the removal of carbon dioxide from the atmosphere via burning of the fossil fuels. When bodies of human, animals and plants stay under the soil for a long time, they form fossil fuels such as oil, coal, and natural gas. We use these fossil fuels in our homes or factories to produce energy. Thus, carbon and its derivatives are released to the atmosphere because of the burning of these fossil fuels…We know that there is almost 0.03 % CO_2 in the atmosphere. Plants are only living things which can use the carbon dioxide in the atmosphere. They use this CO_2 during photosynthesis and produce food. Thus, the carbon element in the carbon dioxide is stored in the food. Then, animals and people eat this food and the carbon compounds in the food are transferred to consumers. They [animals and humans] give out water vapor and carbon dioxide to the atmosphere again breaking up this food with oxygen gas during respiration. And lastly, decomposers separate the dead bodies of the animals, people and plants under the soil and the carbon dioxide returns to the atmosphere. And all processes are perpetually repeated for the maintenance of the life…

From the drawing, it can be inferred that Hale was aware of the reservoirs of the carbon. She referred the sources of carbon element as the structure of living things, atmosphere, and fossil fuels in her explanations during the drawing. On the other hand, she did not state the dissolved carbon compounds in oceans as a reservoir. Besides, she did not address the major source of carbon dioxide as oceans and biomass.

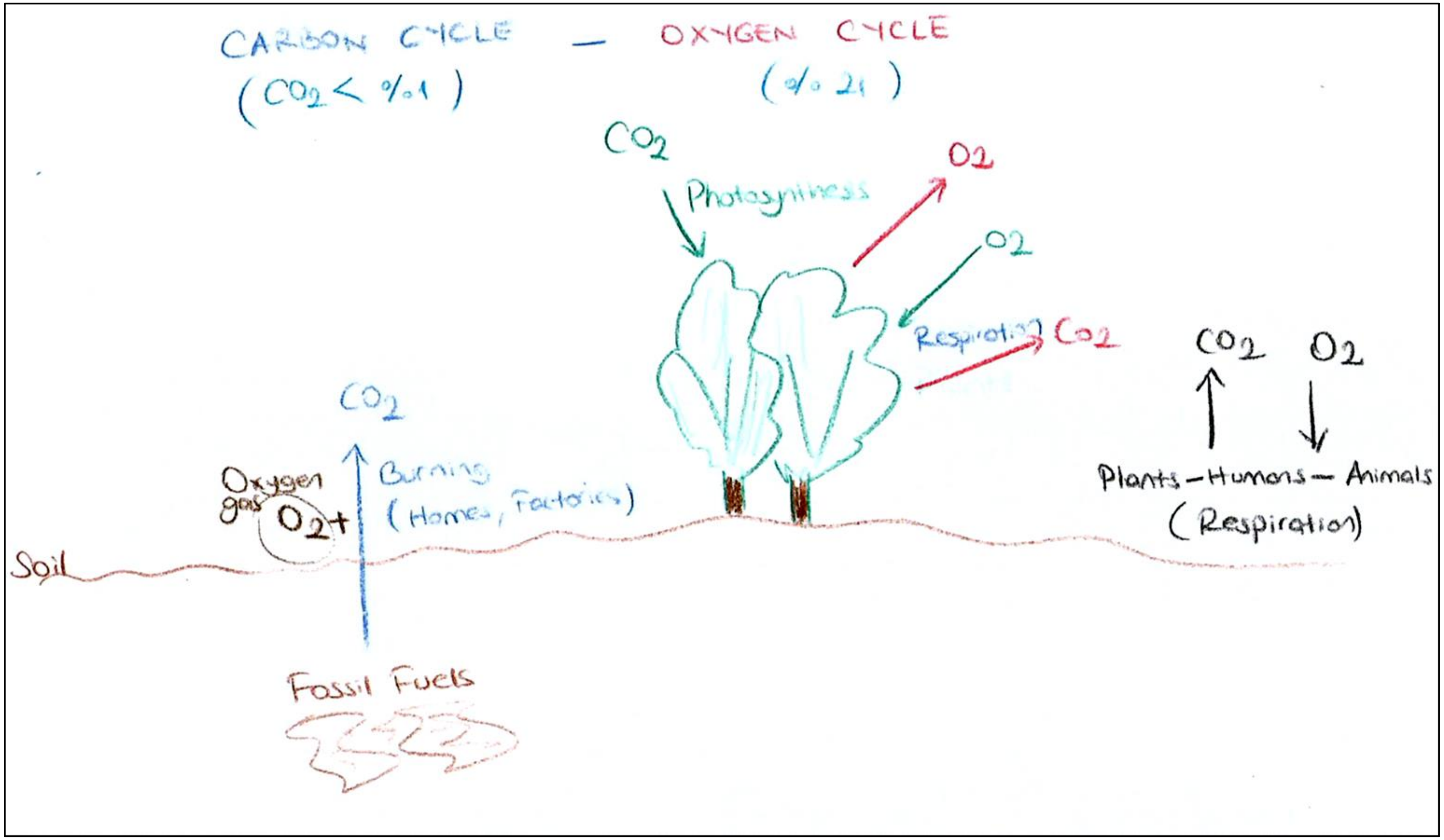

Figure 4.8. Hale's Drawing of Carbon Cycle

H: …Carbon and also oxygen are the main materials of substances that form the structure of the living body and cells. They [carbon and oxygen] are important elements because they constitute the structure of food substances such as proteins, fats and carbohydrates….

…There is almost 0.03 % CO2 in the atmosphere…

…When bodies of human, animals and plants stay under the soil for a long time, they form fossil fuels such as oil, coal, and natural gas…
When we mention plants we're not just talking about plants and trees on land. Algae living in water, i.e., cyanobacteria function as the plants. You know that in the carbon cycle, the producers in the water are algae.

Hale also referred that the oxygen cycle is associated with the carbon cycle. She stated that the processes within these [carbon and oxygen] cycles are interrelated, thus, did not draw the processes of the oxygen cycle separately. She solely emphasized that the process of combustion arises from the existence of oxygen. Moreover, she pointed out the importance of oxygen by explaining the function of ozone layer. She stated that the ozone layer absorbs the ultraviolet rays which are hazardous to the living things. In her explanation of carbon cycle, it can be seen that she explained the existence oxygen in the structure of all living things. In addition, Hale mentioned the proportion of the oxygen gas in the atmosphere.

H: We know that the oxygen cycle is reverse of the carbon cycle. The processes are interrelated in these [carbon and oxygen] cycles. The materials which are products in the oxygen cycle are inputs in the carbon cycle. Moreover, all combustion reactions arise from the existence of oxygen. I said that the carbon dioxide is released to the atmosphere during the burning of fossil fuels. This process [burning] needs the oxygen to happen. Also the process of the breaking of the food substances in the respiration also needs oxygen because this process is also a type of combustion…The atmosphere contains the ratio of 21% oxygen gas. Also, the oxygen is found as ozone in the atmosphere. We know that the ozone layer protects us from the ultraviolet rays…

In a brief, Hale's statements regarding the processes and components of carbon cycle in Table 4.19 were consistent to the scientific explanations. Although she underlined all biotic and abiotic components of the cycle, she did not state the dissolved carbon compounds in oceans as a reservoir. Additionally, she implied the aquatic carbon cycle while her teaching of carbon cycle but her explanations were not substantial. Lastly, she did not address the major source of carbon dioxide as oceans and biomass. In these considerations, Hale's understanding of carbon cycle was labeled as partial.

4.2.1.1.2. Hale's Knowledge about Hydrologic Cycle

To grasp Hale's understanding of hydrologic cycle, she was requested to draw and explain the hydrological cycle. Hale's understanding of hydrological cycle was labeled as sound based on the statements in both her drawing and teaching. In Table 4.20, Hale's understanding related to the hydrological cycle is summarized.

Table 4.20. Hale's Understanding of the Hydrological Cycle

	Hale's Understanding
Components within the cycle	• The plants (as Producers) • The animals, humans (as Consumers) • Oceans, Lakes, Glaciers, Ground Waters and Streams (as Water Resources) • Soil (as Abiotic component) • Sun (as Energy source) • Temperature & Wind (Climatic factors)
Processes within the cycle	• Evaporation • Condensation • Precipitation • Surface Flows • Transpiration • Penetration

Hale began her explanation with the importance of water. She expressed the role of water in the structure of living things which is in line with the scientific explanation. She mentioned the necessity of water in the bodies of organisms for metabolic activities. She exemplified the use of water in photosynthesis for plants and the filtering process of kidneys in human body.

> **H: …**For me, water is most important matter in the earth. The life is derived from the water. For instance, if so, the water was found in Mars, living creatures would come into existence, because the water is equivalent to the life. We need water for all metabolic activities such as eating, breathing, the filtering of the kidneys etc. Besides, the plants have to use water for producing food in photosynthesis…We can say that the water is vital importance for all living things…

Then, Hale mentioned all reservoirs of the water by giving an example for the amounts of the water resources on Earth. At that moment, she addressed the reservoirs of water such oceans, ground waters, lakes, rivers, and glaciers. She also mentioned the oceans as the major water resources.

> **H:** …There are several water sources on earth as oceans, seas, rivers, lakes and underground waters. Let's think that the amount of water on Earth is a hundred glasses in total. The ninety-seven glasses are the salty water in seas and oceans, and we do not use them as drinkable water. Then, two glasses of them are kept in icebergs. We, people, can only use one glass of water for drinking…We know that there are 7 billion people who need water in the world. However, we have one glass of water to drink! If so, we should use this water carefully. We should use our reasonable efforts in order to protect the natural water cycle…

Hale continued to her explanation with the process of evaporation in hydrological cycle. She especially underlined that the water evaporates at any temperature. Additionally, she highlighted the evaporation rate in the oceans. Then she showed the process of condensation in her drawing and mentioned about the formation of clouds. Thereafter, Hale detailed the process of precipitation as snow, rain and hail according to the atmospheric temperature. She also mentioned that the wind causes to the transmission of the precipitation to the different regions. She emphasized the surface flows and the process of penetration, as well. Moreover, she addressed the releasing of water vapor to the atmosphere through respiration and referred the process of transpiration of the plants in the hydrological cycle. However, she showed neither the biotic components as plants, animals and people nor the processes of respiration and transpiration in her drawing (Figure 4.9).

> **R:** Could you please explain the hydrological cycle by drawing?
> **H:**…[Drawing] First of all, through evaporation, water vapor moves from water sources to the atmosphere. Water evaporates at any temperature. The larger the area, the greater the evaporation…Therefore, the evaporation rate in the oceans is always highest among the rates of evaporation in other sources. Besides, all living things, including plants, animals, humans; give carbon dioxide and water vapor to the atmosphere through the respiration. Plants also give water vapor to the atmosphere through transpiration. Water vapor coming to the atmosphere, through all these processes, condenses and falls down as precipitation. We know that clouds forms due to the cooling of water vapor within the Earth's atmosphere. They contain droplets or ice crystals depending on the atmospheric temperature. Therefore, different precipitation types such as rain, snow, hail can occur. The precipitation does not always occur in the region where the water evaporates. The wind causes the clouds to move, so the precipitation falls into the different regions such as the soil, the settlements and the mountains apart from the oceans or lakes. The water percolates into the soil and forms the ground-water or joins to oceans or lakes through surface flows. Again, the water in oceans and lakes evaporates and returns to the atmosphere. In this manner, the water moves as a natural cycle…

In conclusion, Hale's explanations related to all abovementioned processes and components of the hydrological cycle (Table 4.20.) were consistent to the scientific explanations. However, considering the lack of the knowledge regarding the sun and gravity as the driving forces for the cycle, Hale's understanding of hydrological cycle was labeled as partial.

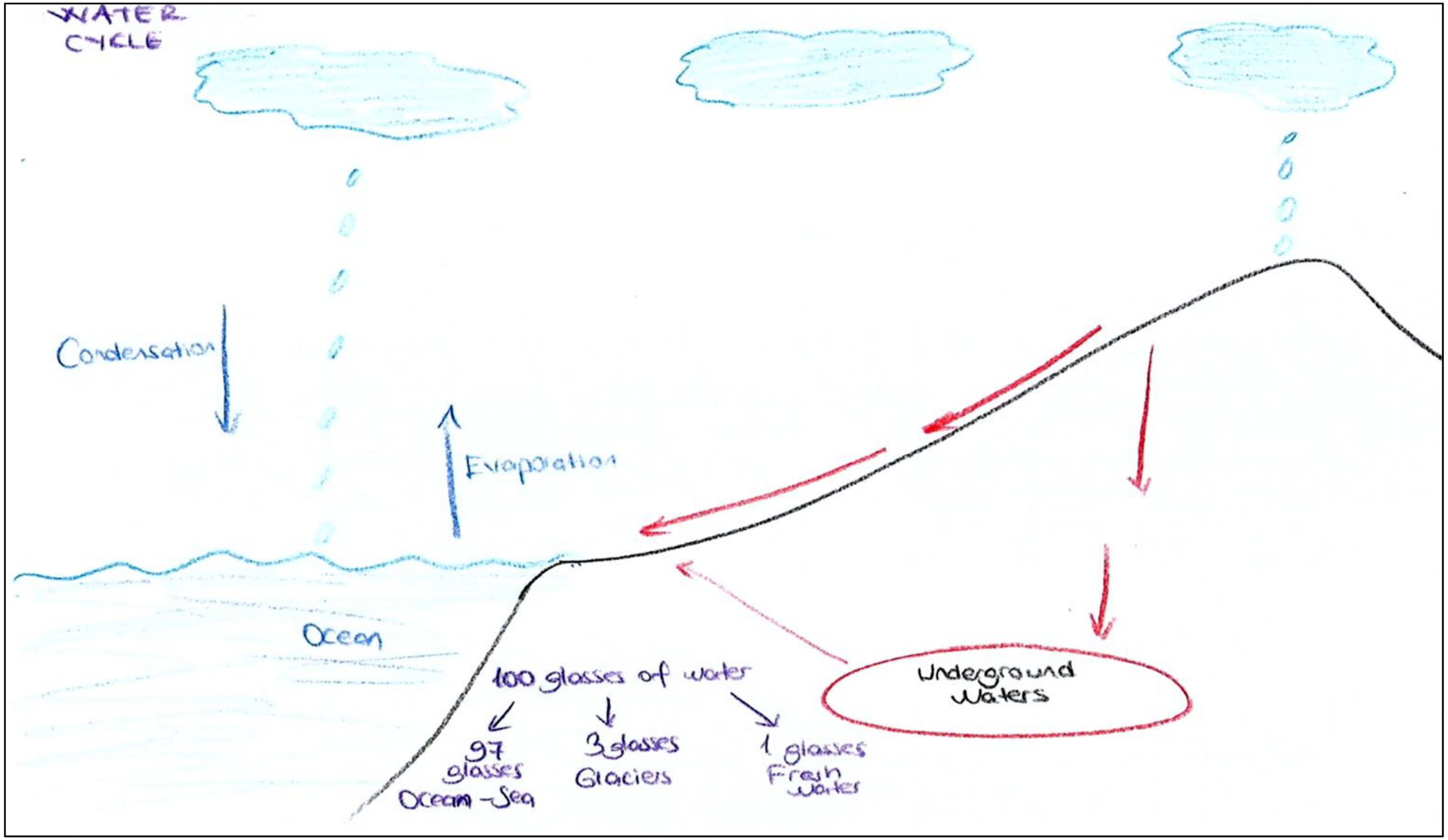

Figure 4.9. Hale's Drawing of Hydrological Cycle

4.2.1.1.3. Hale's Knowledge about Nitrogen Cycle

To identify Hale's understanding of nitrogen cycle, she was requested to explain the cycle through drawing. Hale's understanding of nitrogen cycle was labeled as partial based on the statements in both her drawing and teaching. In Table 4.21, Hale's understanding related to the cycle is summarized.

Table 4.21. Hale's Understanding of the Nitrogen Cycle

	Hale's Understanding
Components within the cycle	• The plants (Legumes) (as Producers) • The herbivores, the omnivores, the humans (as Consumers) • Decomposers • Nitrogen-fixing bacteria • Nitrifying & Denitrifying bacteria • Atmosphere and the soil (as Nitrogen reservoirs) • Water (as Abiotic component)
Processes within the cycle	• Nitrogen fixation • Nitrification • Denitrification • Transformation of nitrogen compounds in living things (N-Assimilation) • Lightning

Hale first emphasized the atmospheric reservoir of nitrogen gas. She mentioned that nitrogen gas in the atmosphere is used in neither photosynthesis nor respiration by producers or consumers. She detailed that plants can only use the nitrogenous compounds in the soil such as ammonia, ammonium or nitrate. In here, she touched upon the soil as a nitrogen reservoir. Then she highlighted that nitrogen is the one of the basic components in the structure of living things. She elaborated that proteins and nucleic acids such as DNA, RNA and vitamins contain the nitrogen. Hale, thus, underlined the importance of nitrogen for living things.

> **H:** …In the atmosphere, there is in the ratio of 78% nitrogen gas. However, living things cannot use this nitrogen gas directly in the processes of photosynthesis or respiration. Plants can only use the ammonia, ammonium or nitrate in the soil. In

other words, the nitrogen gas should be converted to the nitrogenous compounds due to be usable form for living organisms…The nitrogen element is required for the proteins, nucleic acids such as DNA and RNA and also vitamins which form the basic structures of the organisms. So, the nitrogen is essential for the continuation of life…

After that, Hale was requested to explain the nitrogen cycle through drawing (Figure 4.10). She initially addressed the lightning process. Then, she mentioned the process of nitrogen fixation. She explained that the nitrogen gas in the atmosphere is converted to the ammonia by the nitrogen fixing bacteria in the soil or on the roots of legumes. Besides, she clearly defined the processes of nitrification, nitrogen assimilation and decomposition such in the scientific explanation. Lastly, she underlined the process of denitrification as the conversion of nitrogenous compounds in the soil to the nitrogen gas by denitrifying bacteria. She referred the plants, herbivores, omnivores, decomposers, nitrogen-fixing and nitrifying-denitrifying bacteria as the biotic components of the nitrogen cycle. On the other hand, Hale did not mention the cyanobacteria as nitrogenous bacteria in aquatic systems.

R: Could you please explain the hydrological cycle by drawing?
H: …[Drawing] Now, we can separate the soil as upper and under. Thus, there are organisms living both under the soil and on the soil. First of all, some of the nitrogen gas in the atmosphere fixes to the soil as nitrogen oxides through the process of lightning. Furthermore, there are the nitrogen-fixing bacteria in the soil and on the roots of the legumes. These bacteria convert N_2 to the nitrogenous compounds as the ammonia and the ammonium. Also, they convert the ammonium and ammonia to the nitrate. The nitrogen compounds in the soil are absorbed by the plants. Herbivores first eat these plants and then omnivores eat the herbivores. In other words, the nitrogen element transforms to the organic compounds in the structure of plants, animals and people. After the plants, animals and people die, the organic nitrogen compounds in the wastes and the bodies of them is separated to the inorganic compounds by the decomposers in the soil. Lastly, these nitrogenous compounds in the soil either are used by plants or returns to the atmosphere as nitrogen gas through the denitrifying bacteria in the soil…

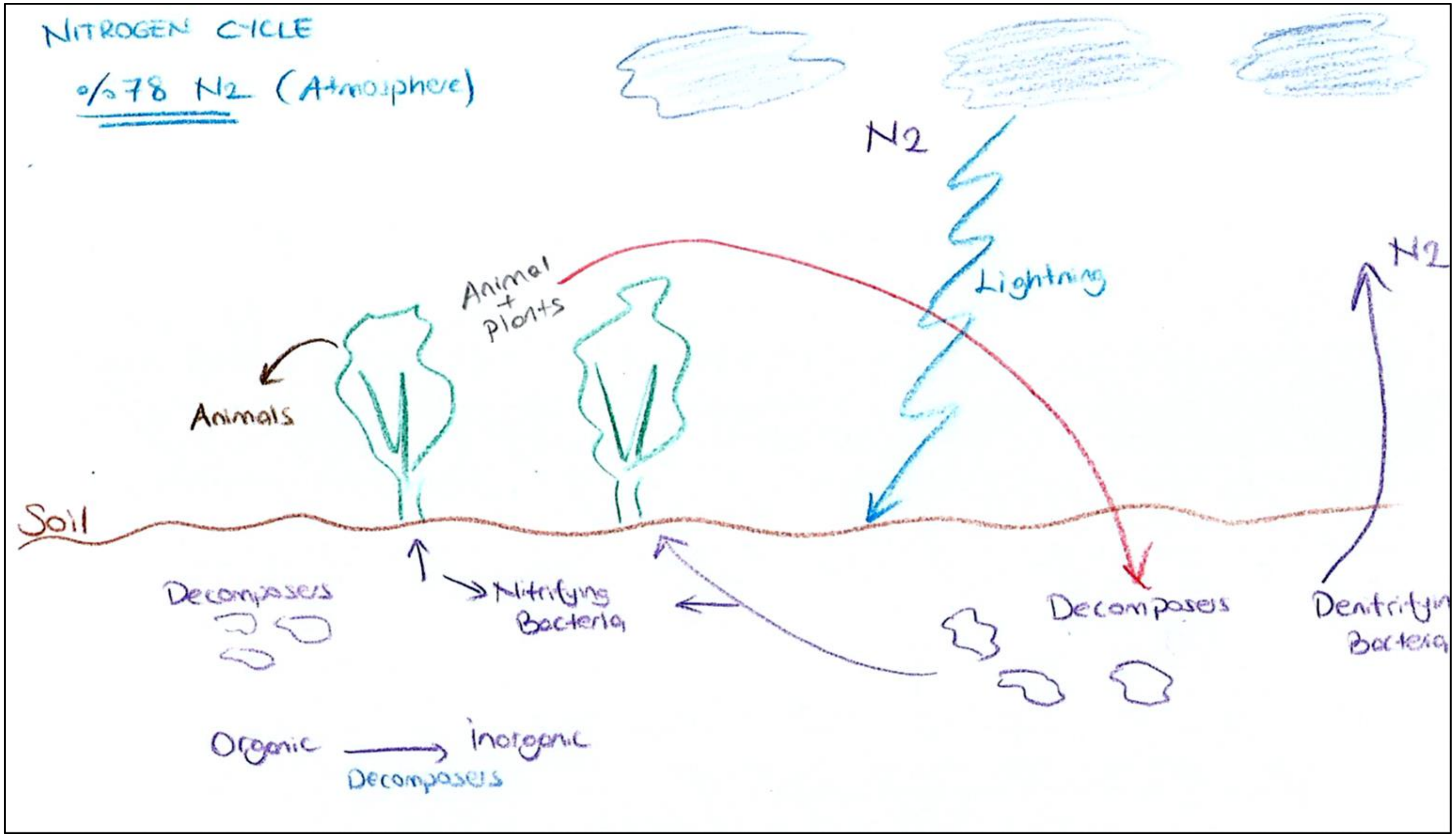

Figure 4.10. Hale's Drawing of Nitrogen Cycle

In short, Hale's responses regarding the all processes and components of nitrogen cycle in Table 4.21 were consistent to the scientific explanations. On the other hand, Hale's statements in both her drawing (Figure 4.10) and teaching did not refer the sun as energy source and the cyanobacteria in aquatic systems as a component of the cycle. In these considerations, Hale's understanding of nitrogen cycle was labelled as partial.

To conclude, it can be said that Hale's substantive knowledge in the topic of biogeochemical cycles was partial considering her responses related to the components and processes of the cycles. In the next section, Hale's syntactic knowledge regarding her NOS understanding was documented.

4.2.1.2. Hale's Syntactic Knowledge

In this section, the results of Hale's syntactic knowledge (NOS view) were presented based on empirical, tentative, inferential, creative and imaginative, subjective, socio-cultural nature of science as well as the distinction between theory and law.

Empirical NOS: When asked the question of what the science is, Hale first explained the science as ''all of the systematic research carried out to understand the universe and find out solutions to the problems people face with''. She also defined the science as a kind of knowledge gained through the scientific methods including testable procedures. Therefore, it can be said that she accepted the idea that scienctists use step by step procedures known as scientific method in answering their questions. She acknowledged that scientific knowledge requires scientific claims based on the evidences, that the experiments and observations are the testable procedures to develop the scientific knowledge. On the other hand, she did not recognize that non-experimental techniques can also be used to advance scientific knowledge. In the light of her explanations, Hale had a lack of knowledge on the empirical NOS (See table 4.22 for sample quotas).

Table 4.22. Hale's Sample Statements of Empirical NOS

NOS view	**Sample Statements**
Empirical	…Science is all of the systematic studies carried out to understand the world and find solutions to the problems we face in life. It [science] is a type of knowledge obtained through the testable methods such as the experiments… …Science is different from other disciplines by means of including scientific claims based on the evidences. …Scientists make observations by using five senses to find out the answer the research question. They formulate a hypothesis that explains the research question. Then, they should conduct a controlled experiment in order to obtain evidences. Thus, they can reach results by the data at the end of the experiment. Therefore, to obtain a scientific knowledge, such a scientific method is needed…

Theory & Law: When Hale was requested to answer the question what the differences between theory and law, she failed to understand that theories and laws are different kinds of scientific knowledge. She hold the idea that theories are named as laws when became universally accepted. She defined the theories as the knowledge that needs to be proven, and thus she held the misconception that laws are certain knowledge. She detailed her assertion with the example of the laws of thermodynamics and Newton's laws of motion. Therefore, her responses indicated that she hold the misconception that there is a hierarchical view of the relationship between theories and laws. When asked whether greenhouse effect is theory or law, although she explained the greenhouse effect correctly, she failed to understand that it is a theory (Ramanathan, 1988; Wilkins, 1993) because of her misconception on the explanatory function of theories. Thus, her excerpts showed that she failed to understand the functions of theories and laws, as well (See table 4.23 for sample quotas).

Table 4.23. Hale's Sample Statements of Theory & Law

NOS view	Sample Statements
Theory & Law	…I think theory and laws are connected to each other. Many theories can be put forward, but these theories need to be proven. If theories become universal and proven, they are called laws. However laws are certain knowledge that describes the natural phenomena by the mathematical connections [formula]. For example Newton's laws of motion, the laws of thermodynamics are absolute knowledge supported by the mathematical equations… …The greenhouse effect is a natural process that warms the earth. It is defined as the event that the warming of the earth through the rise of greenhouse gases such as methane, CO_2, etc. Recently, the scientists have collected data indicating that the amount of the carbon dioxide in the atmosphere has been increased. They [scientists] also get evidences such as the melting of icebergs and the increased temperature of the earth. Moreover, all scientists around the world have accepted the existence of global warming. I think greenhouse effect is a law in the light of these explanations…

Tentative NOS: When asked whether scientific knowledge can be changed, Hale indicated that scientific knowledge is subject to change in the light of new technologies. She asserted that different interpretations of previous knowledge can advanced the scientific knowledge. She expanded her answers by giving examples of the studies in the states of matter. When asked whether theories and laws can be changed, on the other hand, she emphasized that the theories can be changed but the laws are certain knowledge and cannot be changed. However, her explanations related to the theory change were not associated with a tentative view of science. Rather, she had a naive understanding that theories are steps to generate scientific laws (Abd-El-Khalick, 2005). Thus, the results showed that her misconception related to the functions of theories and laws caused her explanations on tentative NOS to be inconsistent (See table 4.24 for sample quotas).

Table 4.24. Hale’s Sample Statements of Tentative NOS

NOS view	Sample Statements
Tentative	…I believe that the new technologies and the new and different interpretations of the knowledge can change the existing knowledge. For example, in nowadays, the scientific knowledge that there are three states of matter as solid, liquid and gas is not valid. In recent years, scientists have concluded that matter has four states adding its [matter] state of plasma. Besides, it is known that the space has more plasma state of matter than one in earth. …Scientific theories can be changed over time but the change of laws is difficult. The evolution theory and the theory of relativity will change by the exploration of new knowledge and new technologies. I mean these theories will be disproved with new interpretations. On the other hand, before the law of gravity has not become a law, many theories had been put forward. Then, one of these theories had been universal and named as the law of gravity. The thing I want to say, is that the change of the law is quite difficult…

Inferential NOS: When asked how scientists are certain about the appearance of the dinosaurs, Hale acknowledged that scientists make inferences. She did not say the term ‘‘inference’’ explicitly but she implied that scientists make interpretations based on the fossil evidences. She expanded her responses stating that the fossil evidences of dinosaurs’ skeletal help scientists conclude how they looked like. Thus, Hale’s understanding on inferential NOS reflected that scientific claims are based on empirical evidences. Therefore, it can be said that Hale’s understanding of inferential NOS were affected by her view of empirical NOS. Thus, it can be said that Hale had informed views on the aspect of inferential NOS (See table 4.25 for sample quotas).

Table 4.25. Hale’s Sample Statements of Inferential NOS

NOS view	Sample Statements
Inferential	Even though scientists could not observe the dinosaurs, they have investigated the fossil evidences. The fossils of dinosaurs are the proof that these creatures had lived. Scientists can only conclude about how they looked like based on their skeletal systems. Besides, the structure of their teeth and jaws proved that they were herbivore or carnivore. Furthermore, the existence of the fossils belonged to the different creatures in the same area is evidence that dinosaurs had died simultaneously.

Creative and Imaginative NOS: Hale recognized that scientists need to be creative and imaginative for the continuation of their research. She claimed that scientists' characteristics such as exploring and inquiring are the essential parts of their imagination and creativity. On the other hand, she failed to understand that scientists' imagination and creativity have a crucial role in every part of their scientific investigation. She asserted that the imagination and creativity is just needed at the part of the planning or designing a research. Hence, her view of creative and imaginative NOS was affected by her misconception that scientists use step by step scientific method universally accepted. Thus, this misconception caused her understanding on creative NOS to be partial (See sample quotas in Table 4.26).

Table 4.26. Hale's Sample Statements of Creative and Imaginative NOS

NOS view	Sample Statements
Creative and Imaginative	…Scientists' imagination and creativity are essential for their productivity. If these features [creativity and imagination] are absent, science will repeats itself. We define the scientists as explorers, and questioners. For me, all these characteristics are the parts of scientists' imagination and creativity… …For me, scientists should use their imagination and creativity at the beginning of their research, such as preparing of a research question or formulating of a hypothesis. In other parts of their studies, scientists should follow the steps of scientific method…

Subjective NOS: When asked how scientists reach different conclusions with the same data, she referred to the subjective NOS emphasizing that scientists' background knowledge, preconceptions and interests potentially played a role in their interpretation of the data. She claimed that scientists drew varying inferences and thus, reached several different conclusions on the causes of the dinosaurs' extinction due to the subjectivity in science. Additionally, she implied that scientist' interest of area affects how a researcher interprets the data by giving example on the conflict in the causes of global warming. Therefore, Hale had informed views on the aspect of subjective NOS (Table 4.27).

Table 4.27. Hale's Sample Statements of Subjective NOS

NOS view	Sample Statements
Subjective	…Scientists can interpret the same data in different way. Their [scientists] perspectives, background knowledge and field of study might affect their interpretations. …For instance, scientists have different views related to dinosaurs' extinction. They reach different conclusions as meteorite hit, continental drift, or volcanic eruptions. I mean that while geologists interpret the cause of the extinction as continental drift, astrophysicists can conclude as the meteor hit. Their [scientists'] interest of study might influence their claims. In the same way, scientists conflict in the causes of global warming. Some of them said that global warming is a natural process but many of them believed that it [global warming] is a result of human activities…

Socio-Cultural NOS: To be categorized as holding informed understanding of socio-cultural NOS, participant should indicate an understanding that science is a human endeavor and, as such, is influenced by the society and culture in which it is practiced (Lederman et al., 2001). In Hale's case, she believed that science should be isolated from the society and culture. On the other hand, her example related to Turkey reflected the informed view that science is influenced by religion, cultural values and traditions. Thus, Hale's understanding on the tenet of socio-cultural NOS had deficits due to her contradictory expressions. Sample statements can be seen in Table 4.28.

Table 4.28. Hale's Sample Statements of Socio-Cultural NOS

NOS view	Sample Statements
Socio-Cultural	I think that science should not be influenced by the society's culture or values. However, in our country, science is related to the religion, cultural values and traditions. In my lessons, I can observe that student might influenced by their values or home culture. They can answer the questions aligned with their religious beliefs or traditional lifestyles. In my opinion science should have a common language; it [science] should not be influenced by the values of cultures.

In short, Hale's responses implied that she possessed inadequate understanding on NOS tenets. Specifically, she had naïve understanding on the functions of/ differences between theory and law and socio-cultural NOS. In fact, it can be said that there were interactions among Hale's NOS views. For example, although Hale asserted that scientific knowledge can be changed by the new interpretations, she held the naïve idea that the change of laws is difficult because laws are certain knowledge. In here, the deficiencies in her understanding of the differences between theories and laws affected her view of tentative NOS. Likewise, her misconception that there is a scientific method universally accepted led her interpretations to be inadequate in terms of creative NOS. On the other hand, Hale's understanding that scientific claims are based on empirical evidences helped her view of inferential NOS become substantial. To conclude, Hale did not have sophisticated views of NOS because she was not deeply informed in all of the NOS tenets. Moreover, it observed that she did not translate any aspects of NOS into her classroom practice of biogeochemical cycles.

4.2.1.3. Hale's Understanding of Sustainable Development Regarding Biogeochemical Cycles

In order to reveal Hale's understanding of sustainable development (SD) regarding biogeochemical cycles, she was requested to answer what the causes, results and solutions to the disruptions to the cycles. Besides, her teaching of biogeochemical cycles was observed. Therefore, her responses and practice were unveiled how Hale linked the biogeochemical cycles to the issues of sustainable development.

Initially, Hale emphasized the human activities are main causes of the problems related to the biogeochemical cycles. She touched upon the unconscious use of natural resources by humans. Therefore, she attributed the damage of the environment to the population explosion by emphasizing environmental aspect of SD. She especially had the idea that the balance of nature should be sustained without damaging the environment.

Researcher (R): What are the causes of the disruption in biogeochemical cycles? Please explain.
Hale (H): The balance of the ecosystems is very important to the continuation of life. We know that when humans interfere with nature, it often produces disastrous consequences. When the balance of the cycles is destroyed, all living things are affected by the consequences…For me; the main cause of the disruption of the cycles is human. Because of our activities, not only the water resources, but also the air and the soil are polluted. One and other day, the consequences of these pollutions will influence the people's life adversely…

4.2.1.3.1. Hale's Knowledge on the Connections between Carbon Cycle and Sustainable Development

Concerning of the degradation in carbon cycle, Hale stated that the environmental problems such as the extensive use of fossil fuels and deforestation caused to the increase in emissions of CO_2 and greenhouse gases to the atmosphere. She tried to connect the scarcity of energy resources and energy problem to the population growth. Hale, in here, implied the issue of the unsustainable consumption of energy sources. She attributed the damage of the balance of the environment to the unsustainable lifestyles of human beings. She also referred the interdependence of living thing by explaining the results of the deforestation. Therefore, she mentioned about the issues of three aspects of SD, namely; environment, energy and society by mainly emphasizing the damaging the environment, scarcity of energy resources and unsustainable consumption behavior.

H: …Plants are very important for the cycles. Do you know that the amount of O_2 produced by one oak tree in a day satisfy the O_2 need of seventy-two people. I believe that the destruction of plants or forests threatens the lives of the other living creatures that exist there. We, all living things, are dependent to each other….Especially in carbon cycle; we know that they [plants] are the single organisms that remove the CO_2 from the air. If we destroy the vegetation and the forests, the amount of the CO_2 in the air will increase. Additionally, we use too much fossil fuel for satisfying the need of the energy in our homes, factories and cars. If we continue to use the non-renewable energy sources extensively, the balance of the carbon cycle will get worse from day to day. Carbon emission will increase; as a result air pollution will increase.

Hale especially drew attention to the increase in the amount of diseases in the regions where the industrial activities is high. In other words, she attributed the health problems to the atmospheric pollution and global warming originating from the unsustainable industrial development. Therefore, she approached to sustainable development by the environmental social and economical aspects regarding that unplanned industrial development affects both the environment and society. She also imply to refer the environmental aspect of sustainable development by mentioning the scientific environmental research.

> **H:** …In recent years, there is an extreme increase in the amount of the diseases. According to the researches carried out in our country, there is an increase in lung diseases in and around Zonguldak (a city where there is the coal mining industry in Turkey) where carbon dioxide gas is released too much. Furthermore, scientists discuss about many unknown diseases that may be the result of the insolation of the living species hidden in icebergs in water through the melting of glaciers...

In addition, it can be seen that Hale tried to address the unsustainable modes of production and consumption through the industrialization. She mentioned that the unplanned industrialization causes to be destroyed the vegetation from land for construction. She emphasized that development policies to improve the society's living standards should sustain the balance of the nature. She, therefore, linked the environmental problems arising from unplanned development policies to the social aspect of SD. Besides, she implied that the wealth of the society is based on the transffering its resources to future generations. In here, she touched upon the SD aspects of environment, energy, society, economy and politics by underlying the environmental damage, energy need, unsustainable production and lifestyles, and unplanned development policies.

> **H:…** Our forests are not our heritage. We have to transfer these sources from the generations before us to future generations. Evliya Çelebi said in his book 'Seyahatname' that the wealth of its forests is the indicator of the country's total wealth. However, when we look at surroundings today, we destroy forests and build residences. We build roads and factories. We demolish the detached houses with gardens; we plan multi-storey apartments instead of each garden house. At least 100 people start to live in the place where 10 people lived. This means more

consumption, more energy demand, more carbon emissions and therefore more pollution…

Hale, furthermore, emphasized the geopolitical issues in preserving the balance of the cycle. She underlined the Kyoto protocol as an international treaty signed in order to reduce the greenhouse gases emissions to the atmosphere. In here, Hale touched upon the need of sharing social responsibility for action. She especially addressed the use of renewable energy sources to solve the environmental problems related to the carbon emission. Therefore, she implied the issue of non-carbon economy mentioning the investments in renewable energy sources needs to be made in order to stop CO_2 emissions. In here, Hale addressed the environmental, social, economic and political aspects of sustainable development issues. Besides, , she suggested that the use of renewable energy sources should be increased to be able to find permanent solutions to the environmental problems.

H:… As we know, Kyoto is the only international contract signed to reduce the onset of global warming. The purpose of this contract is to reduce the emissions of greenhouse gases to the atmosphere. The US is the only country that has signed but not ratified this protocol. In this country, which has the greatest economic power, we know that carbon emissions are very high. As a country with a population of 75 million, our carbon emissions are high, too. Increase in carbon emissions is big threat in the global sense. If so, nations should not only sign such protocols, but also implement them. In particular, I think that the exact solution is to use renewable energy sources like wind and sun. I think it would be more useful to use solar, wind or water energy instead of building a thermal power plant.We can establish governmental policies by making investments in renewable energy sources, by this way; our solutions can be permanent and long-term…

Moreover, Hale explained that the increase in carbon emission causes to the negative effects on Earth such as global warming and climate change. While she was explaining the global warming, she referred also the greenhouse effect and greenhouse gases. Furthermore, she emphasized the change in the weather events, the sea level rise and the loss of ice mass as the results of climate change. She pointed out the global warming and climate change as the main results of the increase in carbon emissions arising from the antropogenic activities. He, therefore, touched upon that human activities should sustain the balance of nature.

> **H:** … The increase in the amount of carbon dioxide in the atmosphere brings many negative effects. Especially in recent years, what we call global warming threatens our world. We know the Earth warms through the reflection of sun rays from the surface of Earth. I mean that greenhouse gases hold these reflected sun rays and Earth warms. However, with the increase in the amount of carbon dioxide, greenhouses gases blocked the return of these rays to the atmosphere and the Earth' temperature increase in time.In fact, we perceive global warming as an increase in Earth's temperature but this is actually a deterioration of the balance of nature. It means that winters will be colder and summers will be hotter. In other words, it means that droughts in summer and extreme rainfall in the winter can occur. The glaciers that have existed for millions of years have started to melt. Water levels are expected to increase in the coastal countries. Those are the signals of climate change…

Briefly, when Hale's responses related to the causes, results and solutions to the degradation of the carbon cycle were examined, it can be seen that she touched upon the important environmental phenomena such as greenhouse effect, global warming, climate change and atmospheric pollution. Additionally, she connected these phenomena with the all issues of sustainable development except the poverty. During her explanations of the connections between the carbon cycle and SD, Hale also addressed five aspects of sustainable development including environment, society, economy, politics and energy.

4.2.1.3.2. Hale's Knowledge on the Connections between Hydrological Cycle and Sustainable Development

Hale generally touched upon the disruptions to the water cycle originating from the water pollution. She connected the unplanned urbanization as a factor affecting the water cycle. In here, she touched upon the unplanned land use through the damage of the environment to build roads and constructions. Tus, she implied that industrial development should sustain the balance of the nature without damaging the environment. Then, she underlined the health impacts such as skin and intestinal diseases arising from the polluted water resources. She also referred the interdependence of living thing by explaining the results of the water pollution.

Therefore, she approached to sustainable development by the environmental and social aspects regarding that damage of the environment affect the both social and biological life.

> **H:** …We, people, pour the waste oils and detergents to the sinks and do not even think whether these wastes are contaminated to the water resources. The chemical wastes of factories, also, pollute the surface and ground resources. Therefore, the water pollution threatens the organisms living in waters. On the other hand, we build the excellent bridges, roads, and residences but meanwhile we ignore other living things, too. This unplanned urbanization also causes to the decrease in the number of both the organisms living on/under the soil and the ground waters over time…

During her teaching of hydrological cycle, it can be seen that Hale, additionally, mentioned the issue of scarcity of water. She addressed the use of non-conventional water resources to overcome the scarcity of potable water. In here, she drew attention to the underdeveloped countries' economic and technological dependences on foreign trade. In other words, she implied that to be able to have a strong economy, governments should support the investments in technological development. Therefore, it can be said that Hale referred the SD aspects of politics, economy and technology.

> **H:** Waste water treatment in order to produce drinking water is not common in our country. However, in a few countries, treated water is consumed. In other words, waste or salt water is processed and transformed into potable water. Especially in Israel, there is a great system that transforms the ocean water into drinking water. However, there are no economic and technological developments in our country to establish such a system. Unfortunately, our technological development is dependent on foreign countries as a developing country…

In the same way, Hale complained about the absence of the policies in order to protect water resources in Turkey. In here, she, again, mentioned the issue of dependence of foreign trade. She underlined the issue of water conflict by stating that the precautions need to be taken for the water scarcity. Again, she approached to sustainable development from the aspect of environment by emphasizing the environmental research to increase the awareness of the society. She referred that responsibility should be shared in order to overcome the global water conflict by implying that world peace is necessary for the development of future generations. Therefore, she linked the SD aspects of environment, society, economy and politics.

> **H:** When we look at our country, we have a lot of underground resources. It is possible to use these waters by artesian wells. Turkey is also a peninsula surrounded by sea on three sides. Then Turkey should not be a country where there is a problem of scarcity of water. However, there is a shortage of water in Turkey in recent years. If so there is a serious problem with our water policy. Twenty years ago, in his report, an American scientist underlined that if Turkey does not get control the water resources, water shortage will be happened in 40-50 years. Twenty years passed, and he's right. We are not able to use our underground resources because their usage is under control of foreign countries. As a country, if we cannot control water resources, which are our most important natural resource, we cannot develop. In many countries, the future has signaled the scarcity of water. Turkey is one of these countries. As long as environmental problems continue, there will be a water conflict in 25 years. Moreover, it is said that third world war will be due to the water conflict…

To summarize, when Hale's responses related to the causes, results and solutions to the degradation of the water cycle were examined, it can be seen that she touched upon the important environmental problem of water pollution. She also underlined the issues of the potable water scarcity, heath impacts through water pollution, trans-border water conflict and non-conventional water resources. On the other hand, she did not refer the phenomena such as soil and water salinization through salt water intrusion, desertification and glaciation. Therefore, regarding hydrological cycle, Hale's understanding of SD mainly focused on the aspects of environment, society, politics, technology and economy emphasizing that finding permanent solutions to environmental damage, unplanned development policies based on foreign trade, development technologies and shared responsibility for future generations.

4.2.1.3.3. Hale's Knowledge on the Connections between Nitrogen Cycle and Sustainable Development

Considering the degradation of the nitrogen cycle, Hale addressed the negative effects of extensive use of fertilizer in agricultural activities. She emphasized that unsustainable lifestyles of human beings threaten the many species in water and soil. Therefore, she underlined the environmental and social aspects of SD. Moreover, she suggested the alternative agriculture methods in order to cope with the pesticides in her teaching. After that, she connected to health problems to the pollution in water and soil due to the arising from the absence of good agriculture practices. Thus, she linked the social, environmental and economical aspects of SD by underlying that the sustainable production and consumption is necessary for the finding permanent solutions to environmental damage.

> **H:** The degradation of the nitrogen cycle affects the all living things directly because all living things consume the nitrogen through nutrition. We know that in recent years, farmers have used more chemical fertilizers in the agricultural lands. The organisms living in water and soil are under threat due to excessive use of pesticides. Furthermore, the percolation of the chemicals to the soil and ground waters causes the excessive nitrogen in the soil. As a result, the soil will be infertile. Furthermore, the food produced by plants will be unhealthy due to the chemicals. As soon, health problems will arise…
>
> …In old times, farmers planted fruit trees on the side of their fields or gardens. The birds that came to eat fruits also eliminated the pesticides without damaging the crops. This is a very simple agricultural method. People have practiced this method for centuries. Thus, they didn't cause to mix any chemicals into our soil or our water resources. However, with the methods used in agriculture practices in recent years, the soil and water has been heavily contaminated. We eat the potatoes in the polluted soil and consume the fish in polluted lake. The foods we consume threaten our health [Classroom Observation].

Moreover, Hale mentioned the acids rains as an environmental damage originating from the industrial development. She also attributed the water pollution to the acid rains and again emphasized the increase in health problems in society.

> **H:**…The gases exiting through nuclear explosions or industrial activities combine with water vapor in the atmosphere, causing an environmental problem called acid rain. Therefore, these dangerous precipitation causes water sources to

> become contaminated. Many studies conclude that there is an increase in skin diseases, stomach and intestinal diseases in places where the excessive water pollution is occurred…

Regarding the issue of food safety from the social aspect of SD, Hale complained about the insufficient agricultural development policies. She addressed the decrease in the agricultural production and as a result, the increase in dependence on imported seeds due to insufficient investments in agricultural industry. She, thus, addressed the political, economic and social aspects of sustainable development.

> **H:** Turkey's seed warehouses are empty because of the agricultural investments. Most of our seeds are now imported from foreign countries. Being a country with an endemic species as much as Europe, it is very scary to be dependent on foreign countries. In our country, both scientific studies and investments are insufficient. I don't know the consequences the use of these imported seeds on the lands. Financial support for farming is lacking and thus, domestic production decreases. There should not be such agricultural policy.

To sum up, it can be seen that Hale touched upon the important environmental problems of acid rains and soil pollution as the results of the degradation of the nitrogen cycle. She also underlined the health impacts through water and soil pollution, alternative agricultural methods, food safety and the use of fertilizers as the issues of sustainable development related to the nitrogen cycle. On the other hand, she did not refer the phenomena of eutrophication and greenhouse effect of nitrogenous gases in the cycle. Besides, she did not mention the issue of sewage treatment. In that case, Hale's understanding especially environmental, social, economical and political issues regarding the connections between nitrogen cycle and sustainable development issues.

Finally, while mentioning the solutions, Hale especially focused on the SD aspects of education, society and economy. She gave example of SAP to stress the social and economical aspects of SD by underlying the social equity and creating job opportunities. She also emphasized that developments in education could create more livable world for the future generations with the help of educated and awared society.

H: There's a balance in nature. This balance between human and nature should be preserved in a way that can meet our energy needs without damaging the natural resources. For example, a project called GAP was made in the 90s in our country. That region was chosen because women, children and farmers living there were disadvantaged groups. The aim was to ensure the same level of social, cultural and economic equity of these citizens such the ones living in other regions by both increasing the job opportunities and improving education in the region. It was a great project. Such projects should be increased if we want to catching up with the developed countries. Especially, education is an important issue for our future generations. All citizens in our society should be educated in terms of using natural resources in balanced way. Environmental awareness is a key issue to create greener society. If you can develop environmental awareness, you can fullfil the responsibilities to make our world more livable for our children…

To conclude, When Hale's explanation related to the results, causes and solutions to the depletion in biogeochemical cycles examined, it can be seen that she mostly underlined the issues and aspects of SD in the carbon cycle. Moreover, ,it can be said that although she can not connect the nitrogen and hydrological cycles to the related sustainable development issues, she mainly mentioned environmental, social, economical and political aspects of SD issues related to these cycles. Additionally, Hale intensively approached to the phenomena and issues of sustainable development from the environmental, social and economical aspects whereas she addressed the aspects of education and technology rarely. To sum up, Hale's conceptions of SD regarding biogeochemical cycles can be seen in Figure 4. 11.

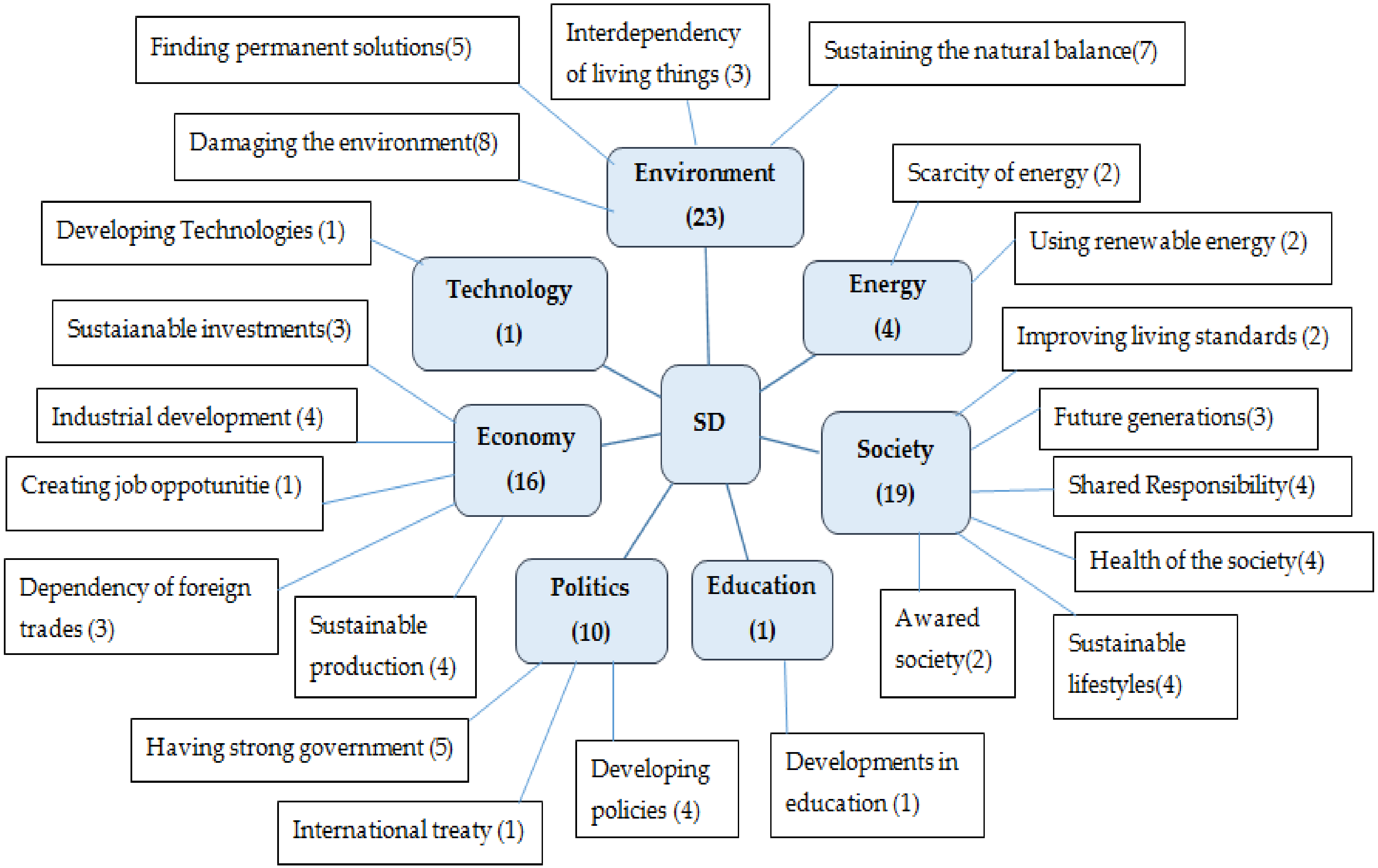

Figure 4.11. Hale's Conceptions of Sustainable Development

4.2.2. Hale's Pedagogical Content Knowledge

4.2.2.1. Hale's Orientation to Science Teaching

In this section, Hale's beliefs about goals of science teaching at grade 8th were presented based on the analyses of her responses to the card-sorting scenarios and the interviews related to the goals of science teaching and classroom observations.

Hale stated that her beliefs about central purposes for science teaching were determined by the slogan as ''science is the life itself''. She addressed that her main goal of science teaching was to prepare learners to life. Moreover, she pointed out that science teaching helps learners to find solutions to their problems faced with in daily life. Her responses also included that science teaching is also necessary to develop environmental awareness (See Table 4.29 for sample quotas).

Table 4.29. Hale's Sample Statements Related to Beliefs About Central Goals for Science Teaching

Central Goals	**Sample Statements**
To prepare learners to life	My basic goal of science teaching is to prepare my students to the life. We have a slogan that science is life itself. In this way, science teaching is an important for the students to get in touch with daily life…
To help learners to find solutions the problems in daily life	…Science teaching also should be given to help students find solutions to the problems they face with in their daily lives. Life is a combination of physics, chemistry and biology. We want students to gain basic understanding of science concepts such the physical and chemical changes, the structure of living things. That is to say, science education is necessary to obtain basic knowledge related to the life…
To help learners to develop environmental awareness	…I, as a human, pay attention to the environmental protection. I also try to help my students to establish a relationship between human and environment. The environmental knowledge that they have gained in science lessons also helps them to achieve this goal. When this knowledge is not enough, I make effort to develop their environmental awareness…

When it comes to her peripheral goals for science teaching, Hale pointed out that she also considered the national curriculum and the examination system in Turkey. Therefore, she touched upon that she has to transmit the scientific concepts required by the curriculum. Hereby, she emphasized that one of her goals of teaching science is to prepare her students to the TEOG [High School Entrance Exam] (currently known as LGS) examination. In addition, she expressed that science teaching also prepares the students to high school courses such as physics, chemistry and biology. (Sample quotas can be seen in Table 4.30).

Hale's beliefs about the central and peripheral goals of science teaching nearly overlapped with the orientations that she chose as parallel to her science teaching. Hale expressed that the scenarios related to activity driven, discovery, conceptual change, guided inquiry, project-based, inquiry, process and curriculum goals corresponded to her science teaching.

Table 4.30. Hale's Sample Statements Related to Beliefs about Peripheral Goals for Science Teaching

Peripheral Goals	**Sample Statements**
To help students to comprehend the knowledge required by curriculum	For me, the important thing is that students should comprehend the science concepts and relate them to the daily life. The Ministry of National Education also requires us to transmit basic science concepts to the students through science and technology curriculum …
To prepare learners to high school exam	…We should acknowledge that there is an exam in our country in order to be enrolled to a qualified science or Anatolian high school. Because of this situation, I try to prepare my students to this exam solving different questions in my lessons. However, my primary goal is to prepare them to the life not the high school…
To prepare learners to high school courses	As you know, science education is divided into the branches as physics, chemistry and biology at high school. Therefore, science education at elementary level also includes the basis knowledge necessary to understand more complex and abstract knowledge in high school courses…

When she was asked why she selected those scenarios, Hale stated that because the scenarios shared a common characteristic of being student-centered. She emphasized that she gave importance to the active participation of the students in her science courses. Hale cited that she generally tried to prefer the alternative teaching and assessment techniques apart from the traditional ones. She, therefore, pointed out her preferred scenarios were generally accordance with her science teaching at 8th grades. Hale's sample quotas related to these scenarios can be seen in Table 4.31.

> **Researcher (R)**: In your opinion, what are the common characteristics of these scenarios?
> **H:**…7th and 8th grade students' hormonal system changes because of the puberty. Students have also an anxiety for the TEOG exam. Therefore, it's hard to get students' attention. But when I present a topic in different ways, I can see that many students understand it better. I chose these cards because they include alternative learning and teaching methods apart from traditional teaching and learning methods. Additionally, the strategies are generally student-centered in these cards. They [scenarios] include many different strategies referring different intelligence groups. For example, in one of them, students can interpret the statistical data. Here, it is related to the logical mathematical intelligence. Again, one of them includes the interviewing process. Students good at language skills can prepare interview questions easily. Thus, students have an active role in the teaching and learning process. In the same way, in my lessons, I generally try to use different activities such in these scenarios. I want my students to be active in the classroom…

Table 4.31. Hale's Sample Statements Related to Orientations Parallel to Her Teaching

Orientations	Scenarios	Sample Statements
Activity Driven	One way to effectively teach about biogeochemical cycles to use laboratory and/or classroom activities in which will provide the students the best opportunity to learn the topic.	Now, I just have thought the science lessons in the laboratory. We can do every experiment we want in here. We have all kinds of material in our laboratory. We often use experimenting in the unit of electricity. Again, I want them to set up different experiments on the topic of simple machines and friction force.
Conceptual Change	A good way to teach students about recycling is to ask questions and/or to use a demonstration that will check on the students' prior knowledge of the topic and then try to eliminate their misconceptions with scientific conception.	I generally encountered students' misconceptions in the heat and temperature unit and mass-weight topic. In addition, especially in the first semester of 8^{th} grade, there are a lot of misconceptions in terms of adaptation, mutation, natural selection, artificial selection and modification. I first try to observe students' prior knowledge. This is primarily important for me. I ask them some questions to determine the misconception. Then I try to help my students to grasp the concept giving examples of everyday life. Using many different activities such as concept and mind maps, I try to eliminate the misconception. In addition, in order to evaluate whether the concept is understood, I analyze my exam questions. Because if the student understands the concept, I think that the student will interpret the question related to the concept regardless of the type of the question.

Table 4.31 (Continued)

Orientations	Scenarios	Sample Statements
Process-Scientific Skill Development	The best way to teach the carbon cycle is to use data obtained from the research on the topic. Then you ask students to formulate hypothesis, interpret data, analyze the data, and communicate their results with others in the class.	It is very important for me to know the steps of scientific research. If the student is not sensitive to the environment, it is possible neither to realize the problem nor to provide solutions to solve the problem. For example let's say that TUBITAK (a governmental research organization in Turkey) has done a scientific research on the ratio of the carbon dioxide in the air. It has data showing that the carbon dioxide ratio in the air increases. I would like them to interpret and analyze the data and discuss the reasons of this increase.
Academic Rigor	One way to effectively teach students about renewable and nonrenewable energy source is to solve different and difficult questions (problems).	I always solve different questions in my science courses. Also students in 8th grades are going to take the TEOG exam so they should see different questions related to the topics. As I said before, I solve different questions that can appeal to different intelligence groups. For example, if I ask a question according to linguistic intelligence, I address the logical-mathematical intelligence in the other question. I ask the question in the form of column chart, pie chart, line graph. Sometimes I prepare a question including a table shape or a structured grid. So I ask questions in different versions. However, to solve the difficult question, I think, does not help students to grasp the subject.

Table 4.31 (Continued)

Orientations	Scenarios	Sample Statements
Guided Inquiry	One way to effectively teach students about the disruption of biogeochemical cycles is to allow students to design their own experiments using variables they decide upon.	It's important for me to design an experiment. The students know how to design a scientific experiment, prepare research questions, formulate hypotheses, and identify variables. It is a process that they need to use many scientific skills together.
Inquiry	By separating the students into groups and giving them a scenario from their surroundings, an effective way of teaching environmental problems caused by non-renewable energy sources is to ask students to educe a cause-and-effect relationship with these problems and to assess the validity of the information in order to generate these outcomes.	I give them a statistical data or a scenario related to the rate of carbon dioxide in the air in Turkey or in Ankara in recent years. I want them to discuss the importance of the carbon dioxide cycle and the increase in the amount of carbon dioxide through this data…I am concerned about the cause and effect relationships rather than assessment of the validity of their information gathered.
Project-based	One of the effective ways of teaching recycling is to encourage students to participate in NGOs interested in environmental protection, and to cooperate with these non-governmental organizations in order to provide solutions to waste disposal.	Especially students in the environmental club, members of the Young TEMA or Eco-Schools are doing such activities. They invited experts from TEMA for the conference. TÜRÇEV held a conference and invited our students. The best thing we did was to plant 200 pine trees in the backyard of our school with the help of the Ministry of Forests last year. It is important for us.

Table 4.31 (Continued)

Orientations	Scenarios	Sample Statements
Curriculum Goals	One of the effective ways in order to teach the contributions of researches and developed technologies on renewable energies and technologies to the environment and the country's economy is to ask students to interview experts (engineers and scientists etc.) related to the subject and to present their research results to their classmates.	My students can implement such things in the second semester as group performance project. I want my students to talk to the experts. In the interviews, I would like them [the learners] to take photographs and make videos. They should make power point presentations according to the information and documents gathered. We do these kinds of interviews frequently on biology subjects.
	An effective way to educate learners as environmentally responsible citizens is to ask students to investigate how to find solutions to the problem of waste, one of the most important problems of our day as a result of human activities.	Generally, when we say waste, we think of garbage, plastics, etc., but they are not waste, they can be recycled. I think the storage of chemical and medical wastes is in the shortage in Turkey. So, my students conduct research on the collection and storage of the wastes. They can specify the problems and offer solutions to these problems. They are generally responsible for such activities as a performance assignment.

Hale pointed out that she could not utilize the remaining scenarios, including didactic, discovery, liberation and reality of educational system due to their teacher-centered nature. She explained that she avoided carrying out these methods because either teacher is at the center of the learning environment or the students are completely alone in these scenarios. Hale emphasized that she regarded the active participation of the students in her lessons so she did not choose the above-mentioned scenarios. Hale's sample quotas related to these scenarios can be seen in Table 4.32.

> **R**: What are the common characteristics of the scenarios that you do not prefer to use?
> **H:** I do not carry out these scenarios because either the teacher is at the center of the learning environment or the student is alone. I'm interested in a student-centered learning environment and group work without much intervention. However many colleagues perceive student-centered education differently. In their science lessons, they separated all units to the students, and students try to present the topics. The teacher does nothing. This is not student-centered. I don't think they know what student-centered education means…

Observation data revealed that Hale used project-based learning to help her students comprehend the biogeochemical cycles, as well. As she stated, she also used direct instruction being varied by different daily-life examples, figures, and questions to facilitate students' understanding of the basic concepts. Her teaching was generally based on the students' project presentations and discussions. Therefore, it can be said that as far as possible, her teaching was line with her orientations.

Table 4.32. Hale's Sample Statements Related to Reasons of Orientations Not Corresponded with Her Teaching

Orientations	Scenarios	Sample Statements
Didactic	A good way to effectively teach students about biogeochemical cycles is by lecturing to draw the figures of the cycles by using the blackboard and tell the students the differences between the cycles.	I don't think it's an effective method. I think that giving concept and mind maps are better than giving direct information. For me, it is better to explain animations and visual materials than drawing.
Discovery	The best way to teach students about the renewable and nonrenewable energy sources is to ask students plan an investigation/activity that allows them to present the areas of usage of these sources.	I do not expect my students to plan an activity or investigation. I think it's better to discuss together in class rather than planning.
Liberation	After having studied the concepts related to the subject, one of the effective ways of teaching recycling is to allow students to discuss these concepts clearly and develop their own concepts.	Concepts are clear in general. So, I do not allow my students to develop their own concepts for a topic. But discussion is important in peer education. However, I do not use discussions long enough to develop their own concept.
Reality of Turkish Educational System	As a teacher, you think that the best thing to do for students is to prepare them for high school. Therefore, you teach the topics and then try to solve as many problems/questions as possible.	I believe the most important thing is to prepare them [the students] for life, not high school. For me, their grades do not matter. In my lessons, I solve many questions; I also prepare questions and give homework to the students. I said my goal is not their success in high school or the exam. Therefore, I try to solve the questions from previous years as a requirement of the system, but this is not my priority.

4.2.2.2. Hale's Knowledge of Curriculum

4.2.2.2.1. Hale's Knowledge of Goals and Objectives

In the Science Curriculum (2005), there was only one objective specific to the topic of biogeochemical cycles, which is *students are able to explain biogeochemical cycles parallel to the energy flow in the food chain* (MoNE, 2005, p.354). The acquisition of this objective is closely related to the understanding of the previous topic which is energy flow in the food chain. Hence, the objectives of previous topic should be considered as a reminder to teach the topic of biogeochemical cycles.

Hale also emphasized that the aim of the teaching biogeochemical cycles was to explain the concepts with their connections with the topics of energy flow in the food chain. Hereby, she expressed that student could easily understand the connections between biogeochemical cycles and biotic/abiotic environment. While Hale was teaching the biogeochemical cycles, it was observed that when needed, she checked whether the students gained the objectives related to the nutrition and energy flow in the food chain recalling their prior knowledge. When Hale was asked the aim of teaching the topic of biogeochemical cycles, she stated that she mainly expected her students to gain the objective required by the curriculum.

> **Researcher (R):** What is your aim of teaching the topic of biogeochemical cycles?
> **Hale (H):** First of all, students' comprehension of the previous topics is very important for the teaching of matter cycles. For this reason, I expect that the students had gained the objectives of photosynthesis, respiration, energy flow and energy pyramid. They should know the connections between biotic and abiotic components of the ecosystems so I always begin to teach matter cycles by repeating these topics. We then define the concept of cycle and the importance of the cycles of carbon, oxygen, water, nitrogen, and the problems that may occur as a result of the deterioration of the cycles. In general, I follow the curriculum and help my students gain the curriculum objectives…[CoRe Interview].

Hale also pointed out that she expected her students to gain some affective domains, indicated in Table 4.33., in addition to the curriculum objectives. She cited that she gave importance to develop students' environmental consciousness in especially environmental topics. Therefore, she stated that students should comprehend the importance of the balanced use of the natural resources. Hale added she helped learners to raise awareness for environmental problems caused by the deterioration of the biogeochemical cycles.

> **H:**…I usually expect the students to develop some attitudes and raise environmental awareness in such environmental topics. For example, the students should be aware of the balanced use of these matters in nature. Rather than consume the existing one, they should be aware of what needs to be done to preserve the amounts of them. I think they [students] should be aware of what may happen as a result of the deterioration of the cycles. I mean that Earth is bordered but there is no limit in the sky. If a fire or a disaster happened in our country, they [students] must be aware of the consequences in other countries. They have just known the effects of the explosions in Chernobyl and Fukujima. Therefore, I hope that in the future, they will transform their environmental awareness to their daily lives… [CoRe Interview].

Table 4.33. Hale's Intended Objectives Related to Topic of Biogeochemical Cycles

Intended Objectives
To comprehend the importance of the balanced use of natural resources
To recognize what needs to be done for the continuation of the biogeochemical cycles
To raise awareness for environmental problems caused by human based deterioration of the biogeochemical cycles.

In line with Hale's CoRe interview, observation data (the teaching of cycles) pointed out that she tried to attract her students' attention to the importance of the natural resources and the results of human effects on biogeochemical cycles. For instance, during her course on the carbon cycle, she emphasized the deforestation and excessive use of fossil fuels as a human based cause of deterioration of the cycle.

> **H:…** We have destroyed the green plants that will take the carbon dioxide gas in the air. Researches show that over the last thirty years, one fifth of the trees on the earth have been destroyed. Reducing so much of the plants, of course, means that the atmospheric proportions of carbon dioxide will increase. Unfortunately, we are consciously destroying forests to build roads. Which else human activity can damage the carbon cycle of? Do you have opinion?
> **Student (Std):** The smokes releasing from factory and houses chimneys.
> **H:** Yes, absolutely. In our lives, we use fossil fuels in many places such as factories, homes, wherever energy is needed. If you consider the amount of fossil fuels used by the world's population, you can understand how the excessive

carbon dioxide gas sent to the atmosphere causes global warming. [Classroom Observation].

Furthermore, Hale was aware of both vertical and horizontal relations to the topic of biogeochemical cycles in the science and technology curriculum. Regarding the horizontal relations, she pointed out that she considered whether the students comprehended the previous topics of photosynthesis, respiration and energy flow in food chain before the teaching of biogeochemical cycles. She emphasized that these topics were prerequisite knowledge affecting students' understanding of biogeochemical cycles. When Hale's teaching of cycles was examined, it was also observed that she often recalled the previous topics during her teaching of biogeochemical cycles.

When the vertical relations were taken in consideration, Hale emphasized that the biogeochemical cycles are also closely related to the topics in the science curriculum at the grades of 5, 6 and 7. She stated that students' prior knowledge of the topics of the weather events (the formation of cloud and hail) in the 5th grade, the topic of physical and chemical changes in the 6th grade, and lastly, the topics of the properties of elements and compounds, the chemical bonds and basic building blocks of living things in the 7th grade are important for their comprehension of biogeochemical cycles. In her teaching of biogeochemical cycles, it was observed that Hale often touched briefly on the required topics related to the each cycle. For example, at the beginning of her teaching of carbon and nitrogen cycles, she started to remind her students the properties of carbon and nitrogen elements and the role of these elements in the structure of living things (building blocks of living things). In the same way, in the teaching of water cycle, she recalled her students' prior knowledge related to the formation of cloud, hail and the changes of matter states-physical change.

When asked the presentation sequence of the cycles in the curriculum, Hale was aware of the place of the topic and the sequence of the sub-topics. Hale stated that the curriculum presented the cycles respectively water cycle, carbon-oxygen cycle and nitrogen cycle. She expressed that she also presented the cycles with accordance with the curriculum. In her teaching of the cycles, it could be seen that she did not change the sequence of the sub-topics, too. However, she also pointed out that she can sometimes change the place of the topic based on her students' prior knowledge. In other words, Hale expressed that she can modify the curriculum in order to ease her students' understanding.

4.2.2.2.2. Hale's Knowledge of Materials

In terms of resources used, Hale explained that she has actively used the textbook and student exercise book to teach the biogeochemical cycles. She underlined that she generally used the textbook to follow the curriculum. Besides, Hale pointed out that she preferred the student exercise book and her activity sheets to evaluate the students' understanding of the topic. She emphasized that she prepared the activity sheets through the results of her communication with her colleagues in social media. Moreover, she also pointed out that she reaped the benefit of the presentations and animations during the teaching of biogeochemical cycles. In here, she stated that she used the internet both to show the animations and to obtain updated information related to the cycles (Table 4.34).

Table 4.34. Hale's Aim of Using Teaching Sources

Sources that teacher use	**Aim of using in teaching**
Textbook	To follow the curriculum
Presentations/Animations	To teach the water, carbon-oxygen and nitrogen cycles.
Student Exercise Book	To evaluate the students' understanding of the biogeochemical cycles
Activity sheets	To evaluate the students' understanding of the biogeochemical cycles
Internet	To show the animations & To update the information related to the topic of cycles
Summary Sheets	To repeat the topic of biogeochemical cycles

During the classroom practice, it was observed that Hale actively used presentations with animations to transmit the concepts and processes of the biogeochemical cycles. At the end of the teaching of cycles, she expected her students make the activities in student exercise book and in her own activity sheet. Lastly, she distributed a summary sheet of each cycle in order to both repeat the topic and attach to the students' notebooks.

4.2.2.3. Hale's Knowledge of Instructional Strategies

In this section, the knowledge of instructional strategies of participant teachers was reported in two categories namely, knowledge of subject specific strategies and knowledge of topic specific strategies.

4.2.2.3.1. Hale's Knowledge of Subject Specific Strategies

Hale stated that she prefer to use project/problem-based learning in the teaching of biogeochemical cycles. She explained that she expected her students to investigate the causes, results and solutions to the deterioration of the cycles and discuss the results in the classroom. Then, she pointed out that she mostly used direct instruction and questioning method to complete the students' missing points. She pointed out that she often let her students to answer questions and share their ideas about the topic.

> **Researcher (R):** How do you teach the topic of biogeochemical cycles? Which instructional strategies do you use in general?
> **Hale (H):** I said that I teach the topics parallel to the curriculum. While I teach the biogeochemical cycles, I often use questioning method to transmit the concepts of the topic. In the same way, I ask several questions in order to remind their knowledge related to the previous topic. I usually benefit from the figures and animations in order to explain the processes of the cycles. I also give examples from their daily lives. I show photos from Hiroshima, Nagasaki and Chernobyl to attract my students' attention to the consequences of the environmental problems…Besides, in these topics, the students generally study in groups and present their products in the classroom. During their presentations, they can use visual materials such as videos and animations, too. [CoRe Interview].

Observation data revealed Hale generally used the direct instruction and questioning to explain the important points related to the biogeochemical cycles as well. Moreover, she gave her students chance to both present their studies related to the problems and solutions to the biogeochemical cycles and discuss the results with their peers.

As she stated, she also mostly preferred the questioning method in order to either remind her students the previous knowledge or understand what they learn about the topic. For instance; during the teaching of carbon cycle, Hale used questions to monitor what her students know about fossil fuels and the sources of carbon in nature.

> **H:** Let's continue with the carbon cycle. You know there is 0.03 % carbon dioxide in the atmosphere. This amount of carbon is important for us. The increase in the amount of the carbon is a problematic, and unfortunately in recent years we know this value has increased. Except the atmosphere, where is the carbon stored in nature?
> **Std:** There is in fossil fuels.
> **H:** Yes. What does fossil fuel mean?
> **Std:** In the oxygen-free environment, the detritus of the plants and animals…
> **H:** With oxygen or oxygen-free?
> **Std:** Oxygen-free, yes. The detritus of plants and animals constitute the fossil fuels such as wood, coal and natural gas under the soil.
> **H:** Yes, absolutely. Fossil fuels are the detritus of the dead plants, animals and human bodies that contain carbon and they [fossil fuels] are formed as a result of a long period of time without oxygen under the soil. What else?
> **Std:** In the structure of plants and human.
> **H:** Yes. C, H, O and N are found in the structure of living things... And also in the oceans, the carbon compounds are found as dissolved carbon compounds. [Classroom Observation].

In conclusion, when Hale's teaching of biogeochemical cycles was examined, it could be seen that direct instruction and questioning dominated her courses on the topic of biogeochemical cycles. Although the main characteristic of her teaching was its teacher-centeredness, she also preferred the project-based learning as a student-centered strategy in order to make her students to be active.

4.2.2.3.2. Hale's Knowledge of Topic Specific Strategies

4.2.2.3.2.1. Hale's Knowledge of Representations

Results showed that Hale used the representations like presentations, illustrations, animations, and examples in order to aid students in developing the comprehension of the topic of biogeochemical cycles. She actively used the presentations to help the students to comprehend the cycles. When necessary, she expressed the processes of each cycle through the different visuals in the presentations. For example, she used the schemas (Figure 4.12) in order to both explain the concepts of hydrological cycle and summarize the cycle at the end of her lesson. Moreover, she showed an animation to explain the process of transpiration in the plants (Figure 4.13).

While teaching of carbon cycle, Hale also used a schema (Figure 4.14) in order to aid her students' understanding**.** Besides, she showed two animations (Figure 4.15) related to oxygen and carbon cycles so she could attract her students' attention to the connections between producers, composers and decomposers in these cycles. Besides, during her teaching the nitrogen cycle, she noticed that her students had difficulties on the processes of nitrification, nitrogen assimilation and decomposition. Therefore, she used different visuals and animations to explain the processes of the cycle. She showed the schemas in order to explain the components and processes of the cycle (Figure 4.16). Then she used the animations to both emphasize the relations between biotic and abiotic components and summarize the processes of the nitrogen cycle (Figure 4.17).

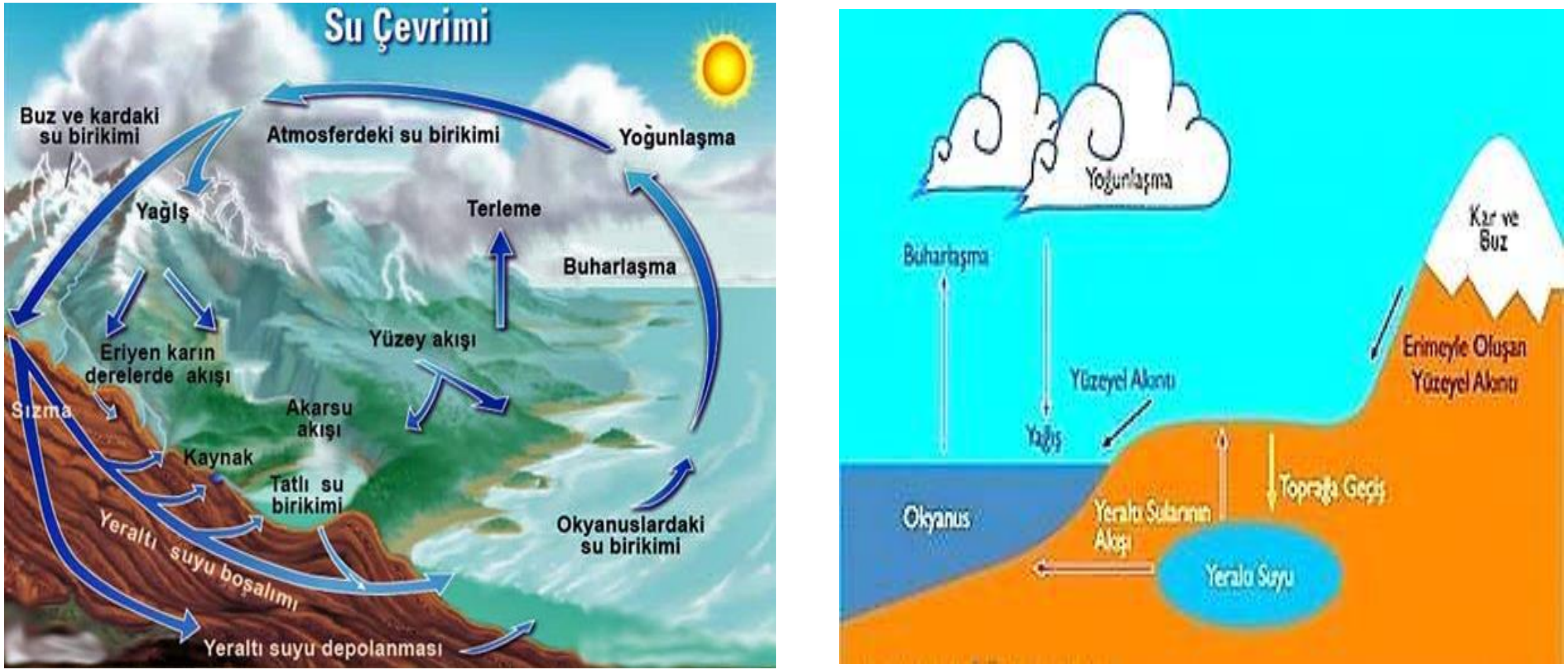

Figure 4.12. The Schemas Hale Used to Teach the Hydrological Cycle

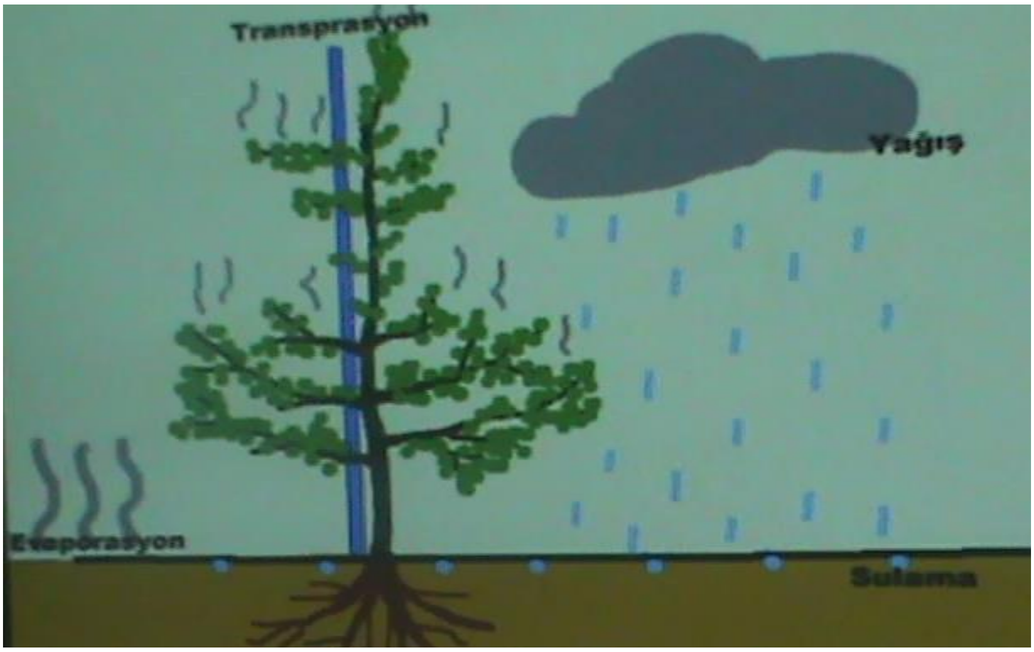

Figure 4.13. The Animation Hale Used to Show the Transpiration

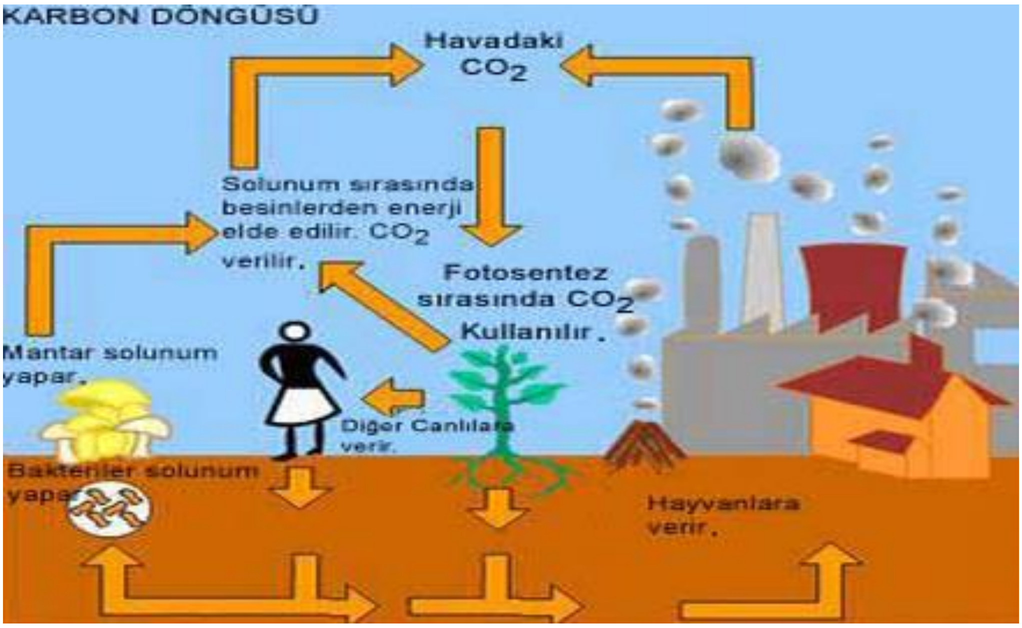

Figure 4.14. The Schema Hale Used to Teach the Carbon Cycle

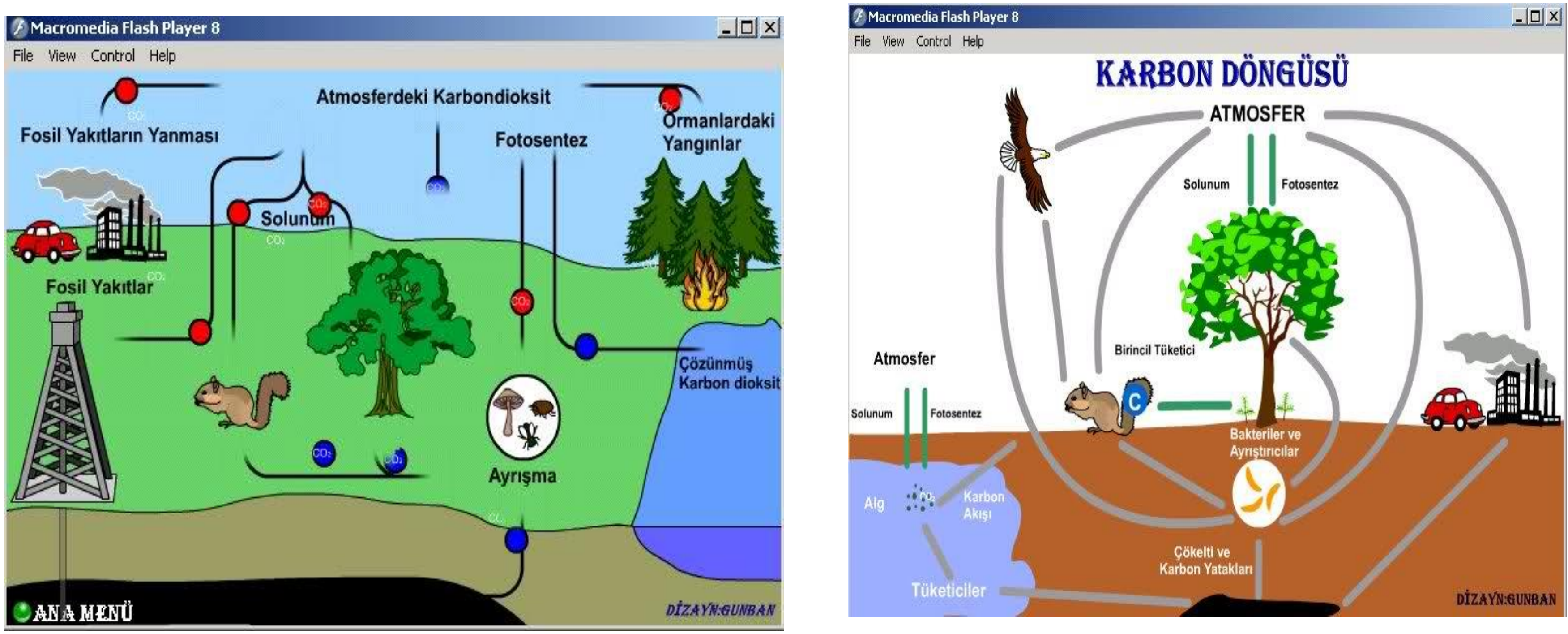

Figure 4.15. The Animations Hale Used to Show the Carbon and Oxygen Cycles

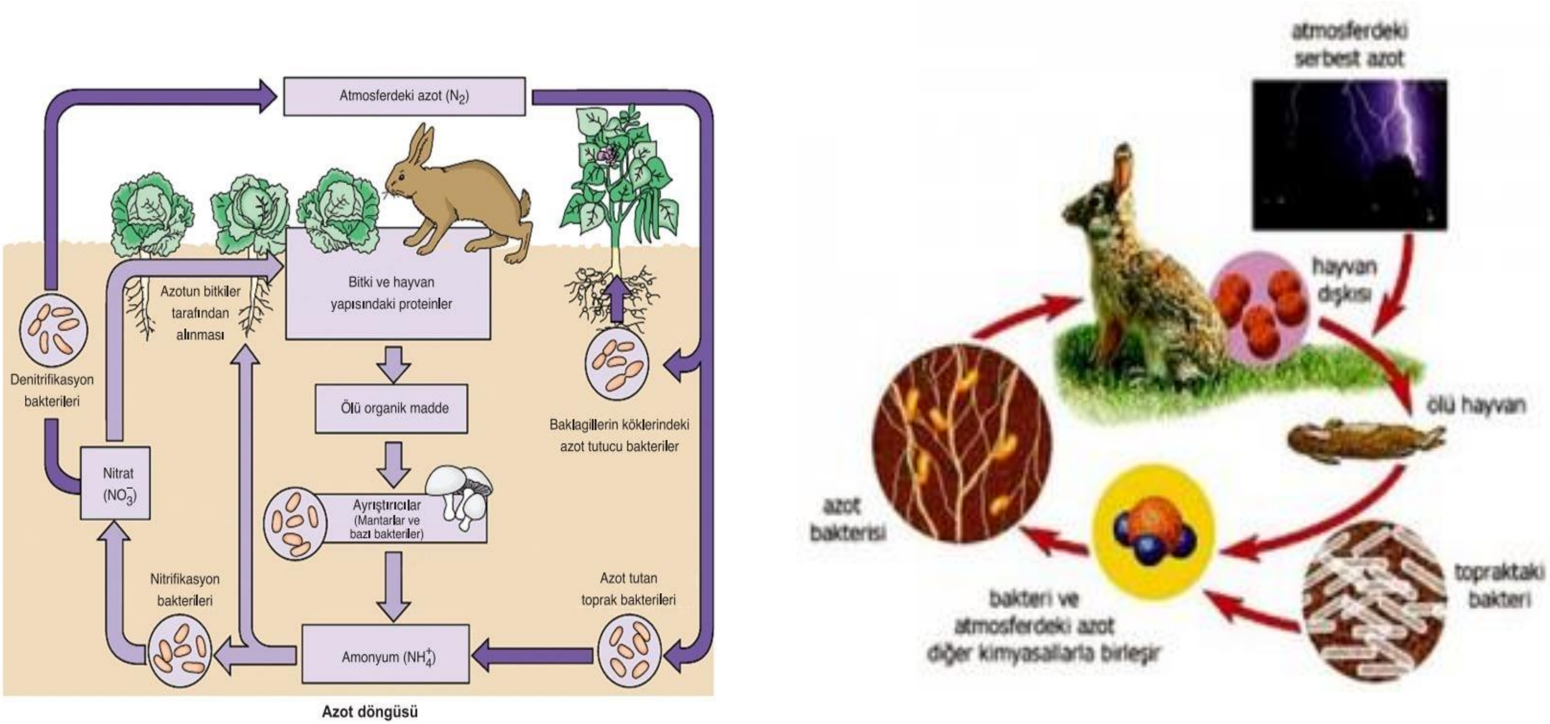

Figure 4.16. The Schemas Hale Used to Teach the Nitrogen Cycle

Figure 4.17. The Animations Hale Used to Show the Nitrogen Cycle

Moreover, Hale gave various daily life examples to support the comprehension of her students. For example, in her teaching of hydrologic cycle, Hale gave an example from her experiences to emphasize the deterioration of the water cycle as a result of human-based activities.

> **H:** In the water cycle, we wonder about the decrease in the amount of usable water. If so what is the cause of this problem in the water cycle? As your friend just said, the poisonous gases, entering the atmosphere, caused trouble in the structure of the rains falling on the earth. The rains fall down to earth as acid rains. There's something I remember from my grandmother: in old times, there had been five-pound oil cans. After these cans had been empty, my grandmother's mother had put them in the garden. The rainwater had been falling on those cans. They had used the rainwater to wash vegetables and fruits or to bathe. Now it is not possible to do such a process with rain water. Particularly, after the nuclear explosions or volcanic eruptions experts warn us to avoid exposure to the first rain as much as possible. Why? Because they contain acids, and are dangerous for the living things [Classroom Observation].

Hale also used a simple example of a hundred glasses of water to attract her students' attention to the amount of usable water resources on Earth.

> **H:** As you know, there are many sources of water such as oceans, seas, groundwater, rivers, and lakes. The amount of these resources is expressed in units of million cubic meters. It's hard to keep them in mind, of course. A scientist has made an analogy that every individual can understand. He likened the total amount of water resources on earth to a hundred glasses of water. The ninety-seven glasses of the hundred glasses are composed of salty waters such as ocean and seas. Three glasses of water left behind. He says two glasses of these three glasses of water are hidden in icebergs. It remained one glass of water. One glass of water also creates fresh water resources such as ground waters, lakes and rivers. An average of 7.5 billion people will consume this water. Imagine, if a drop is disappeared, what happens as a result of this decrease? Today, we see that more than a drop has disappeared from the water resources. The lakes are dried and the rivers are shrinked. Then why is the amount of water decreased?.

4.2.2.3.2.1. Hale's Knowledge of Activities

Hale stated that she conducted the activities found in the textbook and student exercise book. As she cited, she included the activities regarding the topic of biogeochemical cycles in her lessons. Although she generally preferred a wide range of representations, she also used the puzzle solving and concept map completion activities in order to understand whether her students comprehend the topic of the cycles. In this cross puzzle activity, students are required to ask the appropriate questions for the each concept (hydrological cycle, cloud, oxygen, decomposer, nitrogen, lightning) shown numbers. (Figure 4.18).

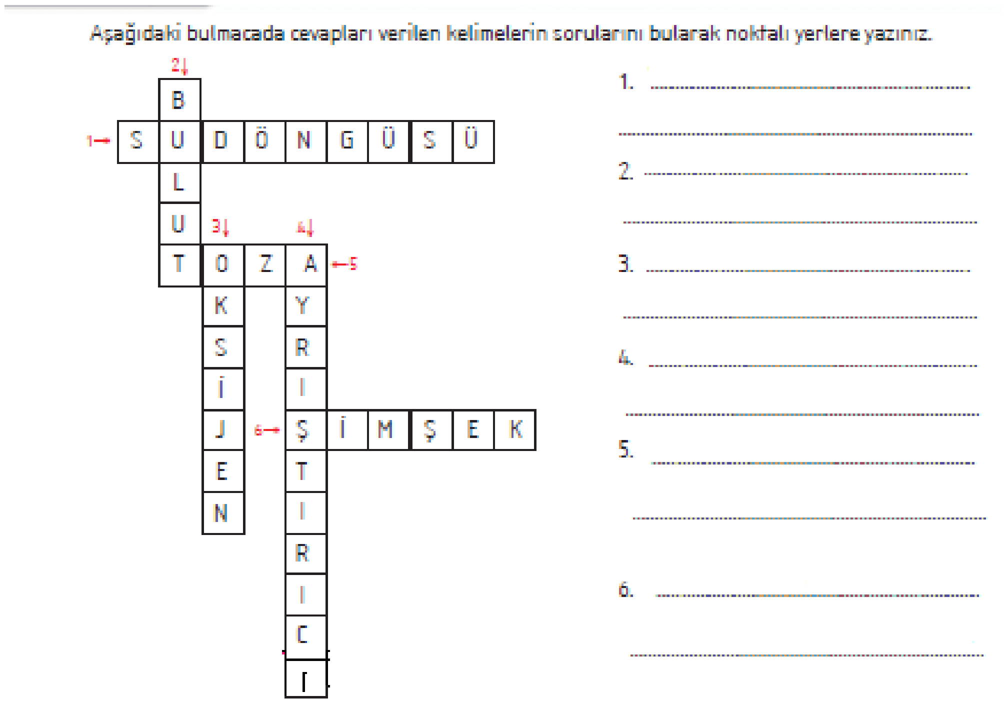

Figure 4.18. The Puzzle Activity Hale's Used to Assess Students' Learning *(In Turkish)*

In addition, Hale asked her students to complete the concept maps with the given concepts regarding the unit of living things and energy relations. After students complete the concept map, she showed the completed concept map (Figure 4.19) as a visual on the board through the projector. In this map, students are required to fill the empty boxes with the appropriate concepts such as living things, decomposer, composer and respiration.

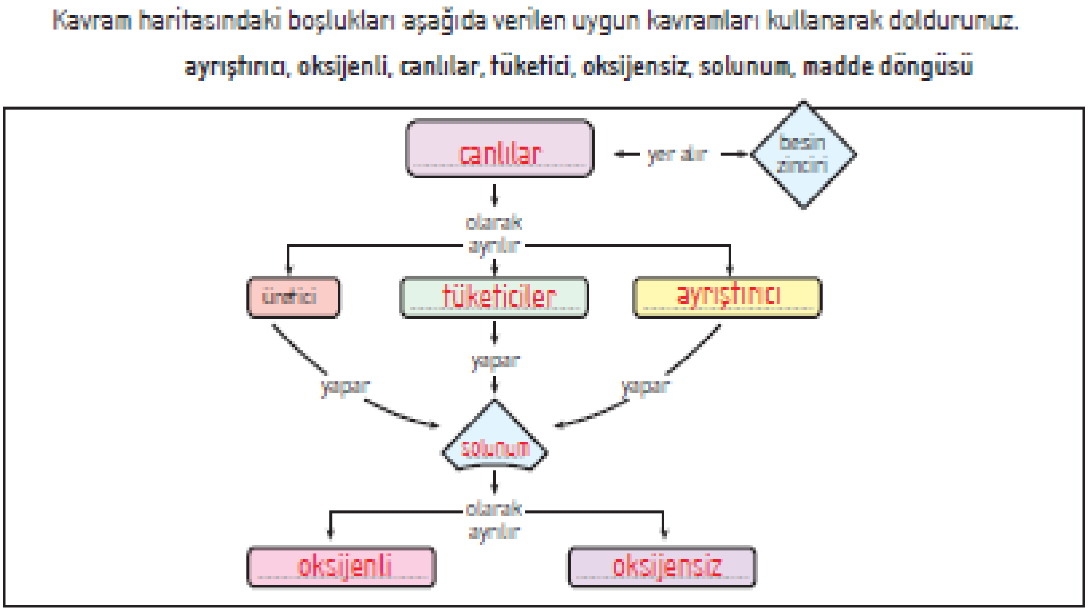

Figure 4.19. The Concept Map Completion Activity Hale's Used to Assess Students' Learning *(In Turkish)*

4.2.2.4. Hale's Knowledge of Students' Understanding of Science

This component of PCK focuses on the teachers' knowledge in order to help students develop specific scientific knowledge. There are two subcomponents: requirements for learning and areas of difficulties. In this section, Hale's knowledge of learners' understanding regarding the topic of biogeochemical cycles was presented.

4.2.2.4.1. Hale's Knowledge of Requirements for Learning

Hale was aware of the pre-requisite knowledge needed by students to learn the topic of biogeochemical cycles. She initially underlined that students need to know the structure of the carbon, hydrogen, oxygen, and nitrogen elements, the compounds they formed, the amount of these elements in the atmosphere. Then she pointed out that the organic structure of the living things is the other pre-requisite knowledge that students need to learn.

> **Researcher (R):** What prerequisite knowledge do students have to learn the topic of biogeochemical cycles?
> **H:** They must know the structures of carbon, oxygen, hydrogen and nitrogen. What are the structure of carbon, oxygen, hydrogen and nitrogen? What kind of compounds do these matters form? Where are they stored in nature? They [students] have already learned these concepts in 7th grade and previous units of this year. Therefore, they are able to connect these topics to the biogeochemical cycles. Another point is that students need to know the roles of these substances in the structure of living things. Besides, students also should know the amount of these matters in the atmosphere. By this way, they can easily comprehend the consequences of the deterioration of the cycles… [CoRe Interview].

After that, she emphasized that students' comprehension of the topics of energy flow in the food chain, and the processes of the photosynthesis and respiration is also important for students' understanding of the biogeochemical cycles. In this regard, she expected her students to know the relations between biotic and abiotic components of the ecosystems.

> **H:** I give information to the children about energy transformations. I say that the source of our energy is the sun. Starting from the green plants that can use the energy of the sun directly, they know how this energy can flow among the plants, animals, and people. What do producers and consumers mean? What is the relationship between producers and consumers? I expect them to know these topics. They also need to know about the nutrition of living things because I expect them to know that energy can be transformed by food chains and webs among living things. They have already known the importance of green plants. Other than that, we talks about blue-green algae and cyanobacteria as a producer. If they know these relationships between biotic and abiotic components in nature, they can understand the importance of the ecological balance that they form and that they need to be protected. The students' prior knowledge on these issues make their comprehension of matter cycles topic easier. [CoRe Interview].

As she mentioned, Hale often used the pre-requisite knowledge to aid his students' learning of the new topic of biogeochemical cycles in her teaching. For instance, before the teaching of the topic of nitrogen cycle; she wanted her students to remind the topic of the organic building blocks of the living things. She expected her students to remember the role of nitrogen in the structure of living things in order to teach the processes between biotic and abiotic components in the cycle.

> **H:** You learned the buildings blocks of living things last year. Now, let's remember the molecules found in the structure of living things. Which molecules constitute the structure of living things?
> **Std1:** Carbon hydrates, proteins and fats.
> **H:** Yes. Which elements are there in the structure of proteins?
> **Std2:** Carbon, hydrogen, oxygen.
> **H:** Yes. What else?
> **Std3**: Nitrogen.
> **H:** Yes, Nitrogen, phosphorous and sulphur so the nitrogen element, which forms the proteins in the structure of living things, is one of the most important matter for us…[Classroom Observation].

In the same vein, it can be seen that she reminded the topic of the compounds to explain the nitrification process in the nitrogen cycle.

> **H:** …There are nitrogen-binding and nitrogen-decomposing bacteria in the roots of the legumes and in the soil. Through these bacteria, nitrogen can be converted into compounds like nitrate, nitrite, ammonium, ammonia and nitric acid in the soil. You remember these nitrogenous compounds from the topic of elements and compounds, right?... [Classroom Observation].

Moreover, Hale considered her students' both skills and abilities and learning styles during her teaching of biogeochemical cycles. She preffered both use of project-based stragetgy and various topic-specific strategies. She gave her students an opportunity to discuss their peers' projects and reflect their ideas. Furthermore, it could be said that she was concerned the different types of learning styles due to the existence of various representations.

4.2.2.4.2. Hale's Knowledge of Areas of Students' Difficulties

Hale stated that her students did not have any difficulty or misconception in the topic of biogeochemical cycles. She pointed out that students were knowledgeable about the related topics because of the private lessons in the cram school. On the other hand, Hale emphasized that students cannot transform their environmental knowledge to daily life. She complained that the learners cannot develop an attitude in accordance with their environmental awareness. In here, it can be said that Hale was concerned about the lack of her students' skill development on affective domain.

> **R:** Do students have learning difficulties that affect your teaching about biogeochemical cycles? This may be misconception or partial understanding. At what points do students have difficulties?
> **H:** There is no point that students have difficulties or misconception in these topics but I think there is a problem with the transformation of their knowledge to the daily life. For example, s/he [student] knows that s/he shouldn't throw the trash to the street or knows how to use natural resources consciously. But learners have some habits so they can't transfer their knowledge to the behavior. This is a difficulty we generally face with in environmental issues and unfortunately we cannot easily assess the students' behaviors or attitudes. However, as far as I can, I try to help my students to comprehend the environmental issues and problems im my science lessons.
> **R:** Do not their prior knowledge have any misconception?
> **H:** As I said, my students have learned the topics and known the atmospheric events related to the biogeochemical cycles since the 4th grade. Therefore, they do not have any misconception with their prior knowledge. [CoRe Interview].

4.2.2.5. Hale's Knowledge of Assessment

This category of PCK includes two subcomponents namely; knowledge of dimensions of science learning to assess and knowledge of methods of assessment. Kemal's knowledge of assessment regarding the topic of biogeochemical cycles was presented in this section.

4.2.2.5.1. Hale's Knowledge of Dimensions of Science Learning to Assess

Hale's knowledge of assessment on students' learning was examined in the dimensions of conceptual understanding, NOS understanding, and the connections sustainable development issues regarding biogeochemical cycles. Hale stated that during the teaching of the science topics, it is important to know whether the students understand the related concepts. Therefore, Hale emphasized that she preferred to evaluate the conceptual knowledge presented in the curriculum during the lessons. Besides, she cited that in her teaching of biogeochemical cycles, she used the project work to engage the students in the learning process. She underlined that, in the projects, she could evaluate her students' skill development through the peer assessments. Hale emphasized that the peer assessment supports the students' development of critical thinking, and interpersonal skills, as well as enhancing understanding the conceptual knowledge related to the biogeochemical cycles. Additionally, she expressed that students could also develop both cognitive skills such as problem solving, decision making, critical thinking) and science process skills (communicating, analyzing and interpreting etc) during the preparation of their projects.

When Hale's teaching of biogeochemical cycles examined, it was observed that she gave her students chance to present their projects as a group work on the related topics. Her students could only evaluate their peers' performance during the presentations by the help of an asseesment rubric. Besides, observation data revealed that although Hale generally focused on the assessment in order to evaluate her students' conceptual understanding, through her different questions, she tried to draw her students' attention to the SD related issues. It was also observed that she used questioning to either reveal her students' conceptual knowledge or monitor her students' prior knowledge on previous topic, as well. For example, she tried to elicit students' prior conceptual knowledge on the photosynthesis and respiration before his teaching on biogeochemical cycles.

> **H:** …Now, let's remind the topics that you learned in the previous weeks. You know, we have learned and made generalizations about the needs of living things. What kind of needs do you have? What are the needs of the living things, when you think of plants, animals, and people?
> **Student (Std):** The common need of them is food.
> **H:** Yes, your friend Dilan says that plants, animals, and people needs food. What else?
> **Std**: Plants needs water.
> **H:** Do not the people need water?
> **Std:** Yes, they need water, too. However, the plants need to produce food and water is necessary for producing food in the photosynthesis.
> **H:** Yes, all living things need water? What else?
> **Std:** They need energy to survive.
> **H:** Yes. They need energy for the continuation of their metabolic activities. What else do they need?
> **Std:** The plants need the light for the photosynthesis.

H: Yes, what else?
Std: Again plants need the carbon dioxide in order to photosynthesize.
H: Yes, absolutely. What else?
Std: The oxygen in the respiration.
H: I satisfy the need of food and then this food is burned with the oxygen to produce energy. Yes. Is the respiration only done by the people?
Std: No. Plants and animals can do respiration, too.
H: Yes, I want to ask a question in here. The living things need water, carbon dioxide, and oxygen. We do not mention but we also need nitrogen. Some matters in nature are needed for the continuation of the life. We always consume these matters in different ways but we know that the amount of these matters should be stable. How the amount of these matters preserve in the atmosphere?
Std: They can be renewed. In other words, the amount of them is preserved through the matter cycles.
H: Yes. Therefore the amount of the matters can be stable by the help of the matter cycles. And today, you will learn how the matters that the living things need for the life cycle in nature… [Classroom Observation]

Some questions that Hale used to assess his students' learning during the teaching of biogeochemical cycles were presented below in Table 4.35.

Table 4.35. Hale's Sample Questions to Assess Students' Learning

Questions
What are the needs of living things in order to survive?
What is the importance of water for living things?
Where is the carbon stored in nature?
What does fossil fuel mean?
Where are fossil fuels used?
Which compounds does the nitrogen form?
Where is the nitrogen found in the structure of living things?
What are the humans' effects on the carbon cycle?
What should be done for prevention of the balance of the carbon-oxygen cycle?

4.2.2.5.2. Hale's Knowledge of Methods of Assessment

Hale stated that she preferred to use different assessment methods namely; informal questioning, activities on textbook and students exercise book, her own activity sheets, peer assessment for students' project works, and written exam. She emphasized that she generally used the questioning method to either recall the students’ prior knowledge or understand how much students learn in her lessons. Furthermore, she pointed out that she expected her students to both answer the questions and do the activities in the textbook or student exercise book. She also cited that she often distributed to the students the activity sheets she prepared after the teaching of the topics. She mentioned that when suitable, she used the alternative assessment methods like concept map and peer assessment through the topic of biogeochemical cycles.

> **R:** Are there any specific methods that you generally use to assess students’ learning on the topic of biogeochemical cycles? How do you use these methods?
> **H:** …In written exams, I can assess whether the students understand or not. Before the exam, I use the questioning very often in the topic of biogeochemical cycles. Again, students have done activities such as the completion of a concept map. We also use activities in the student exercise book. Sometimes I can distribute the activity sheets I prepared. Then, for the reinforcement, we solve many test questions asked in previous TEOG exams at the end of the unit. In addition, students also make presentations about these issues. I also expect them to evaluate their friends’ performances. I give them a guideline and a criteria table for the presentations. According to these documents, they can both make presentations and evaluate their friends’ group work. They can also learn the related topics by the help of the presentations.
> **R:** Ok, why do you assess in this way? What are the reasons?
> **H:** I think it is more effective than the written exam. When you assess the students learning during the lessons, you can see whether the students can answer properly or not. For example, I usually ask my questions to the students who do not raise their fingers. When I asked the question, I can see whether the student can establish the connections between the topics. Students can also recognize their lack of knowledge through the discussion in the classroom. But they [students] can forget assignments you gave as homework or they [students] can get the answers from their friends before they come to class. Then I can't understand whether students can learn the content in such way. However, I can observe easily by the help of the various activities in the classroom. Students’ participation is very important for me. I expect them to express their opinions and knowledge. Then if I have to do the activity and if I couldn't do it in the classroom, I can give it as homework. After that I solve the question in the classroom next lessons... [CoRe Interview].

During her teaching of the cycles, Hale preferred generally the open-ended questions to provide feedbacks on how much her students understand. Furthermore, the whole students presented their projects related to the topic of biogeochemical cycles in groups. Hale tried to provide feedbacks or review the points that learners have difficulties through these presentations. Although she tried to develop her students' affective or cognitive skills through peer assessment technique, her students could only evaluate their peers' performance during the presentation. In this regard, Hale's formative assessment was missing.

> **R:** Do you assess your students' learning during the course?
> **H:** Yes, I try to evaluate my students' comprehension during the lesson as much as possible because I can be aware of the misconceptions or missing points immediately. You know, it is really hard to assess whether all of 40 students understand in a 40-minute lesson. However, I prefer these assessment techniques because if I cannot get answers in some questions, I return to the related topics and help my students to comprehend properly.

It was observed that Hale also focused on the summative assessment at the end of both the related cycle and the unit. She used the activities on the student exercise book to evaluate whether students learn the related concepts. Moreover, she used her own activity sheet after the teaching of biogeochemical cycles to evaluate students' learning. She also held a written exam including multiple choice items (twenty questions). In the exam, there was only one multiple choice question in order to assess students' conceptual understanding on the biogeochemical cycles. In the light of the explanations above, Hale's knowledge of assessment was summarized in Table 4.36.

Table 4.36. The Summary of Hale's Knowledge of Assessment

Method of Assessment	**Aim of the Assessment**	**Type of Assessment**	**Way of Assessment**	**What is Assessed**	**Types of questions**
Questioning	To provide feedbacks on students' understanding on related concepts	Formative	Informal (Open-ended questions)	Prior Knowledge & Content (Conceptual Understanding)	Open-ended
Exercises on textbook and student exercise book	To monitor students' understanding after the teaching of related concepts	Summative	Formal	Content (Conceptual Understanding)	Concept Map Completion Puzzle
Activity Sheet	To evaluate students' understanding after the teaching of the biogeochemical cycles	Summative	Formal	Content (Conceptual Understanding)	Summary Concept Map
Peer Assessment on the project work	To evaluate the students' performance during their presentation on the cycles	Summative	Formal	Content (Conceptual Understanding) & Performance	Rubric
Written Exam	To evaluate students' learning at the end of the unit	Summative	Formal	Content (Conceptual Understanding)	Multiple-choice

4.3. CASE 3: Selda's Subject Matter Knowledge and Pedagogical Content Knowledge on Biogeochemical Cycles

In this study, the researcher used the pseudonym for the participant teachers and Selda was called as Case 3. Selda is female and forty-eight years old. She was graduated from biology department in Faculty of Arts and Science of a public university in 1993. After teaching as a classroom teacher for one year in a public primary school, she has been teaching science for twenty years in public middle schools as a science teacher. Selda has already been working in Eco-schools project implemented by TÜRÇEV for three years in her current middle school. Selda has taught 6, 7 and 8th grades in 2013-2014 education year and has twenty course hours as work load per week. There were thirty students in her classroom. In this section, Selda's results of subject matter knowledge and pedagogical content knowledge were presented.

4.3.1. Selda's Subject Matter Knowledge

4.3.1.1. Selda's Substantive Knowledge

The results of Selda's substantive knowledge regarding biogeochemical cycles are presented in three headings, respectively; carbon, hydrological and nitrogen cycle.

Initially, Selda requested to answer the question what the biogeochemical cycle is. She explained the cycle as '' the process in which the matters such as water, carbon, oxygen, nitrogen, phosphorus and sulfur are used by living things and return to their resources again. She continued to the definition by emphasizing the limited amount of these matters. Thus, she underlined that they [matters] should be used in balanced way. She explained that the survival of the life is based on the continuity of the matter cycles. It can be seen that Selda referred the living things as biotic components of the cycles. On the other hand, she did not address the abiotic components such as the sun and soil although she highlighted the reservoirs of chemicals in her definition. As a result, Selda's understanding of the cycle was labeled as partial according to the scientific definition.

Researcher (R): How can you define biogeochemical cycles?
Selda (S): In nature, matters such as water, nitrogen, phosphorus, sulfur, carbon and oxygen are used by living things and returned to their sources. These matters used by living things are not unlimited…Therefore, it is important to preserve the amounts of these substances and to use them in a balanced way because these substances are very important for living things and for the continuation of life. Any increase or decrease in the amount of these substances or any deterioration in the cycle prevents the system from functioning properly…

4.3.1.1.1. Selda's Knowledge about Carbon Cycle

To reveal Selda's understanding of carbon cycle, she was requested to explain the carbon cycle through drawing. Selda's understanding of carbon cycle was labeled as partial based on the statements in both her drawing and teaching. In Table 4.37, Selda's understanding related to the carbon cycle is summarized.

Table 4.37. Selda's Understanding of the Carbon Cycle

	Selda's Understanding
Components within the cycle	• Plants (as Producers) • Animals, herbivores, omnivores and people (as Consumers) • Decomposers • Organic compounds in the structure of all living things, fossil fuels, CO_2 in the atmosphere (as Carbon Reservoirs) • Soil (As abiotic component) • Water (As abiotic component) • Sun (As energy source)
Processes within the cycle	• Burning of fossil fuels • Photosynthesis of plants • Respiration of living things • Transferring of carbon element from plants to consumers through food chain • Decomposition

When asked the question of why the carbon cycle is important, Selda first stated the existence of carbon and oxygen elements in the structure of living things. She highlighted their [carbon and oxygen] functions in the formation of organic compounds such as proteins, carbohydrates, and fats. Furthermore, she underlined the importance of both CO_2 in photosynthesis for the producing food and O_2 for the respiration of living things.

R: Why is the carbon cycle important?
S: Carbon and oxygen are important elements because they are found in the structure of living organisms. The proteins, carbohydrates and fats are the basic organic molecules including carbon, hydrogen and oxygen. All living things compromised of these molecules…Moreover; we need the energy to survive. Hence, humans do respiration to satisfy their need of energy. We can use the oxygen gas and the food produced in photosynthesis by used CO_2. In this manner, CO_2 is also important to get energy…

Afterward, Selda began to explain carbon cycle through drawing (Figure 4.21). She first addressed the process of combustion explaining the release of CO_2 to the atmosphere through the use of fossil fuels in human activities. She continued to her drawing the process of respiration and photosynthesis. She expressed that the carbon dioxide is released to the atmosphere by the way of respiration of living things. After that, Selda explained the photosynthesis as the process that the plants use both the carbon dioxide and the water in the soil; therefore, make food by the help of the energy of the sun. As is seen, she clearly pointed out the abiotic components of the cycle as the sun, water and soil. Although she did not show the process of transformation of organic carbon in her drawing (Figure 4.20), she mentioned that the carbon element is transformed to the consumers (i.e. herbivores, omnivores,) through the food chain. After that, Selda mentioned about the decomposition process. She, however, did not show the process of decomposition in her drawing (Figure 4.20).

R: Could you please explain the carbon cycle by drawing?
S: …[Drawing] Let's draw a settlement. There's a road here. There's a house and a factory at the side of the road. The burning of fossil fuels from the chimneys of these houses and factories results in gases such as carbon dioxide and carbon monoxide. Also, there are humans, here. They are respirating. Millions of human around the world takes O_2 from the air and gives CO_2 to the atmosphere. I'm drawing a lot of trees as producers, across the road. Carbon dioxide released by respiration and as a result of burning fossil fuels is used in the photosynthesis by green plants. Water is needed in the cycle. Plants are receiving water from the soil and carbon dioxide from the air. I'm drawing a leaf because I need to show

chlorophyll. As a result, plants produce oxygen and food through the photosynthesis by the help of the sun and chlorophyll. Later, the carbon in the food is passed to other organisms through the food chain. In other words, herbivores eat plants and take carbon compounds into their bodies. Again, the food is transferred from herbivores to carnivores and all other living things in the food web. Then the dead animal and plant residues are decomposed by the decomposers and the carbon dioxide returns to the atmosphere and thus, the carbon cycle is completed…

She also added that carbon and oxygen cycles are interrelated. She explained that the process of respiration is reverse of the process of the photosynthesis. Thus, Selda did not separately draw the processes of the oxygen cycle. She also mentioned the proportion of 21 % oxygen gas in the atmosphere.

S:…As known, there is 21% oxygen gas in the atmosphere. The only living things that can produce oxygen are plants. Plants are the most important organisms for the continuity of life because they place in the lowest step of the food chain. As in the carbon cycle, in the oxygen cycle, the oxygen produced by the plants through photosynthesis must be used in the respiration process. As a result, these [carbon and oxygen] cycles are inseparable and reverse of each other. There's no need to mention the oxygen cycle separately. The continuation of one depends on the continuation of the other. Therefore, I think the cycle should be called as the carbon-oxygen cycle.

Moreover, observation data revealed that Selda was aware of the reservoirs of carbon. She pointed out the sources of the carbon element as organic compounds in living things, fossil fuels and carbon dioxide in the atmosphere during her teaching of carbon cycle.

S: …In general, carbon is included in the structure of the organic compounds such as carbohydrates, fats and proteins. As I mentioned before, these [organic compounds] are the basic substances that form the structure of living things so all living things contain carbon. In addition, fossil fuels contain carbon, and as a result of the burning of them, carbon dioxide is released to the air. Lastly, we know that the atmosphere contains approximately 0.03% carbon dioxide. These are the sources of carbon dioxide that are basically involved in the carbon cycle…

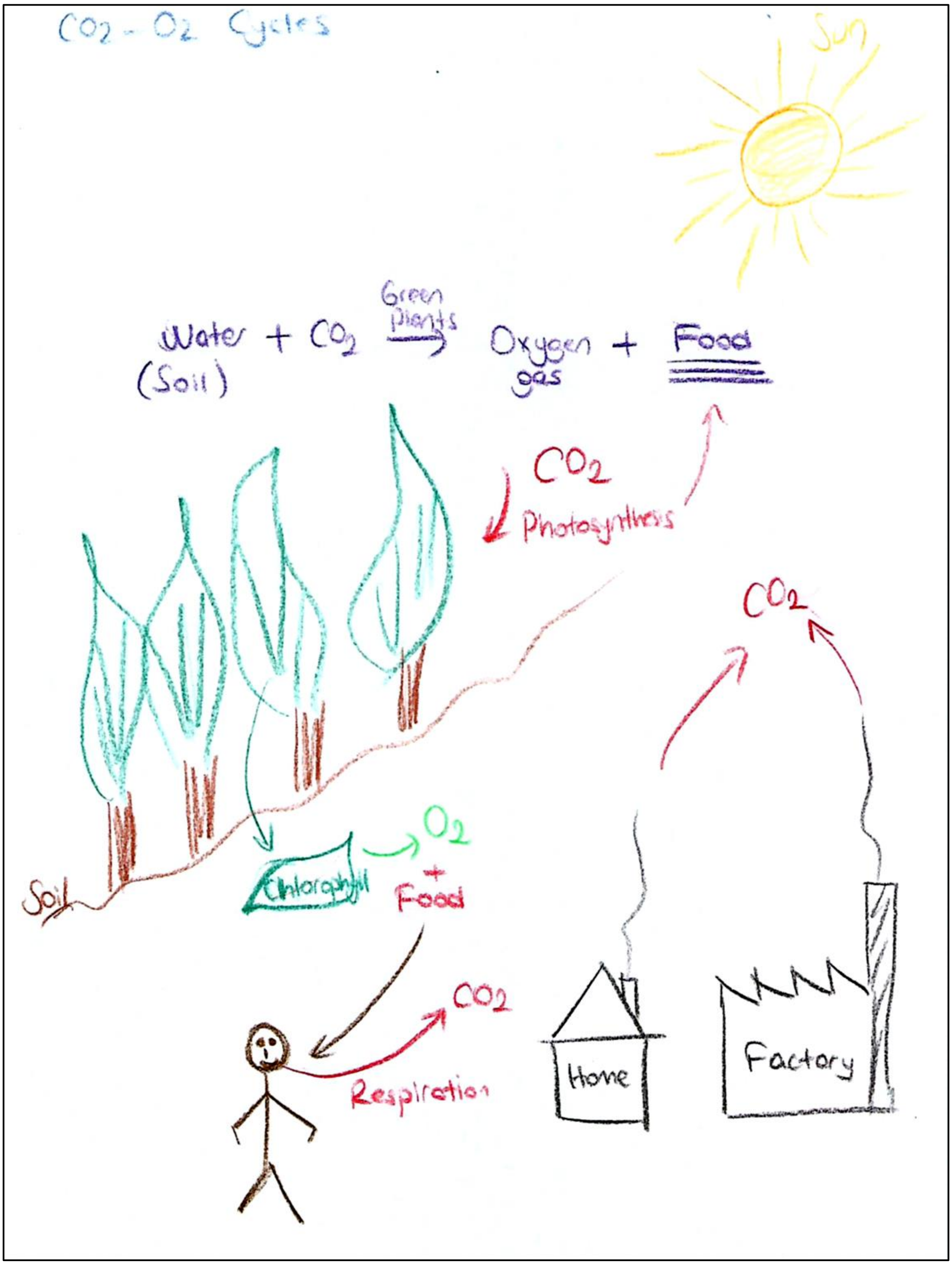

Figure 4.20. Selda’s Drawing of Carbon Cycle

In a brief, Selda's statements regarding the processes and components of carbon cycle in Table 4.37 were consistent to the scientific explanations. However, she did not state the dissolved carbon compounds in oceans as a reservoir. She did not refer the algae and cynobacteria as producers, as well. Additionally, she did not touch upon the aquatic carbon cycle in neither her drawing nor teaching. Lastly, she did not address the major source of carbon dioxide as oceans and biomass. In these considerations, Selda's understanding of carbon cycle was labeled as partial.

4.3.1.1.2. Selda's Knowledge about Hydrologic Cycle

To grasp Selda's understanding of hydrologic cycle, she was requested to explain the cycle through drawing. Selda's understanding of hydrologic cycle was labeled as partial based on the statements in both her drawing and teaching. In Table 4.38, Selda's understanding related to the hydrological cycle is summarized.

Table 4.38. Selda's Understanding of the Hydrological Cycle

	Selda's Understanding
Components within the cycle	• The plants (as Producers) • The animals, people (as Consumers) • Oceans, Lakes, Glaciers, Ground Waters and Streams (as Water Resources) • Soil
Processes within the cycle	• Evaporation • Condensation • Precipitation • Surface Flows • Penetration

Selda initially addressed the importance of water. She expressed the need of water for the metabolic activities. She expanded her explanation by stating the organisms consist of cells and, cellular activities can only occur in the watery environment. Thus, she expressed the role of water in the structure of living things accordance with the scientific explanation.

> **S:**…It is impossible to think of a life without water. Water is a vital and necessary matter for living things because cellular activities can only occur in the presence

of water. Since all living things are made of cells, we need water for all our metabolic activities…

Then, Selda mentioned all reservoirs of the water as the abiotic components of the hydrological cycle. Although she explained the water resources as oceans, ground waters, lakes, rivers, and glaciers; she only showed the oceans and ground waters in her drawing (Figure 4.21). However, she only showed the oceans and ground waters as the reservoirs in her drawing. Selda continued to her explanation with the drawing of the evaporation process in the hydrological cycle. She pointed out the formation of clouds by the water vapor evaporated from the water resources. She, then, addressed the process of precipitation as snow and rain. Then, she explained the surface flows and penetration process in the cycle.

R: Could you please explain the hydrological cycle by drawing?
S:…[Drawing] There is a mountain in here. At the top of the mountain, the water is found as snow and ice. Let's draw an ocean and ground waters accumulated under the soil. In addition to these water resources, there are lakes, rivers, streams and glaciers. Now, first the water evaporates from these water resources and the water vapor forms the clouds. Later, it falls down to the earth as snow or rain. As a result of precipitation, while some of the water percolates as ground waters, some flows to the rivers and oceans. And the water evaporates again, and the cycle continues like this…

Although she did not touch upon the condensation process in her explanations through drawing, she explained this process in her teaching of the cycle. Besides, during her teaching of water cycle, she explained the respiration as a process that all living things (plants, animals and humans) give water vapor to the atmosphere. Therefore, she referred both the biotic components and the process of respiration. On the other hand, she addressed the transpiration process neither through her drawing nor her teaching. Moreover, she did not mention about the sun and gravity as the abiotic components of the hydrological cycle.

S:… The water cycle begins with the evaporation of the surface and underground waters. The water vapor meets the cold air layer and falls down to the Earth again as precipitation. Plants and animals also give water vapor to the atmosphere through the respiration [Classroom Observation].

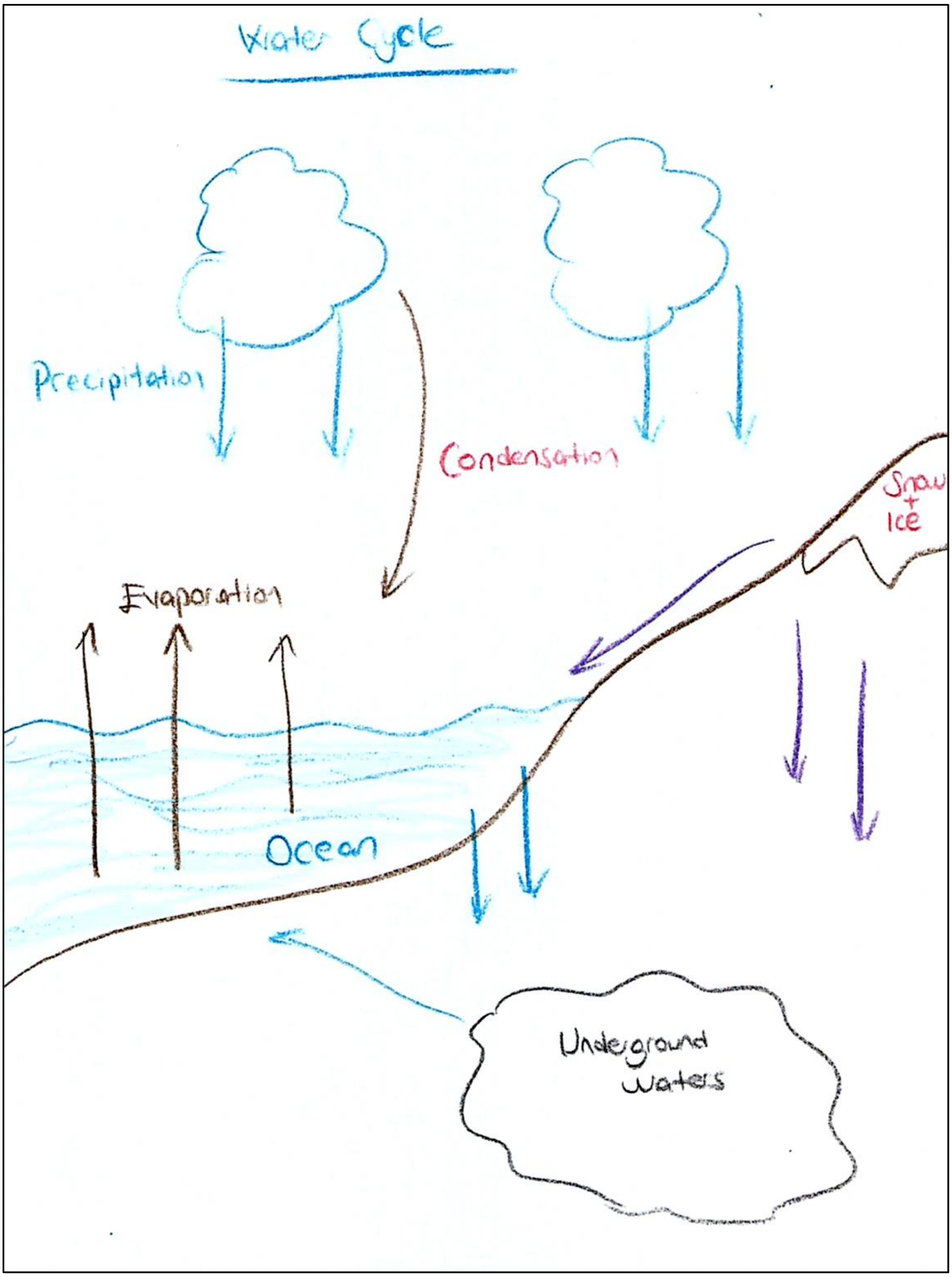

Figure 4. 21. Selda's Drawing of Hydrological Cycle

In conclusion, Selda's statements regarding the processes and components of hydrological cycle in Table 4.38 were consistent to the scientific explanations. However, Selda did not mention about the abiotic components such as sun and gravity. Besides, she did not touch upon the climatic factors such as temperature and wind affecting the hydrological cycle. Finally, she did not address the transpiration process of the hydrological cycle. In these considerations, her understanding of hydrological cycle was labelled as partial.

4.3.1.1.3. Selda's Knowledge about Nitrogen Cycle

To identify Selda's understanding of nitrogen cycle, she was requested to explain the cycle through drawing. Hale's understanding of nitrogen cycle was labeled as partial based on the statements in both her drawing and teaching. In Table 4.39, Selda's understanding related to the cycle is summarized.

Table 4.39. Selda's Understanding of the Nitrogen Cycle

	Selda's Understanding
Components within the cycle	• The plants (Legumes) (as Producers) • The herbivores, the omnivores, (as Consumers) • Nitrogen-fixing bacteria • Atmosphere and soil (as Nitrogen reservoirs)
Processes within the cycle	• Nitrogen fixation • Transformation of nitrogen compounds in the plants to animals through food chain • Lightning

Selda initially highlighted the importance of the nitrogen for the living things. She detailed that nitrogen is one of the major elements in the structure of organic molecules such as proteins and nucleic acids. Her responses regarding the importance of the nitrogen were consistent with the scientific explanations. Afterward, Selda began to explain the nitrogen cycle through drawing (Figure 22). She continued to her explanation by emphasizing the atmospheric reservoir of the nitrogen gas with the amount of 78%. She underlined that this atmospheric nitrogen gas cannot be used directly by the organisms. She added that only producers can take the nitrogen from the soil as dissolved nitrogenous compounds. Additionally, she addressed the lighting as a process that the nitrogen gas fixed to the soil. Here, she implied the soil as a reservoir of the nitrogen. Then, she drew the bacteria which she called nitrogen bacteria in the soil and roots of plants. In pursuit of her drawing, she continued to explain the process of the nitrogen fixation stating that the nitrogen bacteria in the soil fix the nitrogen gas and convert to the nitrate. Later, she touched upon the nitrogen-assimilation explaining the transformation of the nitrogenous compounds from the plants to the herbivores through the food chain. However, she did not show the plants as a biotic component in her drawing (Figure 4.22). She also addressed the decomposition process through the nitrogen bacteria. In here, however, she did not differentiate the decomposers and nitrifying bacteria. She also did not state other nitrogen bacteria such as denitrifying and cyanobacteria as biotic components of the cycle. Therefore, she could not explain the main processes of nitrification and denitrification correctly neither in her drawing nor teaching practice.

R: Could you please explain the hydrological cycle by drawing?
S:…[Drawing] Nitrogen is also very important element like carbon, hydrogen and oxygen. Why is it important? It is involved in the structure of proteins. There is nitrogen in proteins and nucleic acids in the structure of living organisms. Although with the amount of 78%, the most found gas in the air is nitrogen but living things cannot use this nitrogen directly. First, there are nitrogen bacteria in the roots of the legumes and in the soil. These nitrogen bacteria take the free nitrogen in the air in the form of ammonia and convert it into nitrogenous compounds and nitrate. Then these nitrogenous compounds are taken by plants. These plants are consumed by herbivores and then carnivores eat the herbivores. Therefore, in this way food including nitrogen compounds can be transferred between living organisms. Let's draw one rabbit there. Rabbit will eat the plants. Then it [rabbit] will give the nitrogen to the soil again. In other words, the plant and animal residues will be separated by the decomposers and nitrogenous compounds will return to the soil again. At the same time, the free nitrogen in the atmosphere is fixed to the soil by the help of the lightning and thunderstorms…

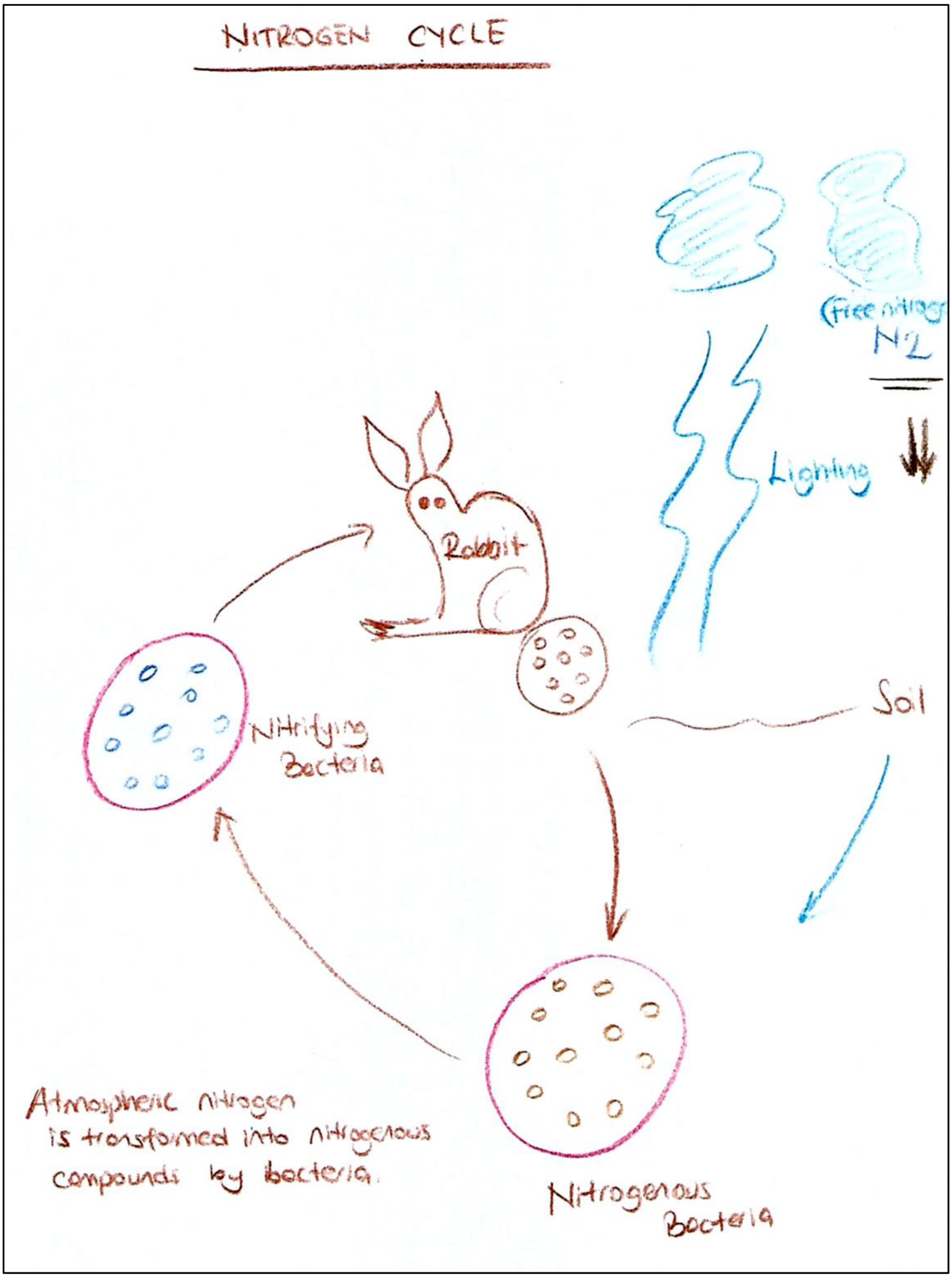

Figure 4.22. Selda's Drawing of Nitrogen Cycle

In short, Selda’s statements regarding the processes and components of nitrogen cycle in Table 4.39 were consistent to the scientific explanations. On the other hand, she did not differentiate the decomposers and nitrifying bacteria. Furthermore, she did not state other nitrogen bacteria such as denitrifying and cyanobacteria as biotic components of the cycle. Therefore, her explanations about the processes of nitrification and denitrification were not substantial. The statements in both her drawing (Figure 4.22) and teaching did not include the sun as energy source which is the important component of the nitrogen cycle as well. In these considerations, Selda’s understanding of nitrogen cycle was labelled as partial.

To conclude, it can be said that Selda’s substantive knowledge in the topic of biogeochemical cycles was partial considering her responses related to the components and processes of the cycles. In the next section, Selda’s syntactic knowledge regarding her NOS understanding was documented.

4.3.1.2. Selda’s Syntactic Knowledge

In this section, the results of Selda’s syntactic knowledge (NOS view) were presented based on empirical, tentative, inferential, creative and imaginative, subjective, socio-cultural nature of science as well as the distinction between theory and law.

Empirical NOS: When asked the question of what the science is, Selda first stated that science is a process including the sense of wonder. She explained the science as ‘’the process of finding solutions to the problems people face with in their daily life’’. She accepted that scientific knowledge is based on the evidences; and that scientist make conclusions based on the data collected through observation and experiments. In order to assert her view, she stated that scientists can conclude the existence of global warming based on data and observations such as graphs increase in temperatures. On the other hand, she also adapted the view that there exist stepwise procedures to reach conclusions and, thus, failed to understand that experiments and observations are not the sole way to advance the scientific knowledge. In the light of these considerations, Selda's understanding had missing points in terms of empirical NOS (See Table 4.40 for sample quotas).

Table 4.40. Selda's Sample Statements of Empirical NOS

NOS view	Sample Statements
Empirical	Science is first a process including the sense of wonder. It [science] is the process of finding solutions to the problems people face in the world they live in… Science serves all areas of our lives. For example, in education field, we can use computers and other technological devices by the help of the scientific developments… …Science is different from other disciplines by means of its realistic structure because science is based on the experiments. Scientists can make conclusions based on the evidences… …Why all people around the word mention about the global warming? Scientists can provide evidences, make observations and experiments…They observe based on their senses. They also propose a research question, formulate a hypothesis, and then do an experiment…Finally; they collect data and conclude the results. NASA, for example, can show a lake's situation in a period of time with the photographs, graphics, in other words with evidences. So they [scientist] have collected data for years and have reached to the conclusion that Earth's temperature has increased approximately 4 degree since 1900's.

Theory & Law: Requested to answer the question of differences between theory and law, it was understood that Selda was not aware that theories and laws are different kinds of scientific knowledge. Asserting that theories become laws when universally accepted, she possessed naïve understanding that there is a hierarchical relationship between theories and laws. Besides, her responses included the misconceptions that the theories are the knowledge that needs to be proven and laws are certain knowledge. She gave examples from Newton laws of motion and Evolution theory. Although she explained the greenhouse effect correctly, she failed to understand that it is a theory (Ramanathan, 1988; Wilkins, 1993) because of her misconception on the explanatory function of theories. Thus, her excerpts indicated that she failed to understand the functions of the theories and laws, as well (See table 4.41 for sample quotas).

Table 4.41. Selda's Sample Statements of Theory & Law

NOS view	Sample Statements
Theory & Law	… Many theories can be put forward, but these theories need to be accepted by all scientists around the world. If the theories are proven, they are called laws. For example no one disclaim the certainty of Newton's laws of motion or Principle of Pascal. However, I can accept the Darwin's theory but you cannot accept it; because this theory needs some evidences…That is, it needs to be proven… …The greenhouse effect is a law for me. Scientists have a common conclusion that the global warming really happens. They all concluded that the increase in the temperature is caused by the greenhouse gases. The results of the studies, conducted in twenty years, have indicated that the temperature of the earth has been increasing. There are many evidences, such as the graphics showing the change of the temperature on Earth in twenty years. Therefore, greenhouse effect is a law, under these circumstances…

Tentative NOS: When asked whether scientific knowledge can be changed, Selda realized that scientific knowledge is subject to change. She argued that there are different interpretations of previous knowledge and new technologies can advanced the scientific knowledge. She elaborated her answers giving examples from the ways of treatment of diseases and the opinions on the shape of Earth. When asked whether theories and laws can be changed, however, she hold a naïve view of the laws are certain knowledge and difficult to change. Additionally, although she asserted that theories can be changed, her assertion was not accordance with the tentative view of science. Rather, she reflected naïve understanding of theories as a step in the generation of laws (Abd-El-Khalick, 2005). Thus, the results showed that her misconception related to the functions of theories and laws caused her understanding on tentative NOS to be partial (See table 4.42 for sample quotas).

Table 4.42. Selda's Sample Statements of Tentative NOS

NOS view	Sample Statements
Tentative	…Scientific knowledge can be changed. Science is not a stable rather a constantly developing phenomenon. More realistic results can be obtained by observations and experiments. For example, the flat earth opinion. This opinion had been researched over time, and rejected by the new interpretations based on different research. Additionally, technologies on the treatments of the diseases such as cancer have been developing day by day… …I think laws are the scientific knowledge difficult to be changed. On the other hand, theories are more open to change. The evolution theory of Darwin can be developed over time, and if all scientists accept its certainty, we can call it as Darwin's Law. However, do you think that the Newton's laws of motion can be changed? I think, this is almost impossible…

Inferential NOS: When asked how scientists are certain about how dinosaurs looked like, Selda acknowledged that scientists make inferences. She did not use the term ''inference'' explicitly but she implied that scientists make interpretations based on the evidences. She expanded her responses stating ''based on the fossil evidences, scientists concluded that dinosaurs were descended from reptiles and had lived millions of years ago.'' She also expressed that the fossil evidences of dinosaurs' skeletal systems and their habitat help scientists be certain about their appearance and feeding habits. Hence, Selda's understanding of inferential NOS was substantial (See table 4.43 for sample quotas).

Table 4.43. Selda's Sample Statements of Inferential NOS

NOS view	Sample Statements
Inferential	…It is now a well-known fact that dinosaurs had lived millions of years ago and reptiles were their ancestors. Scientists investigated the fossil evidences as they [scientists] obtained the proof of their [dinosaurs] existence. We can see the models of dinosaurs based on fossil evidences in museums. In addition, scientists can provide the evidences of the physical structure and feeding patterns of the dinosaurs through their habitat and fossil evidences of the skeletal systems…

Creative and Imaginative NOS: Selda was aware of the crucial role of imagination and creativity in science. She realized that scientists' imagination and creativity is essential for the continuation of their investigation. Hence, her responses were informed because of the understanding that scientists' imagination and creativity have an important role in every part of the scientific investigation. In here, it can be also seen that Selda acknowledged that scientific knowledge can develop by the help of scientists' different perspectives. In other words, she was aware of the subjectivity in science. Selda's sample statements related to the creative NOS can be seen in Table 4.44.

Table 4.44. Selda's Sample Statements of Creative and Imaginative NOS

NOS view	**Sample Statements**
Creative and Imaginative	…It is impossible to think that science is apart from imagination and creativity. The scientist first begins with curiosity…then, imagination and creativity are necessary for the development of their research. Perhaps this characteristic [creativity and imagination] of science is most used in planning, but at every stage, I think that scientists should need creativity and imagination. For example, he/she is in a certain part of his or her research but can come up with different ideas and use the advantage of creativity and imagination. Therefore, she/he can develop his/her research…

Subjective NOS: When asked how scientists reach different conclusions with the same data, she accepted that science is influenced by the scientists' background knowledge, preconceptions, political views and values. Likewise, her responses on the aspect of creative and imaginative NOS supported her informed view on subjective NOS. On the other hand, she asserted that subjectivitiy causes scientific knowledge to be unreliable, thus she reflected the naïve view that science should be objective and value-free. From this point of view, the results showed that Selda's inconsistent expressions on the subjective NOS caused her understanding to be partial. Sample statements can be seen in Table 4.45.

Table 4.45. Selda's Sample Statements of Subjective NOS

NOS view	Sample Statements
Subjective	Unfortunately, the work of scientists, of course, is influenced by political views, lifestyles, background knowledge, religious views or economic concerns. On the other hand, I think that scientists and science should be objective; scientists' values should not affect their research. Unfortunately, the countries that hold the power in the global world influence on science. I think the results are distorted and reflected us differently…If science was a authority that could be changed according to interests, individuals or values, how could people trust science?...

Socio-Cultural NOS: To be categorized as holding informed understanding of socio-cultural NOS, participant should indicate an understanding that science is a human endeavor and, as such, is influenced by the society and culture in which it is practiced (Lederman et al., 2001). Giving example related to Muslim societies Selda accepted that science is influenced by religion, culture and values of the society. On the other hand, aligned with her partial understanding regarding subjective NOS, Selda asserted that science should be value-free and scientific research is isolated from the norms and values of the society. Thus, Selda's understanding had deficits on the tenet of socio-cultural NOS due to her contradictory expressions. Sample statements can be seen in Table 4.46.

Table 4.46. Selda's Sample Statements of Socio-Cultural NOS

NOS view	Sample Statements
Socio-Cultural	Science is also influenced by the culture, religion, norms and values of the society. For example, Notice that, European societies have always produced, and Arab countries have always consumed. As the Muslim societies, we had used what Europeans were produced. We haven't advanced in technology. The Muslim societies and Arab Peninsula was the least affected by the science and technology revolutions in the Renaissance. It's all about the religious views of Muslim societies. I think all kinds of social, cultural and religious values affect science in this way…However, I think that science should be universal. It should be independent from the religion or cultural values of the society. It should not deal with superstition…It should have a common and unique language…

To sum up, Selda's responses implied that she possessed inadequate understanding on NOS tenets. Specifically, she had naïve understanding on the functions of/ differences between theory and law. In fact, it can be said that there were interactions among Selda's NOS views. For example, although Selda asserted that scientific knowledge can be changed by the new interpretations, she held the naïve idea that the change of laws is difficult because laws are certain knowledge. In here, the deficiencies in her understanding of the functions of theories and laws affected her view of tentative NOS. Likewise, her partial understanding of subjective NOS caused her understanding of socio-cultural NOS to be partial, as well. On the other hand, Selda's understanding that scientific claims are based on empirical evidences helped her view of inferential NOS become substantial. To conclude, Selda did not have sophisticated views of NOS because she was not deeply informed in all of the NOS tenets. Moreover, it observed that she did not translate any aspects of NOS into her classroom practice of biogeochemical cycles.

4.3.1.3. Selda's Understanding of Sustainable Development Regarding Biogeochemical Cycles

In order to reveal Selda's understanding of sustainable development (SD) regarding biogeochemical cycles, she was requested to answer what the causes, results and solutions to the disruptions to the cycles are. Besides, her teaching of biogeochemical cycles was observed. Therefore, both her responses and practice unveiled how Selda linked the biogeochemical cycles to theaspects of sustainable development.

Selda mainly touched upon the unconscious use of natural resources as the cause of the disruption to the biogeochemical cycles. She pointed out that people have abused the limited natural resources. She, therefore, attributed the population growth to the main cause of the environmental damage. She had the idea that human activities should sustain the balance of the nature. She, also, implied the interdependency of the living things by emphasizing the energy flow through the biogeochemical cycles. Therefore, she approached the use of natural resources by the environmental aspect of SD.

Researcher (R): What are the causes of the disruption in biogeochemical cycles? Please explain.
Selda (S): We know that there are living and non-living things in ecosystems. The living organisms in this ecosystem provide their need of energy and food through the biogeochemical cycles. Therefore, cycles are necessary for the energy flow and the continuity of life. Unfortunately, in recent years, people have damaged the cycles. They [cycles] are negatively affected by people's activities… The resources on earth are limited. If we do not use the resources in a balanced way and prevent them functioning properly, we will suffer the consequences.

4.3.1.3.1. Selda's Knowledge on the Connections between Carbon Cycle and Sustainable Development

Regarding the deterioration of the carbon cycle, Selda emphasized the deforestation and unsustainable consumption of natural resources as the main environmental problems related to the carbon cycle. She tried to connect the scarcity of energy resources and energy problem to the population explosion. Because of the increase in energy need, she stated that there has been an increase in damage of the environment. Thus, in here, Selda attributed the environmental problems to the energy. Moreover, Selda tried to address the unsustainable modes of production through the industrialization. Specifically, she underlined the unsustainable energy production through the increase in the number of power plants using non-renewable energy resources. Moreover, she touched upon the unplanned industrialization as the factor leading vegetation removal to build constructions. As a result, she connected the increase in CO2 emission to the excessive use of fossil fuels and deforestation. In here, she also referred the atmospheric pollution because of the excessive carbon emission. Therefore, she emphasized the three aspects of SD namely; environment, energy and economy.

S: …The world' population is constantly increasing and we have the energy shortages. In order to satisfy the world's need of energy, the number of thermal power plants is rapidly increasing. We're cutting the trees and destroy the forests to build more power plants. Again, the increase in population causes unplanned

> urbanization. The green lands were destroyed to build the residences and shopping malls. For example, you can't breathe in Istanbul (Most crowded city in Turkey) because of intense air pollution. In other words, as a result of the excessive use of fossil fuels in these constructions and the destruction of forests, the more carbon dioxide is released to the atmosphere. Therefore this situation negatively affects the carbon and oxygen cycle…

Then, Selda addressed the governmental policies to cope with the problems related to the energy need. She especially mentioned that the best solution is to support the use of renewable energy sources with sufficient development policies. In here, Selda implied the shared responsibility to cope with the problems related to the scarcity of energy both universally and socially. She also touched upon the importance of scientific research for the development. Therefore, in here, she referred the environment, society, energy and politics aspects of SD by emphasizing the solutions the envrionmental problems with the use of renewable energy resources, development policies, responsibilities shared by internationally and socially and finally scientific research for development in every area.

> **S:** Carbon emission is one of the biggest problems in the world. Whether developed or not, all countries have to take steps in this regard. As long as it is supported by state policies, there can be permanent solutions to these problems. Especially, regarding the energy problem, the measures to be taken and policies are very important. We know that as all natural resources on Earth, energy resources are limited. If so, the best solution is to support the use of renewable energy sources and to do scientific research and projects in this regard; I think that it is necessary to develop policies towards this sector.

When Selda was asked the results of the disruption in biogeochemical cycles, she, again, stressed the aspect of environment implying the sustaining the natural balance. She pointed out the global warming and climate change as the main results of the disruption of the carbon cycle arising from the anthropogenic activities. She mentioned that the increase in the amount of greenhouses gases due to the unconscious use of fossil fuels causes to the global warming. She added that the climate changes as a result of the global warming over time. Thus, she emphasized that human activities devastated the sustainable balance of the nature.

> **S:** …Burning of fossil fuels and cutting of the trees causes directly or indirectly increase in carbon dioxide in the atmosphere. If the more carbon dioxide is released to the atmosphere, the Earth's temperature will increase. The increase in the amount of greenhouse gases such as carbon dioxide in the air means the increase in the temperature of the earth. We call this event as global warming you know. Over time, this warming causes to the climate change. As a result, these problems cause the damage of the balance of the nature…

Briefly, when Selda's responses were examined, it can be seen that she touched upon the important environmental phenomena such as greenhouse effect, global warming, climate change and atmospheric pollution. Additionally, she connected these phenomena with the scarcity of energy resources and unsustainable production due to the population growth. She also referred the geopolitical implications emphasizing the development policies that support the use of renewable energy sources. However, she did not refer the carbon economy policies to overcome the problems related to deteriorations of the carbon cycle. Furthermore, she did not mention about the poverty as an issue of SD related to the carbon cycle. During her explanations of the connections between the carbon cycle and SD, Selda also addressed five aspects of sustainable development including environment, society, economy, politics and energy.

4.3.1.3.2. Selda's Knowledge on the Connections between Hydrological Cycle and Sustainable Development

Selda generally pointed out the environmental problem related to the water such as water pollution and the scarcity of water. She touched upon the damage of water resources due to the energy need. Moreover, she attributed the water pollution to the decrease in the number of living things into the waters. In here, she referred the interdependency of living things by the aspect of environment. She also underlined the water scarcity because of the unconscious use of water resources. She exemplified the decrease in the occupancy rates of dams because of the high temperature as a result of global warming. Thus, she only pointed out the issue of drought as a cause of the deterioration of water cycle. Therefore, Selda mainly addressed the environment and energy aspects of SD through the water scarcity and water pollution.

> **S:** … I've just said we destroy the rivers and streams to build a hydroelectric power plant. We also consume the water unconsciously in cities. We pour the waste oil into the sink or tankers cause oil spill to the seas. Thus, we pollute our water resources. We are endangering the life of both ourselves and the living things in the waters. Recently I have heard that there will be water shortage in Ankara and Istanbul this year. The reason is the decrease in the rate of occupancy in dams. The reason for this situation is that the water evaporates too much due to increasing temperatures due to the greenhouse effect. When there is a lot of evaporation, the dams are not filled. In result, the deterioration of a cycle actually causes other cycles to deteriorate...

To summarize, when Selda's responses were examined, it can be seen that she only touched upon the issues of droughts and water scarcity for the hydrological cycle. However, she did not refer how these issues related considering the disruption of the hydrological cycle. Again, she did not touch upon the phenomena such as soil salinization, desertification and glaciation. Moreover, she did not address the trans-border conflicts of water, the diseases arising from water pollution or the non-conventional water resources as sustainable issues related to the hydrological cycle. As a result, Selda mainly focused the environmental aspect of SD in terms of the phenomena and SD issues related to the hydrological cycle.

4.3.1.3.3. Selda's Knowledge on the Connections between Nitrogen Cycle and Sustainable Development

As can be seen above, Selda addressed the water pollution caused by household wastes; industrial and agricultural wastes. She connected the reduction in variation due to the water and soil pollution. She addressed the removal of large quantities of water from rivers and ground water supplies for agricultural activities. Although she also mentioned the excessive use of chemical fertilizers in agricultural activities, she did not connect this problem to the degradation of nitrogen cycle. On the other hand, she stressed the unsustainable production through agricultural activities. She also considered the lives of other living things by emphasizing interdependency of the living things. Thus, she approached the problems of water and soil pollution from the environmental and social aspects of SD.

> **S:** …We pour the waste oil into the sink and also tankers cause oil spill to the seas. Thus, we pollute our water resources. We threaten the life of both ourselves and the living things in the water resources. For example, if the water plants cannot take the sun light to make photosynthesis, therefore they cannot produce oxygen and food for other living things in the water. In a result, the destruction of the carbon-oxygen cycle caused the water pollution causing the decrease in the number of the living things in the water over time…
>
> …There are many people doing agricultural activities in Turkey. They can use the underground waters unconsciously by opening wells for irrigation in agricultural lands. Also, the excessive use of fertilizers can cause the soil pollution in there. These chemicals can reach the underground water resources and consequently, pollute the water resources.

To sum up, it can be seen that Selda only addressed the soil pollution as a phenomenon in the nitrogen cycle. She emphasized the water pollution and the excessive use of fertilizers but she did not relate these issues to the nitrogen cycle. Moreover, she did not emphasize the eutrophication due to the excessive nitrates in the soil or water resources. In the same way, she did not address that the greenhouse gases includes nitrogen. Thus, he did not relate the excessive nitrogen in the atmosphere to the acid precipitation. Besides, she did not mention any issue of sustainable development in nitrogen cycle except for the use of fertilizers. In that case, Selda's explanations on the connections between the nitrogen cycle and sustainable development issues were focused on the SD aspects of environment and society.

Finally, while mentioning the solutions, Selda especially focused on the SD aspect of education. She emphasized that developments in education could create more sustainable world for the future generations with the help of educated and awared people. Thus, she stressed the society aspects by underlying the future generations.

To conclude, When Selda's explanation related to the results, causes and solutions to the depletion in biogeochemical cycles examined, it can be seen that she mostly underlined the issues and aspects of SD in the carbon cycle. Therefore, it can be said that she failed to connect both nitrogen and hydrological cycles to the related sustainable development aspects. Moreover, Selda mainly approached to the phenomena and issues of sustainable development from the environmental aspect whereas she addressed the economic, educational and technological aspects rarely. She also did not stressed the technological aspect of SD. To sum up, Selda's conceptions of SD regarding biogeochemical cycles can be seen in Figure 4.23.

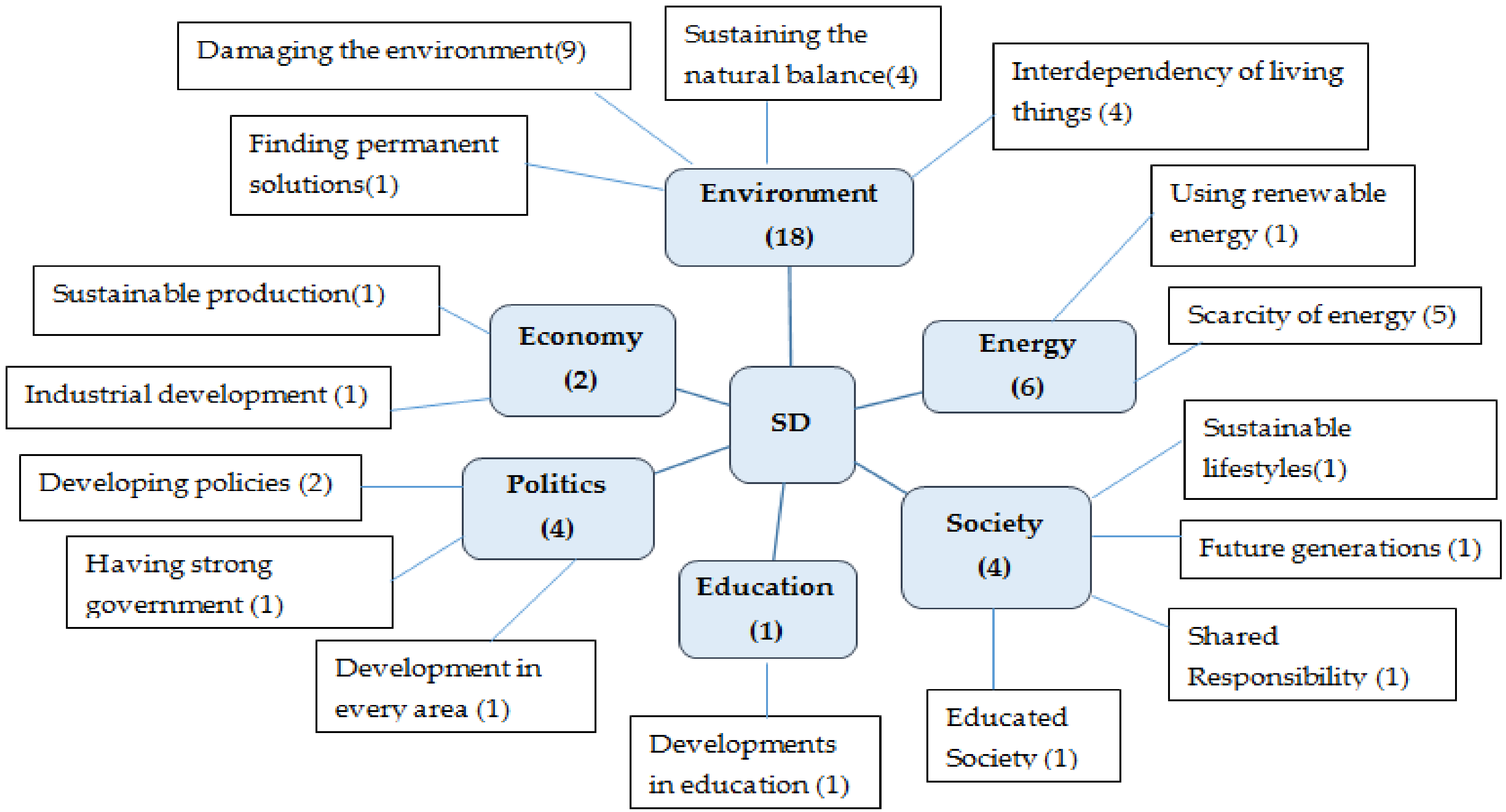

Figure 4.23. Selda's Conceptions of Sustainable Development

4.3.2. Selda's Pedagogical Content Knowledge

4.3.2.1. Selda's Orientation to Science Teaching

In this section, Selda's beliefs about goals of science teaching at grade 8th were presented based on the analyses of her responses to the card-sorting scenarios and the interviews related to the goals of science teaching and classroom observations.

Selda cited that her beliefs about central purposes for science teaching were generally affected by the national science curriculum and the examination system. She expressed that her basic goal of science teaching was to transmit the curriculum knowledge. She also emphasized that in 8th grade level; the goal of science teaching was specifically to prepare learners to the TEOG (currently known as LGS) examination. In addition, she expressed that science teaching also prepares the students to high school courses (See Table 4.47 for sample quotas).

Table 4.47. Selda's Sample Statements Related to Beliefs about Central Goals for Science Teaching

Central Goals	Sample Statements
To transmit the knowledge required by curriculum	We, all science teachers, have to follow the national science curriculum in Turkey. I have to teach the topics required by the curriculum. Therefore, my main goal is to present the topics as a curriculum objective…
To prepare learners to high school courses	…As we know, science teaching is consisted of the science branches such as physics, chemistry, and biology. Science concepts in elementary level are step for the science lessons in high schools. We try to prepare our students to the high school courses by giving the basic scientific knowledge given in the curriculum…
To prepare learners to high school exam	…Especially, at the 8th grade, students, their families, and also our school administration is concerned the TEOG exam. So, I try to prepare my students for the exam in my science lessons. I generally solve retired questions related to the topic…

When it comes to her peripheral goals for science teaching, Selda pointed out that one of her goals for science teaching is to connect science and students' daily life. She stated that in science lessons, she tried to help students fulfill their basic needs in daily life. Her responses included that students are able to develop environmental awareness in science lessons (See Table 4.48 for sample quotas).

Table 4.48. Selda's Sample Statements Related to Beliefs about Peripheral Goals for Science Teaching

Peripheral Goals	**Sample Statements**
To prepare learners to life	We, as a human, born in nature and life. We cannot isolate ourselves from the nature. So, the aim of science teaching is to help students to grasp the relationship between themselves and their natural environment. I mean science education is necessary to obtain basic knowledge related to the life…
To help learners to satisfy their needs in daily life	Who am I?, How do I keep living?, How do I feed?, How do I run?, How do I sleep?...The answers of these questions are given directly in the science lessons. We have basic needs such as seeing, hearing, feeding, sleeping to survive in life. Through the science lessons, we try to help our students to comprehend how they meet these needs in daily life…
To help learners to develop environmental awareness	…We have to protect the nature we have existed. In science lessons, there are also environmental topics in order to emphasize the relationship between human and nature. I try to help my students to comprehend the importance of the relations between human and nature. In this regard, I try to help my students to gain environmental awareness…

Selda's beliefs about the central and peripheral goals of science teaching completely overlapped with the orientations that she chose as parallel to her science teaching. Hale expressed that the scenarios related to the didactic, conceptual change, academic rigor, curriculum goals and the educational system based on examination corresponded to her science teaching. Although she chose the conceptual change as her orientation to science teaching at 8th grade, it could be obviously seen that her explanation was not appropriate to the definition of conceptual change.

When she was asked why she selected those scenarios, Selda stated that the scenarios shared a common characteristic, which is being teacher-centered. She expressed that there is a limited time to complete the topics before the national exam. She, therefore, complained about both the overloaded curriculum and educational system based on the examination. As a result, she cited that those scenarios can be matched for her science teaching at 8th grades. Selda's sample quotas related to these scenarios can be seen in Table 4.49.

> **Selda (S):** The common feature of the activities in these cards is to be designed in order to give intensive curriculum knowledge in limited time. The activities are teacher-centered. These limited activities can only be done because of our examination-based education system. Neither I nor the students can do more activity at 8th grade. I need to have control the time because I have an overloaded curriculum that consists of subjects that should be completed before the TEOG exam. If I have additional time, I want to do different activities but we have to prepare our students to the national exam. Their families and the school administration force us to prepare the students for qualified Anatolian high school…

Selda pointed out that she could not utilize the remaining scenarios, including activity driven, discovery, conceptual change, academic rigor, guided inquiry, project based, inquiry, process and liberation due to their student-centered nature. She explained that such scenarios required time and not suitable for crowded classrooms. She also mentioned the teachers' and students' anxiety regarding national exam, the overloaded curriculum, and the context of the school were most important factors to be done these activities. Selda's sample quotas related to these scenarios can be seen in Table 4.50.

Observation data (the teaching of the biogeochemical cycles) revealed that his teaching was generally based on lecturing as well, although she varied her teaching with daily-life examples, figures and questions to facilitate students' understanding of the basic concepts. She did not use any subject-specific strategies (orientations) apart from the direct instruction. Her teaching was generally structured, sequenced and led by herself which was line with his orientations.

Table 4.49. Selda's Sample Statements Related to Orientations Parallel to Her Teaching

Orientations	Scenarios	Sample Statements
Didactic	A good way to effectively teach students about biogeochemical cycles is by lecturing to draw the figures of the cycles by using the blackboard and tell the students the differences between the cycles.	In general, I have already used this method. Regarding matter cycles, I draw the figures on the board and give some examples in daily life. Then we examine the shapes and content of the textbook in order to repeat the cycles.
Academic Rigor	One way to effectively teach students about renewable and nonrenewable energy source is to solve different and difficult questions (problems).	Generally, I solve different questions in my lessons. I solve the retired questions in TEOG exam related to the topic. The students can understand and solve the problems easily.
Conceptual Change (*His orientation was not conceptual change*)	A good way to teach students about recycling is to ask questions and/or to use a demonstration that will check on the students' prior knowledge of the topic and then try to eliminate their misconceptions with scientific conception.	Generally, I ask my students whether they understand the topic or not at the end of the lesson. Moreover, I repeat the previous topic before I start the new topic. I ask questions related to their prior knowledge. If there are students having misconceptions, I repeat the topic giving different additional examples. Therefore, I try to correct their misunderstanding during the lesson by ask different questions…

Table 4.49 (Continued)

Orientations	Scenarios	Sample Statements
Curriculum Goals	One of the effective ways in order to teach the contributions of researches and developed technologies on renewable energies and technologies to the environment and the country's economy is to ask students to interview experts (engineers and scientists etc.) related to the subject and to present their research results to their classmates. An effective way to educate learners as environmentally responsible citizens is to ask students to investigate how to find solutions to the problem of waste, one of the most important problems of our day as a result of human activities.	I can give such activities as a project and performance assignment in general. I want the students to do research about environmental problems and ask them to discuss with experts. Afterwards, they present their work in the classroom. We do not have any chance or time for all students. Only the students who are willingness want to do project homework can interview with experts or investigate the problems. However, I think that all students can learn through the presentations of their peers who did the project…
Reality of Turkish Educational System	As a teacher, you think that the best thing to do for students is to prepare them for high school. Therefore, you teach the topics and then try to solve as many problems/questions as possible.	Unfortunately, we have an educational system based on the exams. It is not possible to ignore this situation. Therefore, one of my important goals is to prepare my students to the high school entrance exam…As I said before, our students, their families and the school management are also very concerned about the TEOG exam, especially at the 8th grades. For this reason, as far as possible, I solve the retired questions in TEOG examination.

Table 4.50. Selda's Sample Statements Related to Orientations Not Corresponded with Her Teaching

Orientations	**Scenarios**	**Sample Statements**
Process-Scientific Skill Development	The best way to teach the carbon cycle is to use data obtained from the research on the topic. Then you ask students to formulate hypothesis, interpret data, analyze the data, and communicate their results with others in the class.	I do not teach them such topics. These subjects can be taught at laboratory through the experiments but there is no equipment we needed…
Discovery	The best way to teach students about the renewable and nonrenewable energy sources is to ask students plan an investigation/activity that allows them to present the areas of usage of these sources.	I do not expect my students to plan an activity or investigation. I have not done such activity since I began my teaching career…
Inquiry	By separating the students into groups and giving them a scenario from their surroundings, an effective way of teaching environmental problems caused by non-renewable energy sources is to ask students to educe a cause-and-effect relationship with these problems and to assess the validity of the information in order to generate these outcomes.	I can give such activities as project homework but I have yet not wanted my students to do such things. It requires more effort and time to complete the tasks in the activities…
Guided Inquiry	One way to effectively teach students about the disruption of biogeochemical cycles is to allow students to design their own experiments using variables they decide upon.	

Table 4.50 (Continued)

Orientations	Scenarios	Sample Statements
Activity Driven	One way to effectively teach about biogeochemical cycles to use laboratory and/or classroom activities in which will provide the students the best opportunity to learn the topic.	I cannot use laboratory activities in general. Especially in chemistry topics I can use laboratory but unfortunately I do not have necessary time to deal with the experiments. I can only teach the topics in the class theoretically.
Project-based	One of the effective ways of teaching recycling is to encourage students to participate in NGOs interested in environmental protection, and to cooperate with these non-governmental organizations in order to provide solutions to waste disposal.	We have just applied such activities in the eco school project. However, in 8^{th} grades, we do not have time to do such projects…
Liberation	After having studied the concepts related to the subject, one of the effective ways of teaching recycling is to allow students to discuss these concepts clearly and develop their own concepts.	I do not allow my students to develop their own concepts for a topic because it requires additional time. This activity needs to time and the discussion causes to the confusion in the class. As I said before, I have limited time due to the TEOG exam. I cannot use this activity in the 8th grades…

4.3.2.2. Selda's Knowledge of Curriculum

4.3.2.2.1. Selda's Knowledge of Goals and Objectives

In the Science and Technology curriculum (2005), there was only one objective specific to the topic of biogeochemical cycles, which is *students are able to explain biogeochemical cycles parallel to the energy flow in the food chain* (MoNE, 2005, p.354). The acquisition of this objective is closely related to the understanding of the previous topic which is energy flow in the food chain. Hence, the objectives of previous topic should be considered as a reminder to teach the topic of biogeochemical cycles.

In the same way, Selda touched upon that the students should gain the objectives of the topic of energy flow in the food chain in order to enable students' learning of biogeochemical cycles. Therefore, she stated that she often controlled whether her students gained the objectives regarding photosynthesis, respiration, and nutrition and energy flow in the food chain in her lessons. When Selda was asked the aim of teaching of biogeochemical cycles, she responded by stating that she expected her students gain the relevant objectives in the curriculum, as well.

> **Researcher (R):** What is your aim of teaching the topic of biogeochemical cycles?
> **Selda (S):** In 8th grades, we simply present the biogeochemical cycles. I, as a teacher, generally expect my students gain the curriculum objectives. What are they? For example, I want them to learn that matter cycles are important to the continuation of life. Also, they should learn the consequences of the deterioration of these cycles. Thus, I first begin with the concept of cycle and the features of the carbon, hydrogen, oxygen and nitrogen. Then, I generally explain the processes in each cycle, and the factors that can affect the continuation of the cycles. Additionally, these cycles includes the processes such as photosynthesis, respiration, the flow energy and food between the organisms. So, I consider the students' learning on these topics. For instance, before the introduction of the carbon and oxygen cycles I want to ask my students' prior knowledge related to the photosynthesis and respiration…[Core Interview].

Selda also pointed out that she expected her students to gain some affective domains, indicated in Table 4.51., in addition to the curriculum objectives. She stated that she tried to raise the students' consciousness in the use of natural resources in balanced way. She also underlined that she expected her students to comprehend the environmental problems as a result of disruption of the cycles. She cited that students should gain environmental awareness for the continuation of the matter cycles.

> **S:** I focused more on the environmental awareness in such topics. I want my students to know that natural resources are limited and we need to use them carefully and in balanced way. Students should understand the environmental consequences caused by problems in the matter cycles. It is important to find solutions to the environmental problems they often face in their daily lives. I want students to learn to take responsibility in order to ensure the survival of the cycles. We discuss what they can do individually for more livable world…[Core Interview].

Table 4.51. Selda's Intended Objectives Related to Topic of Biogeochemical Cycles

Intended Objectives
To comprehend the importance of the balanced use of natural resources
To raise environmental consciousness for the conservation of the natural resources
To recognize what needs to be done for the continuation of the biogeochemical cycles as an individual

As far as Selda's teaching of cycles was examined, it was observed that she tried to attract her students' attention to the needs to be done for the continuation of the biogeochemical cycles. For example, during her lesson on the carbon cycle, Selda underlined the use of renewable energy sources and planting more trees in order to decrease the carbon emission to the atmosphere.

> **S:** We said cycles are important for the continuation of life but we influence the cycles consciously or through indirect ways. Now, in your opinion, what are the circumstances in which people have a negative impact on the carbon cycle?
> **Std1:** We burn and cut off the forests.
> **S:** Yes. True. What else?
> **Std2:** For example, we burn wood and coal in our homes.
> **S:** Yes, we use fossil fuels too much. What happens if we use fossil fuel?
> **Std2:** More carbon is released. The cycle is adversely affected.
> **S:** Then you have to either increase the oxygen to compensate or not to release more carbon. What should I do?
> **Std3:** More afforestation is required.
> **Std2:** More plants are needed.

S: Yes. We need reforestation. Likewise, I need to reduce the use of these non-renewable fossil fuels because these resources should be balanced. Then what can we do to prevent the consumption of these resources?
Std2: We can use renewable energy.
Std1: We can use solar energy.
S: Well done. We need to use renewable energy sources and plant more trees. We should be respectful and sensitive to the environment...[Classroom Observation].

Regarding the horizontal relations to the topic of biogeochemical cycles in the science and technology curriculum, Selda emphasized that she expected her students to learn the previous topics of photosynthesis, respiration and energy flow in food chain energy flow in food chain, before the introduction of the biogeochemical cycles. When Selda's teaching of cycles was examined, it was also observed that she often recalled the above-mentioned topics during her teaching of carbon cycle.

When the vertical relations to the topic of biogeochemical cycles were taken in consideration, Selda did not mention about the students' prior knowledge related to the topics of physical and chemical changes in the 6th grade, elements and compounds and basic building blocks of living things in the 7th grade. However, in her teaching of biogeochemical cycles, it was observed that Selda touched briefly on the required topics. For example, at the beginning of her teaching of carbon cycle, she helped her students recall their prior knowledge related to the organic and inorganic compounds. In the same vein, Selda expected her students remind the topic of physical and chemical changes to introduce the evaporation and condensation processes in the water cycle.

When asked the presentation sequence of the cycles, Selda was aware of the place of the topic and the sequence of the sub-topics. She stated that the curriculum presented the cycles respectively water cycle, carbon-oxygen cycle and nitrogen cycle. She expressed that she also taught the cycles in the same sequence with the curriculum. In her teaching of the cycles, it could be seen that she did not change the sequence of the sub-topics, too. However, she also pointed out that she can sometimes change the place of the topic based on her students' prior knowledge. In other words, Selda expressed that she can modify the curriculum in order to ease her students' understanding.

4.3.2.2.2. Selda's Knowledge of Materials

In terms of resources used, Selda explained that she has actively used the textbook and student exercise book to teach the biogeochemical cycles. She underlined that she generally used the textbook to both follow the curriculum and repeat the cycles. Additionally, Selda pointed out that she preferred the use of student exercise book to whether the students' understand of the topic (Table 4.52).

Table 4.52. Selda's Aim of Using Teaching Sources

Sources that teacher use	Aim of using in teaching
Textbook	To follow the curriculum & To repeat the related topic
Student Exercise Book	To evaluate the students' understanding of the biogeochemical cycles

During her teaching of biogeochemical cycles, it was observed that Selda actively used the textbook to transmit and repeat the concepts and processes of the biogeochemical cycles. She wanted one of her students to read the related part of textbook and then she repeated the knowledge given in the curriculum. At the end of the teaching of cycles, she expected her students make the questions and activities in student exercise book.

4.3.2.3. Selda's Knowledge of Instructional Strategies

In this section, the knowledge of instructional strategies of participant teachers was reported in two categories namely, knowledge of subject specific strategies and knowledge of topic specific strategies.

4.3.2.3.1. Selda's Knowledge of Subject Specific Strategies

Selda stated that she mostly used direct instruction and questioning method. She pointed out that she expected her students to read the textbook before the introduction of the new topic. Then, she addressed that during the lesson; she always started with the questioning and let her students to share their ideas about the topic. Then she explained that she continued to teach the topic by the help of drawings and daily life examples through the lecture.

> **Researcher (R):** How do you teach the topic of biogeochemical cycles? Which instructional strategies do you use in general?
> **Selda (S):** First of all, I want my students to read the related topic from textbooks or other sources before starting a topic. I ask questions and they share their opinions. I try to ask questions that are related to their daily lives. Then, as the order of each cycle comes, I draw and describe them verbally. I want them to note on their notebooks. I usually draw the figures in the textbook. And finally, I want one of my students to read the knowledge in the textbook. I explain the concepts again when necessary. If I have a time, I choose some students randomly and want them to summarize the relevant cycle. Moreover, I especially solve the retired questions related to the cycles [Core Interview].

Observation data also revealed that Selda generally used the direct instruction to explain the important points related to the biogeochemical cycles. As she stated, she also mostly preferred the questioning method only understand what they learn about the topic. She generally expected her students to summarize the related cycle.

When Selda's teaching of biogeochemical cycles was examined, it could be seen that the main characteristic of her teaching was its teacher-centeredness. She generally used questioning and direct instruction to transmit the content knowledge to learners. Her teaching was generally based on lecturing. She did not use any student-centered strategies like 5E Learning Cycle, Conceptual Change Approach and Guided Inquiry etc.

4.3.2.3.2. Selda's Knowledge of Topic Specific Strategies

Knowledge of topic-specific strategies of participant teacher was presented with two sections as; knowledge of representations and knowledge of activities.

4.3.2.3.2.1. Selda's Knowledge of Representations

Results showed that Selda only used the representations like drawings, illustrations and examples in order to aid students in developing the comprehension of the topic of biogeochemical cycles. She actively used the board to draw the figures (Figure 4.24, 4.25 & 4.26) to represent the concepts of hydrologic, carbon and nitrogen cycles.

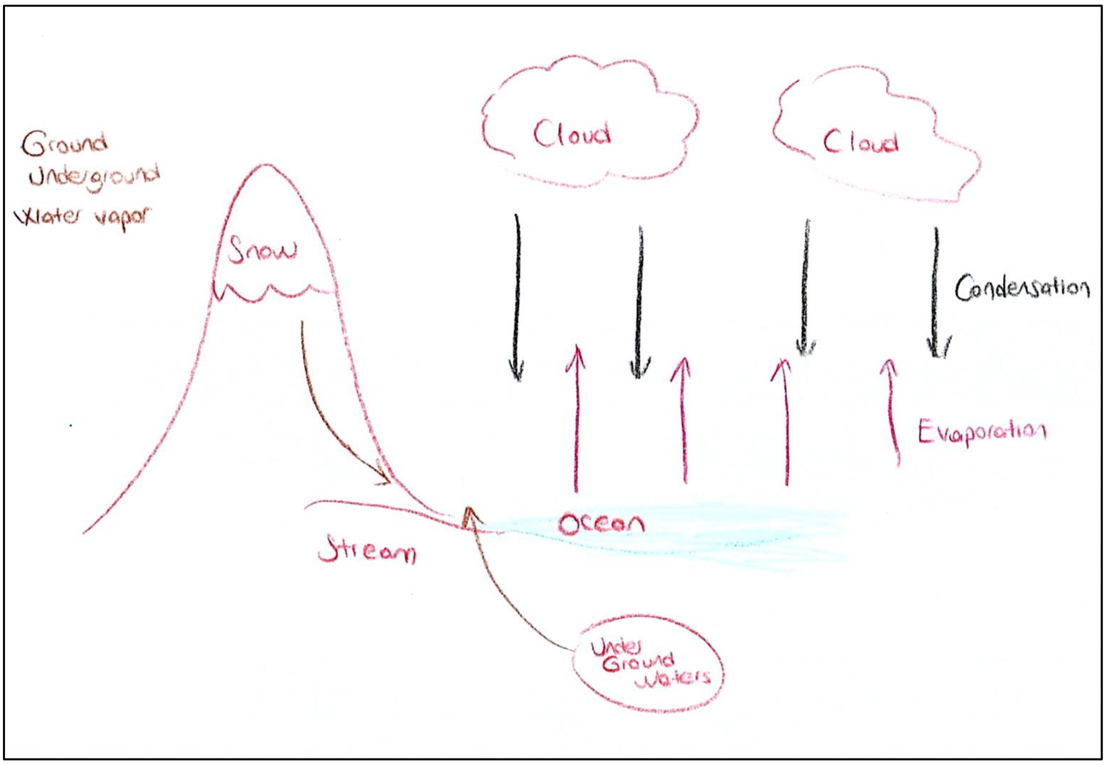

Figure 4.24. Selda's Drawing Used to Teach the Hydrological Cycle

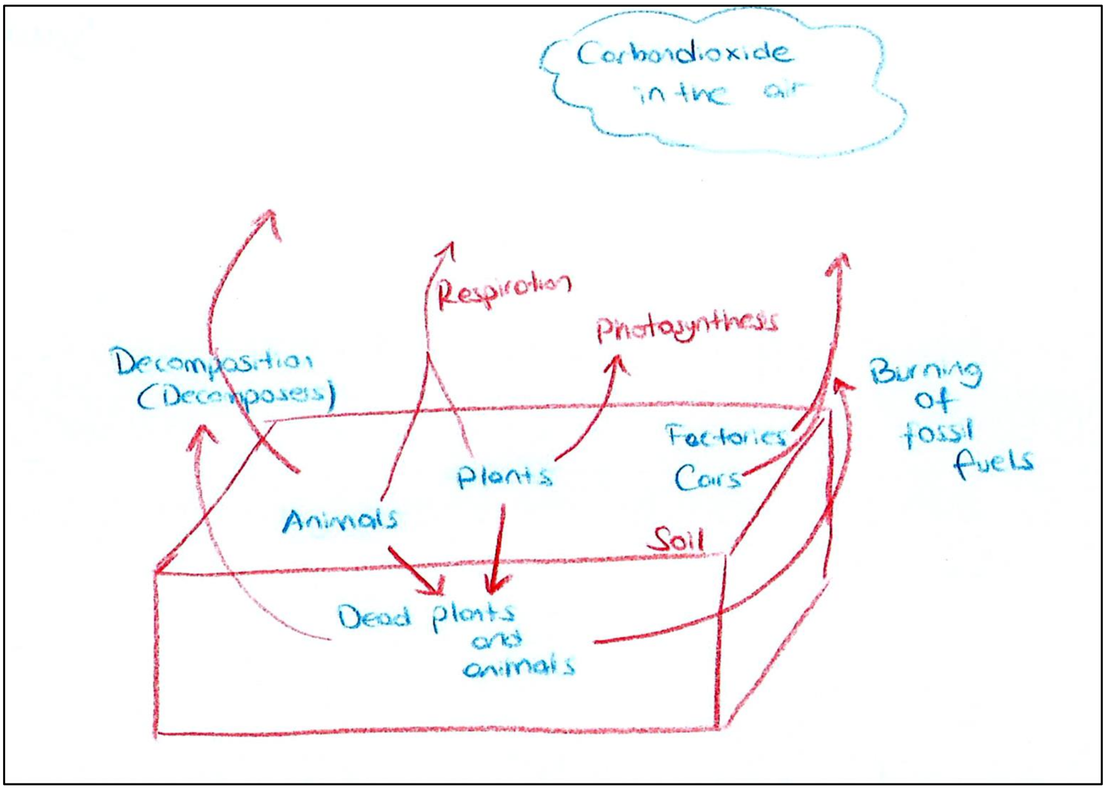

Figure 4.25. Selda's Drawing Used to Teach the Carbon Cycle

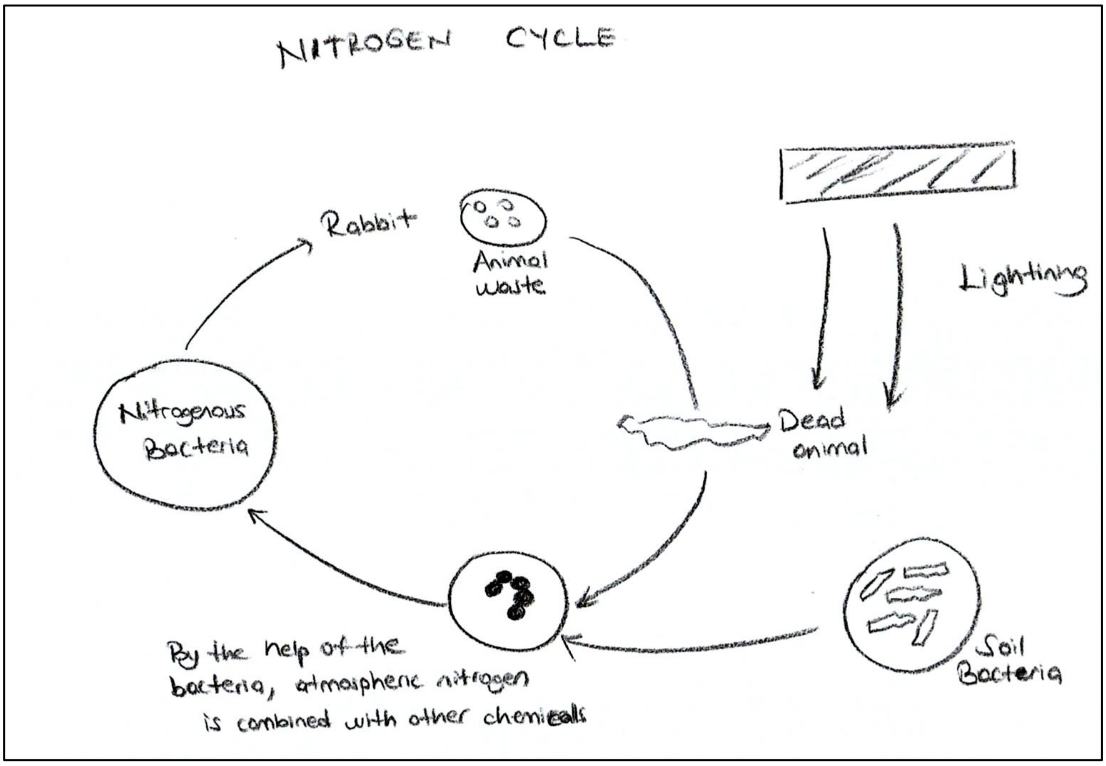

Figure 4.26. Selda's Drawing Used to Teach the Nitrogen Cycle

Additionally, Selda used her students' presentations in order to summarize the biogeochemical cycles. She gave chance her students to present their work on the cycles. She repeated the hydrological, carbon and nitrogen cycles using the illustrations (Figure 27-28-29) in the presentations.

Figure 4.27. Selda's Illustration Used to Repeat the Hydrological Cycle

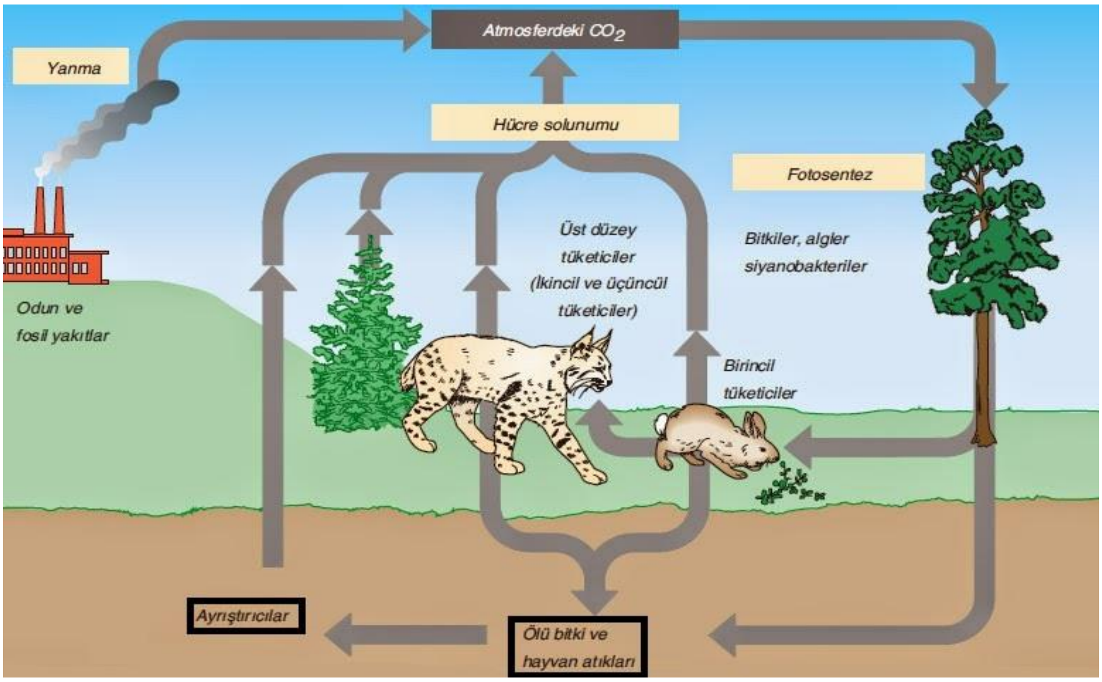

Figure 4.28. Selda's Illustration Used to Repeat the Carbon Cycle

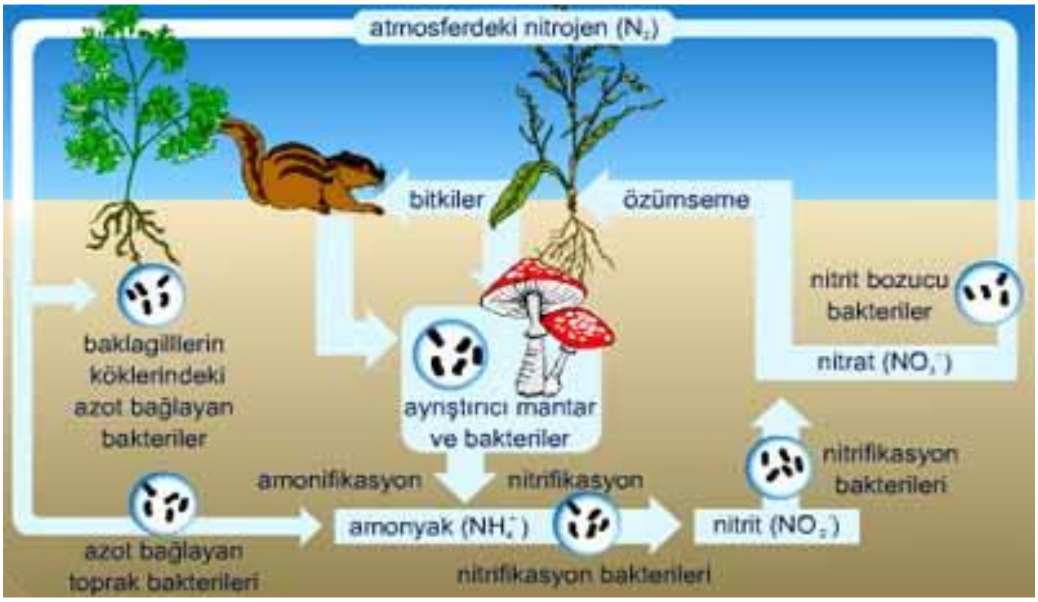

Figure 4.29. Selda's Illustration Used to Repeat the Nitrogen Cycle

Moreover, she rarely gave daily life examples to support the comprehension of students. For example, at the teaching of hydrological cycle, to attract students' attention to the consequences of human based degradation of the cycle; she exemplified the excessive consumption of the water resources in metropolitans.

S: What are the positive and negative impacts of humans on the water cycle?
Std: Global warming.
S: Global warming. Yeah. What is the impact of global warming on rivers, streams and lakes in our country?
Std: They are getting dry.
S: For example, I saw the lake of Eğirdir. It is at the level of drought. What else?
Std: Unconscious use of water resources.
S: Unconscious use. How do we consume water unconsciously?
Std: Contamination, for example, water is mixed with chemicals. The toxic waste is mixed up.
S: Yes. There are many living things in the water. Apart from us, there are plants and other living things that live in the waters. We will not pollute the water by considering other living things. We'll be more conscious. It is very important to use water consciously. For example, we unconsciously consume water resources in the metropolis. When we brush our teeth, we leave the taps open, we spend a lot of water while washing our carpets. This summer, the occupancy rate for dams is expected to decrease in Ankara and Istanbul. The rainfall was lower than previous years. If so, we have to use our water resources consciously. [Classroom Observation].

4.3.2.3.2.2. Selda's Knowledge of Activities

Selda did not include any activities regarding the topic of biogeochemical cycles in her lessons. She used the representations rather than activities. Although she wanted to do the activity related to the hydrological cycle in the textbook, she could not perform due to the absence of the equipment. She stated that she could only give examples and draw figures because of her students' disinterested attitudes. In a result, Selda expressed that she did not conduct any activities found in the textbook and student exercise book.

4.3.2.4. Selda's Knowledge of Students' Understanding of Science

This component of PCK focuses on the teachers' knowledge in order to help students develop specific scientific knowledge. There are two subcomponents: requirements for learning and areas of difficulties. In this section, Selda's knowledge of learners' understanding regarding the topic of biogeochemical cycles was presented.

4.3.2.4.1. Selda's Knowledge of Requirements for Learning

As mentioned in Selda's knowledge of curriculum, Selda only stated that students should comprehend the topic of energy flow in the food chain to learn the topic of biogeochemical cycles. On the other hand, Selda did not mention about the students' prior knowledge related to the topics of physical and chemical changes; elements and compounds and basic building blocks of living things regarding the vertical relations of the topic.

> **Researcher (R):** What prerequisite knowledge do students have to learn the topic of biogeochemical cycles?
> **Selda (S**): Students first need to know the energy flow and food chain. They should know that living things such as producers, consumers and decomposers are connected to each other. Photosynthesis and respiration are important processes that the student must know especially for the understanding of the carbon cycle. Again, we repeat the issues such as how energy is transferred between organisms and how energy is obtained in ecosystems. For this reason, before I begin the topic of matter cycles or during the teaching of the cycles, I

remind to the students these topics in order to ease their understanding of the cycles…[CoRe Interview].

As she mentioned, observation data deduced that Selda generally considered both vertical and horizontal pre-requisite knowledge to aid her students' learning of the new topic of biogeochemical cycles, as well. For instance, she controlled her students' prior knowledge on the energy flow in food chain in order to introduce the new topic of biogeochemical cycles. She expected her students to remember the relations between the biotic (producers, consumers, decomposers etc.) and abiotic components in the ecosystems.

S: Yes, we will start the carbon and oxygen cycle. Tell me where does oxygen exist in nature?
Std: 21% in the atmosphere, my teacher.
S: Yes, what else?
Std: Produced in photosynthesis.
S: How do the plants produce oxygen?
Std: Plants take CO_2 from the air. They get water from the soil and produce oxygen and nutrients.
S: Yes. They produce nutrients and oxygen with the help of sunlight and chlorophyll in their structure. So where is used the products of photosynthesis?
Std: Respiration.
S: Yes. What are the products of respiration?
Std: CO2 and water.
S: Yes. Absolutely. These events are the opposite, aren't they? We learned these issues [photosynthesis and respiration] in the previous topic. As you can see, carbon and oxygen return in nature through the processes of photosynthesis and respiration. [Classroom Observation].

Moreover, she controlled her students' prior knowledge on the topic of building blocks of living things before the introduction of carbon cycle. Furthermore, she reminded to her students the physical and chemical changes during her teaching of water cycle.

S: …Well, first, let's focus on the water cycle. Why doesn't the water in the world run out? How can the amount of water remain constant?
Std: With the water cycle.
S: So what happens in the water cycle that the waters remain constant?
Std: First it is raining but then the water evaporate and return as rain or snow again.

S: Yes. Evaporation. You have learned it in the topic of state of matter. We know the water can boil at a certain temperature but evaporate at any temperature. Do you remember?
Std: Yes.
S: The water falls as rain, snow to the land, then evaporates again and returns to the atmosphere. Well, what is evaporation, physical or chemical change?
Std: Physical.
S: So, the snow, the hail, the rain, they're all solid and liquid states of water. The structure of water is unchanged, only its state changes in the water cycle…[Classroom Observation].

On the other hand, Selda considered her students' neither skills, abilities nor learning styles. She, generally, touched upon her students' requirements for their conceptual understanding.

4.3.2.4.2. Selda's Knowledge of Areas of Students' Difficulties

Selda stated that her students did not have any difficulty or any misconception in the topic of biogeochemical cycles. She mentioned that students were generally insensitive to the environmental topics. She complained that students were not familiar to environmental issues in their daily life, thus the transformation of their environmental knowledge to the environmental attitude was difficult.

R: Do students have learning difficulties that affect your teaching about biogeochemical cycles? This may be misconception or partial understanding. At what points do students have difficulties?
S: They [students] can understand this topic easily. We repeat it many times in the classroom. We read again from the textbook at the end of the teaching. They also solve the questions in the student exercise book. They don't have any difficulty. Many students already know the topic because they are prepared for the TEOG exam. On the other hand, students are not interested in environmental topics in general. They are actually close to such issues. These issues are not talked about in the family, and visual and written media cannot give wide publicity to them. That is, students cannot encounter such issues in his daily life. They only learn at school, in class. Therefore, no matter how hard we try to teach in the lessons, students are unable to apply their learning to their life. It is really hard to create an environmental consciousness and make it turn into behavior. We try to raise awareness for students on environmental issues and expect them to be conscious in their daily lives. But how far can we, as a teacher, accomplish this? This is an issue to be discussed for me. [CoRe Interview].

4.3.2.5. Selda's Knowledge of Assessment

This category of PCK includes two subcomponents namely; knowledge of dimensions of science learning to assess and knowledge of methods of assessment. Selda's knowledge of assessment regarding the topic of biogeochemical cycles was presented in this section.

4.3.2.5.1. Selda's Knowledge of Dimensions of Science Learning to Assess

Selda's knowledge of assessment on students' learning was examined in the dimensions of conceptual understanding, NOS understanding and the connections of sustainable development issues regarding biogeochemical cycles. Selda stated that during the lessons, she considered whether the students understand the concepts given in the curriculum. Therefore, she emphasized that she preferred to evaluate the conceptual knowledge that students were supposed to learn in the curriculum during the lessons.

Data gathered via observations also revealed that Selda generally focused on the assessment in order to evaluate her students' conceptual understanding rather than assessing other types of domains such as sustainable development (SD) and NOS understanding. It was observed that she used questioning either to reveal her students' conceptual knowledge or monitor their prior knowledge during her teaching of biogeochemical cycles. For instance, before the teaching of carbon cycle, she expected her students to summarize the previous topic of hydrological cycle briefly. Moreover, she tried to help the students to catch the missing points on the processes of the water cycle.

> **S:** So we have finished the water cycle. Who will repeat the water cycle? What is the water Cycle?
> **Std:** Once the water on the earth evaporate and when it hits a cold layer in the air, it condenses as a cloud and then come back to the earth as rain or snow.
> **S:** Clouds will form.
> **Std:** Yes, then the water turns back to the earth with types of precipitation of snow, hail or rain. Therefore, the water cycle is completed.

S: How do plants and animals contribute to the cycle?
Std: By respiration, they actually give water to the air in the form of vapor.
S: Yeah. Who wants to add something else? Did you understand the water cycle? Yes. Now let's do the activity on page 137 in your exercise book. After that, we will answer the retired questions in TEOG exams about this cycle...[Classroom Observation].

Some questions that Selda used to assess her students' learning during the teaching of biogeochemical cycles were presented below in Table 4.53.

Table 4.53. Selda's Sample Questions to Assess Students' Learning

Questions
What is the importance of water for living things?
How the plants and people contribute to the water cycle?
What are the sources of the carbon in nature?
Where are fossil fuels used?
Where is the nitrogen found in the structure of living things?

4.3.2.5.2. Selda's Knowledge of Methods of Assessment

Selda stated that she preferred the traditional assessment methods namely, informal questioning and written exam. She underlined that the exam questions were prepared by the all science teachers and asked to all students in 8th grade in the school. Therefore, she emphasized that she could only use written exams which include multiple choice, true/false and open-ended questions to evaluate her students' conceptual understanding. Furthermore, she addressed that the informal questioning was used to either recall the prior knowledge of students or reveal the students' learning of the current topic. She also underlined that she has to evaluate whether the students gain the curriculum objectives because of the national exam. Thus, she stated that she solved the retired questions asked in TEOG exams related to the biogeochemical cycles. On the other hand, she did not mention any alternative assessment methods like concept map, structured grid, peer or self-assessment.

R: Are there any specific methods that you generally use to assess students' learning on the topic of biogeochemical cycles? How do you use these methods?
S: We hold three written exams per semester. For example, we prepare written exam questions with the teachers in science group in common. Thus, we can

measure what the student understands about the topics. During the lessons, we use the questioning technique frequently to understand what the student has learned.
R: Which type of questions do you ask in the exams?
S: There are multiple choice items and open ended items. Sometimes, we can ask as fill in the blanks in order to understand whether the students can comprehend the concepts.
R: Ok, then why do you assess in this way? What are the reasons?
S: In the science group of our school we prepare the lesson plans through the curriculum. We are also concerned about the fulfillment of the topics in the curriculum because of the TEOG exam. Therefore, we cannot evaluate the student in the process of teaching. We don't have time for this assessment. We have to apply such methods because we have an exam-oriented education system. We solve the questions in the textbooks in the classroom or give them as homework. Moreover, the classrooms are too crowded so it is not suitable to evaluate students individually. In order to evaluate the students' learning, we can do only written exams or solve the questions that have been asked by TEOG in the previous years… [CoRe Interview].

During her teaching of the cycles, Selda used the traditional assessment techniques as well. She preferred both close and open ended questions to monitor her students' learning. Additionally, after the teaching of each cycle, she wanted her students to write the summary of the cycle in the blank given in the student exercise book. It was observed that she did not use any other assessment technique except the questioning to monitor the learners' understanding through the topic. She did not provide any feedback or review the points that learners have difficulties. In this respect, the formative assessment was fragmented that does not go through the whole topic. When Selda's summative assessment was taken in consideration, it can be seen that she focused on the assessment of students' learning by the written exam at the end of the unit. She held a common exam consisted of twenty-five multiple choice items. In the exam, there were four questions in order to assess students' conceptual understanding on the biogeochemical cycles. Additionally, she tried to solve the retired questions in TEOG exam to understand whether the learners comprehend the topic of biogeochemical cycles at the end of her teaching. In the light of the explanations above, Selda's knowledge of assessment was summarized in Table 4.54.

Table 4.54. The Summary of Selda's Knowledge of Assessment

Method of Assessment	Aim of the Assessment	Type of Assessment	Way of Assessment	What is Assessed	Types of questions
Questioning	To provide feedback on students' understanding on the related cycle	Formative	Informal	Prior Knowledge & Content (Conceptual Understanding)	Open & Close-ended
Solving TEOG exam questions	To evaluate students' learning after the teaching of related cycle	Summative	Informal	Content (Conceptual Understanding)	Multiple choice
Written Exam	To evaluate students' learning on the related cycle at the end of the unit	Summative	Formal	Content (Conceptual Understanding)	Open-ended, multiple-choice, short answer, true-false.

CHAPTER 5

DISCUSSION, CONCLUSION AND IMPLICATIONS

In this chapter, the findings of the current research were discussed in terms of science teachers' subject matter knowledge and pedagogical content knowledge in the context of education for sustainable development. In the light of the discussed points, the conclusions of the results were made. Afterwards, the implications were presented for pre-service and in-service science teachers', science teacher educators, and curriculum developers. Lastly, some further researches on teacher education were recommended in the light of the findings revealed in the study.

5.1. Science Teachers' Subject Matter Knowledge

In order to reveal experienced science teachers' SMK in the context of education for sustainable development, both teachers' both substantive, syntactic structures and SD understanding regarding biogeochemical cycles were examined. Thus, in this part, the results of participated teachers' SMK were discussed based on the considerations of the findings in the literature.

In this study, substantive knowledge refers to participant teachers' conceptual understanding (basic concepts & processes) related to biogeochemical cycles. Based on the findings of the study, it can be concluded that participant science teachers had deficit conceptual knowledge in the biogeochemical cycles.

Specifically, all teachers had partial understanding on the carbon, hydrological and nitrogen cycles. In terms of the carbon cycle, participant teachers had some inadequate knowledge. For example, Kemal and Selda did not touch upon the carbon cycle in aquatic systems. Although Hale implied the aquatic carbon cycle during her teaching, her explanations were not substantial. Additionally, Kemal and

Selda did not mention the algae and cynobacteria as producers. Furthermore, all participant teachers did not address the major source of carbon dioxide as oceans and biomass. They also stated the sun as the energy source of photosynthesis not a driving force of the cycle. When participant teachers' substantive knowledge regarding the carbon cycle were compared to the explanations and the schemas in the science curriculum (MoNE, 2013), it can be concluded that the science teachers' understanding of the carbon cycle were accordance with the curriculum. For example, in line with the deficits in teachers' understanding, the aquatic carbon cycle and other producers except the plants (i.e. cyanobacteria and algae) in the carbon cycle were not covered in the science curriculum. Additionally, there is no information about the major sources of carbon. Strikingly, in the cycle, the sun was not referred even as an energy source. Considering the hydrological cycle, all participant teachers had lack of knowledge that the sun and gravity were the driving forces for the cycle. When participant teachers' substantive knowledge regarding the hydrological cycle were compared to the explanations and the schemas in the science curriculum (MoNE, 2013), again, it can be concluded that the science teachers' understanding of the hydrological cycle were curriculum-led. The content of the science curriculum did not give place to the sun and gravity as driving forces as well. Lastly, the science teachers' statements related to the nitrogen cycle were inadequate according to the scientific explanations. For example, none of the teachers mention the cyanobacteria in aquatic systems as nitrogenous bacteria and the sun as the energy source of the cycle in their both drawings and teaching. When participant teachers' substantive knowledge regarding the nitrogen cycle were compared to the explanations and the schemas in the science curriculum (MoNE, 2013), it can be obviously seen that the science teachers' understanding of nitrogen cycle differentated. Kemal and Hale's understanding were over the curriculum whereas Selda had lack of knowledge in accordance with the curriculum.

In the light of these circumstances, , it can be concluded that participant teachers' substantive knowledge might be affected by the science curriculum. In this study, specifically, the curriculum might support the science teachers' ignorance of the abovementioned components or processes of the cycles. In other words, the limited content of the 8th grade science textbook might influence on the teachers' substantive knowledge. This means that even if they were experienced, they may forget the unused knowledge over time. This result fits with Arzi and White (2007)'s work which aims to understand what occurs to teachers' content knowledge over time. In their longitudinal study of seventeen-year, Arzi and White (2007) followed twenty-two teachers from their first year of teaching onwards. Based on the findings of their study, they concluded that school curricula which acted as both an organizer and information source had influenced teachers' content knowledge most significantly. Thus, they argued that CK became more coherent over time, while unused CK was forgotten, and little new knowledge was developed. Therefore, teachers become expert at teaching school science, leaving their academic science aside.

Another salient finding related to participant teachers' substantive knowledge was the level of their substantive knowledge. As Hale and Selda's specialist science were biology, it was expected that their conceptual understanding on biogeochemical cycles as an biology topic should be more substantial than Kemal's understanding. However, when teachers' conceptual understanding of the cycles compared, it can be obviously seen that Kemal's substantive knowledge regarding matter cycles was better than Selda. For example, in nitrogen cycle, Selda did not differentiate the decomposers and nitrifying bacteria. Furthermore, she did not state the denitrifiers as one of the nitrogen bacteria in the cycle. Therefore, her explanations about the processes of nitrification and denitrification were not substantial. In that vein, it can be concluded that Kemal had more successful than Selda in terms of undertanding and teaching the biogeochemical cycles which is the topic in his non-specialist subject area. This meant that he was forced to learn the topic of biogeochemical cycles in detail, and seek help to teach effectively in his non-specialist subject teaching. Kind (2009) illustrated this result in her study investigating how science teachers respond in developing expertise to teach outside their specialism. Thus, she showed that science teachers' lessons in their non-specialist sciences were more successful than those taught within specialism. A significant contributory factor was that the teachers made more effort to learn the topic and received more help in preparing their non-specialist science lessons (Ingber, 2009).

Secondly, the science teachers' understanding of nature of science were also investigated as syntactic knowledge (Schwab, 1964) in the current study. Consistent with previous research findings (Abd-El-Khalick & Lederman, 2000; Akerson & Abd-El-Khalick, 2003; Brickhouse, 1990; Cullen, Akerson & Hanson, 2012; Dogan & Abd-El-Khalick 2008; Lederman, 1992; Lederman, 1999; Liu & Lederman, 2007; Schwartz, Westerlund, García, & Taylor, 2010; Shim, Young, & Paolucci, 2010; Tairab, 2001) in-service science teachers possessed inadequate conceptions of NOS in current study. Particularly, teachers' NOS views on the tentative nature of scientific knowledge, differences between theories and laws, scientists' subjectivity and socio-cultural embeddness of scientific knowledge included naïve explanations. Participant teachers realized the tentative nature of scientific knowledge and implied that scientific knowledge can be changed by the new interpretations of existing knowledge. On the other hand, when asked whether theories or laws can be changed, their responses related to theory change were not associated with a tentative view of scientific knowledge. Rather, they reflected a naive view of theories as an intermediate step in the generation of 'true' scientific knowledge as laws (Abd-El-Khalick, 2005). Thus, they held a naïve understanding that laws are absolute knowledge giving examples from laws in physical sciences such as law of gravity, law of motion, and law of thermodynamics. This misconception might have resulted from the deterministic nature of the physical laws (Mc Comas, 1998). In the physical sciences laws are typically deterministic because the connection between the cause and effect are more securely linked (McComas, 1998). Thus, teachers are confident of their naïve understanding of laws are accurate and certain knowledge. Therefore, participant teachers ascribed to a hierarchical view of the relationship between scientific theories and laws whereby theories become laws when 'proven true' which reflects the teachers' misconceptions in the NOS aspect of functions of and differences between theories and laws (Bilican, 2014; Demirdogen, 2012; Dogan & Abd-El-Khalick, 2008)

Next, teachers had common myth that there is one universally accepted scientific method. In other words, teachers thought that scientific method should include testable procedures. This misunderstanding caused teachers' assertion that experimentation is only route to obtain true scientific knowledge. Furthermore, teachers' misunderstanding of universal scientific method led to their naive conceptions that science should be objective. On the other hand, the contributions from both the philosophy of science and psychology reveal that complete objectivity is impossible. Especially from the psychological perspective, the notion of theory-laden observation hinders scientist to be objective (Lederman & Abd-El-Khalick, 1998). Besides, scientists hold myriad personal values, preconceptions and prior experiences about the way the world operates. This is an unavoidable subjectivity that allows science to progress (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001).

Moreover, science teachers' myths on NOS tenets above-mentioned had influence on their conceptions of empirical, inferential, and creative-imaginative NOS tenets. For example, teachers' misconception of universal scientific method seeking correct answer led their views of creativity in science. As a result of the discussion on participants teachers' NOS understanding, it can be said that it is impossible to argue that NOS tenets are independent from each other. To be able to say that teachers have sophisticated views of NOS, they should be deeply informed in all of the NOS tenets (Akerson & Abd-El-Khalick, 2003; Şen, 2014).

In the light of these circumstances, in this study, participant teachers' naive NOS views might be related with their educational backgrounds including their primary, secondary and undergraduate education. Specifically, the science approach in science textbooks and the structure of laboratory activities which they experienced along with their educational lifes and the lack of familiarity of NOS courses in their college education might be important reasons for participants science teachers' naive ideas on NOS. First of all, as being student, participant teachers' experiences on laboratory activities during their previous education might have led to their inaccurate NOS views. Unfortunately, many common science teaching methods such as laboratory activities serve to work against the creativity in science (Abd-El-Khalick, 2005; McComas, 1998). Starting from primary level to undergraduate level, the majority of laboratory works are verification activities. The laboratory manual provides step-by-step directions and students are expected to perform activities, make observations and then arrive at a particular conclusion. There is an expectation that the conclusions formed will be both self-evident and uniform. Consequently, the laboratory activities promote the misconception that science is procedural and objective (Bilican, 2014; Clough, 2006). In his book, Tobias (1990) argued that students are not given opportunities to see science as an exciting and creative pursuit in the laboratories. Thus, due to the way of teaching science, participant teachers could have misunderstanding of nature of science in their student years. The depiction of science in the textbooks might also cause participant teachers' inadequate views on NOS (Abd-El-Khalick, Waters & Le, 2008; Bilican, 2014; Clough, 2006; Irez; 2009; Vesterinen, Aksela, & Lavonen, 2011). The studies just showed that the way of nature and aspects of science portrayed in science textbooks have many problems. Textbooks introduced the science as a procedural process seeking facts. Additionally, they either neglected NOS aspects or reflected inaccurate NOS views (Irez, 2009; Vesterinen, Aksela, & Lavonen, 2011). Therefore, these problems related to science textbooks which introduced at their any education level impeded participant teachers to possess naïve understanding about nature of science. Moreover, the absence of NOS courses in their college education might be another reason hindering teachers to develop NOS understanding. As known, the courses related to the history and nature of science has been integrated to the teacher education programs in Turkey, recently. Throughout the well-organized method or elective courses in science teacher education, teachers are given opportunities to discuss and reflect on the various aspects of NOS within in the different contexts. Thus, NOS is made pervasive theme for teachers by means of teacher education (Abd-El-Khalick, 2000; Bilican, 2014). As the participant teachers in the current research had experiences more than twenty years, they might have been a lack of familiarity of NOS courses in their undergraduate level. Hereby, they could not possess conceptual understanding of NOS.

In this study, participant teachers were expected to reflect NOS aspects into their practice regarding the topic of biogeochemical cycles. However, none of the teachers could translate any NOS aspects into their teaching. Since the rudimentary subject matter knowledge was considered to be one of the constraints that hinder teachers' integration NOS effectively (Abd-El-Khalick, & Akerson, 2003; Schwarzt & Lederman, 2002), the argument that teachers did not translate their NOS understanding into their classroom settings was an inevitable result of the current study. Especially, the teachers had lack of knowledge about the embedded NOS views regarding biogeochemical cycles. For example, when asked whether greenhouse effect is theory or law, although they explained the greenhouse effect correctly, they failed to understand that it is a theory (Ramanathan, 1988; Wilkins, 1993) because of their misconception on the functions of theories. Thus, the emphasis is that teaching about NOS requires science teachers to have *more* than a superficial knowledge and understanding of NOS aspects (Abd-El-Khalick & Lederman, 2000). There has been an consensus among researchers in educational field that deep conceptual understanding of subject matter is a necessary and crucial component of teachers' knowledge and professional base for effective teaching (Abell, 2007; Abd-El-Khalick & BouJaoude 1997, Aydin, 2012; Grossman, 1990; Magnusson et al., 1999; Shulman 1986, 1987; NRC, 1996; 2000). On the other hand, these studies also concluded that subject matter knowledge is necessary but not sufficient requirement for teaching effectively. Even if teachers had desired NOS understanding, they could not translate their beliefs into the instructional practices (Abd-El-Khalick, & Lederman, 2000; Lederman, 1992, 1999; Luft & Roehrig, 2007).

There is a variety of factors constrained the translation of teachers' NOS views into practices except from the conceptual understanding. To be able to teach NOS, teachers must intend and believe they can teach NOS, must concern students' needs and abilities to learn NOS and must have the pedagogical knowledge base for teaching NOS (Schwartz & Lederman, 2002). In other words, teachers' orientations and PCK for NOS are important factors that mediate teachers' translation of their views on NOS into their teaching practices (Clough, 2006; Hanuscin & Hian, 2009; Hanuscin, Lee, & Akerson, 2011; Lederman, 2007). The vision of the science curriculum is to educate learners as scientific literate individuals (MoNE, 2013) and the nature of science is an important element of scientific literacy. Thus, to help students possess an understanding of NOS, science teachers have an crucial role. However, participant teachers in this study did not intend to teach NOS aspects in their teaching of biogeochemical cycles. When their orientations were examined, it could be seen that the science teachers' central goals were to either transmit the curriculum objectives or develop environmental awareness related to the biogeochemical cycles. They did not attempt to teach NOS in their lessons. In other words, it can be said that participated teachers could not develop PCK for NOS because of their lack of orientations to teach NOS. This result is in line with some empirical PCK studies confirmed that orientations to teaching science may function as either an *inhibiting* or *facilitating* factor in the interactions among the PCK components (Aydin, 2012; Bilican, 2016; Demirdogen, 2016; Magnusson et al. 1999; Sen, 2016). Therefore, in here, the absence of teachers' orientations to teach NOS constrained their PCK for NOS. A great deal of research has also indicated that science teachers should be provided with opportunities to develop not only their understanding of NOS, but also their ability to transform this understanding to facilitate student interpretation in the classroom context (Abell 2008; Akerson et al. 2006; Haunscin et al. 2011, Hanuscin, 2013).

Lastly, in the current research, science teachers' conceptions of SD were investigated as a separate subject matter knowledge type. Based on the interdisciplinary nature of SD concept, the study investigated how science teachers connect the biogeochemical cycles and sustainable development issues regarding the seven main aspects of SD namely, environment, society, economy, politics, technology, education and energy. To identify science teachers' conceptions of SD, they were asked to explain the causes, results and solutions to the degredation of the biogeochemical cycles. As can be seen from the findings, seven main conceptual areas identified by Kilinc and Aydin (2013) were raised: 'environment', 'economy', 'society', 'politics', 'energy', 'technology', and 'education'. This picture showed that SD issues was not understood exclusively in terms of the environment or the three popular pillars (the environment, society, and the economy) of SD. Nevertheless, Hale and Selda mainly focused the environmental, societal and economic aspects of SD respectively, whereas Kemal addressed the political issues moslty as third aspect of the SD. Thus, even though some research assumed that people do not take 'politics' into account in thinking about SD (e.g. Gil-perez et al., 2003), this study displayed that science teachers used political arguments in defining SD. Additionally, teachers connected SD aspects to the carbon cycle. Especially, Selda and Kemal did not related the nitrogen and hydrological cycle with the related SD concepts and issues.

It can be said that both formal education of science teachers' professional experience and their informal education through written and digital media (TV, newspapers and internet) may be responsible for this variety of the SD conceptins of the science teachers. In terms of formal education, as participant science teachers studied in middle public shools implementing Eco-Schools Project, they might be familiar with the all conceptions of SD. On the other hand, both the science curriculum in Turkey and both Ecoschool programme were based mainly on biophysical and ecological aspects of environment, so the result that science teachers moslty defined SD in terms of the environment. In that vein, Summers and Childs (2007) investigated teachers' conceptions of sustainable development using questionnaire in secondary science teacher training course. In line with the result of the study, they argued that substantial number of science teachers focused the centrality of the environmental factors while explaining the sustainable development.

Regarding informal ESD, research showed that that both the students and the teachers mostly learn the information about environmental issues via print and visual media; especially television (Kılınç et al., 2008; Öztaş & Kalıpçı, 2009). For instance, Kemal adressed the documentaries about the Al Gore and the news from the activitists of GreenPeace in order to explain the environmental corcerns such as global warming and greenhouse effect. Therefore, it can be argued that news or documentaries about 5-year development plans, the SAP and environmental degradation may lead to awareness among the science teachers. In their study, Kilinc and Aydin (2013) also concluded that development plans have received attention in fora like political discussions in the Turkish popular media. For example, Hale gave SAP as an example to explain the contribution of the project to the local community. Thus, it can be argued that these kinds of excellent examples may help teachers to cover all aspects of SD.

Additionally, the science teachers' conceptions could be specific to Turkish context. Their statements like having strong government, dependence on foreign traits, production of new technology, industrial development for production, improving living standards of the society and creating new job opportunities showed that science teachers faced the current problems of Turkey as a developing country. Therefore, it can be said that contextual reasons might affect teachers' conceptions.

5.2. Science Teachers' Pedagogical Content Knowledge

In order to reveal experienced science teachers' topic-specific PCK regarding biogeochemical cycles in the context of education for sustainable development, teachers' orientations to science teaching and PCK components namely, knowledge of curriculum, knowledge of instructional strategies, knowledge of students understanding and knowledge of assessment were examined. Thus, in this part, participant teachers' topic-specific PCK was discussed based on the considerations of the findings in both the study and the literature.

Labeling teachers' orientations to teaching science is difficult due to its multi-dimensional and complex nature (Luft & Roehring, 2007). Friedrichsen and Dana (2005) concluded that central and peripheral goals related to subject matter, schooling and affective domain formed the orientations to science teaching at any grade level. For example, in this study, Kemal and Selda were focused on both subject matter and schooling goals. In other words, those teachers were attempted to both transmit the curriculum objectives and prepare learners to high school entrance exam (TEOG) as central goals. Thus, it can be said that the two teachers' orientations were limited and teacher-centered such as didactic (lecturing) and academic-rigor. On the other hand, Hale's central goals were to help the learners to connect science and daily life and develop environmental awareness which was related to affective domain goals. During her classroom practice, her beliefs and orientations generally shaped her teaching in a way which the students were participative and active. For example, she preferred the project-based learning as a student-centered orientation and gave opportunity the learners to represent their project and reflect their ideas about the problems related to the cycles.

In the context of the study, many factors might explain teachers' orientations to science teaching such as contextual factors (i.e. exam-based educational system, the context of the school), overloaded curriculum and teachers' discomfort with their SMK as mentioned previously. (Avraamidou, 2012; Feierabend et al., 2011; Friedrichsen et al., 2011; Friedrichsen & Dana, 2005; Samuelowicz & Bain, 1992). First, in Turkey, in order to enroll qualified ''Science or Anatolian Lycee'', students studied in middle school have to take the high school entrance exam (TEOG [currently known LGS]) and get good scores. Due to this examination-based system, elementary education is mostly based on performing multiple-choice exercises, especially at 8th grades. Moreover, the school administration gives importance to the exam-based teaching because the quality judgements about the teachers and schools are shaped based on the scores which the students get from the TEOG exams. This view was supported by their parents as well. Especially, in this study, teachers were aware of the benefits of orientations such as project-based, process, and inquiry which students have participative, interactive and reflective roles. However, they complained about the contextual factors such as type of the school (public/private), crowded classrooms, deficiency of the laboratory and the students' and their families concerns about the TEOG exam. In a result, these contextual factors mentioned above may force teachers to modify ideal goals of teaching and thus, prefer the teacher-led orientations (Friedrichsen et al., 2011; Friedrichsen & Dana, 2005; Samuelowicz & Bain, 1992).

Another probable factor influencing teachers' orientations to science teaching may be overloaded curriculum. Because of the schedule of high school entrance exam, the participants also complained about the time issue for fulfillment of the required topics in the curriculum. They stated that additional time is necessary for preparing and grading the student-centered activities due to the curriculum load. In the same way, studies promoted that teachers preferred to teach didactically due to the time necessary for preparing minds-on activities (Friedrichsen & Dana, 2005) and overload of teaching works (e.g. grading) (Nargund-Joshi, et al., 2011).

Lastly, science teachers' orientations to teaching science may be related to their discomforts with their SMK (Avraamidou, 2012; Feierabend et al., 2011; Friedrichsen et al., 2011; Friedrichsen & Dana, 2005). The findings of the study revealed that all teachers were lack of SMK in the topic of biogeochemical cycles. Especially, both Kemal and Selda's syntactic knowledge and SD understanding regarding environmental topics was generally inadequate. Particularly, in the context of ESD, many researches confirmed that teachers' understanding of sustainable development and environmental issues is crucial for their beliefs for integrating ESD into their practice (Corney, 2006; Spiropoulou, Antonakaki, Kontaxaki &Bouras, 2007; Summers et al., 2005). Therefore, the deficiency of their SMK may force teachers to prefer teacher-centered orientations which they transmitted their conceptual knowledge didactically.

Participant science teachers' knowledge of curriculum was analyzed in two categories, namely, knowledge of goals and objectives and knowledge of materials. In terms of knowledge of goals and objectives, the results of the current research revealed that science teachers could directly addressed the curriculum objectives regarding the biogeochemical cycles. Furthermore, they were aware of the horizontal and vertical relations of the topic. It is thought that science teachers' knowledge of curriculum objectives may be related to their experience. As participant teachers had experiences more than ten years, they were familiar to the curriculum objectives and the pre-requisite knowledge (horizontal and vertical relations) in order to teach the biogeochemical cycles. In the same way, the PCK studies held with novice or prospective teachers also confirmed that pre-service science teachers did not possess adequate knowledge of curriculum. They were not aware of the both objectives and the pre-requisite horizontal and vertical topics (Graf et al., 2011; Hanuscin et al., 2011; Mıhlandız & Timur, 2011; Özcan & Tekkaya, 2011; Tekkaya & Kılıç; 2012; Uşak, 2009).

Another issue in order to be discussed was the teachers' violation and/or modification of the curriculum. Except the curriculum ones, all teachers expected their students to gain additional affective domain objectives such as developing environmental awareness to preserve the balance of the biogeochemical cycles. Additionally, whereas two teachers pointed out that if necessary, they can modify the sequence of the sub-topics, the other participated teacher already changed the sequence of the topic during the classroom practice. Based on the PCK studies, it can be said that the factors such as teachers' interests and beliefs, owing to curriculum saliency, and knowledge of students' understanding might explain teachers' violation of the curriculum (De Miranda, 2008; Friedrichsen et al., 2011; Friedrichsen & Dana, 2005; Rollnick et al., 2008). First of all, the curriculum saliency can defined as ''the teacher's knowledge of the place of the topic in the curriculum and the purpose for teaching'' (Rollnick et al., 2008, p.1367). That is, the awareness of the curriculum saliency might help teachers to diagnose the problems related to the sequence of teaching the sub-topics and cause teachers' modification of the curriculum. In addition, teachers' interests and beliefs also can explain the reason of their violation of the curriculum (Friedrichsen et al., 2011; Friedrichsen & Dana, 2005). Especially, in this study, participated teachers' beliefs and concerns of the topic could be the reason for exceeding the curriculum in terms of the additional affective domain objectives. Lastly, it could be interaction between teachers' violation of the curriculum and knowledge of students. If science teachers are knowledgeable about their students' understanding, they can modify the textbooks (De Miranda, 2008) and curricular sources as response to the students' specific needs and characteristics. For example, one of the participated teachers firstly presented the carbon cycle by reason of the students' familiarity of the previous topic of photosynthesis and respiration.

Finally, regarding teachers' dependence of curriculum materials and sources, the results of the study revealed that all teachers used the science textbook to follow the curriculum. However, in terms of use of the activities in textbooks and student exercise book, only one of the teachers was dependent to the curriculum resources. Other two teachers preferred either solving more questions or repeating the content related to the topic. As a result, they had a deficiency about the activities included in the curriculum. The reason of the ignoring the activities covered in the curriculum might be the contextual factors such as the frequency of the curriculum revisions and the exam-based educational system. First of all, since the republic of Turkey established in 1923, science curriculum were revised or developed 11 times (Çalık & Ayas, 2008). Then, currenty, the science curriculum was revised in 2013 and 2018. Researchers emphasized that teachers could not carry out the existing curriculum completely when the new curriculum was developed (Çalık & Ayas, 2008). As a result, science teachers continue to teach as they used to be (Coll & Taylor, 2012). Thus, the frequent alterations in the curriculum could cause science teachers to ignore of the curriculum. Secondly, the existence of the High School Entrance Exam (TEOG) leads teachers to solve more questions to prepare students to the exam during the teaching of the topics. Thus, this situation could cause science teachers to be tended to ignore of the curriculum activities. In their study, Mıhlandız and Timur (2011) promoted the influence of contextual factors on science teachers' knowledge of curriculum, as well.

In the knowledge of instructional strategies, there were both differences and similarities among the science teachers. The only correspondence was the dominancy of the teacher centered subject-specific instructional strategies like direct instruction and questioning. Although Hale adopted the student centered strategies such as problem and project based learning in her teaching of biogeochemical cycles, her instruction was generally based on questioning. Hale stated that she had gotten training on what student-centered instructional strategies and how they can be used in classroom environment. Moreover, she underlined that she actively used the social media both to share her own experiences on teaching and to regard the different instructional strategies used by her colleagues. On the other hand, two other teachers, Kemal and Selda, did not prefer to use any student centered strategies. Moreover, they were aware of their inadequate knowledge of instructional strategies. The teachers, in fact, agreed that they should be trained about how to use instructional strategies.

In terms of the differences in knowledge about instructional strategies, the level of teacher-centeredness of the instruction was the main distinguishing factor affecting science teachers' use of topic-specific strategies. In other words, science teachers varied in the aspects elaborated during the instruction (e.g. content, SD issues) and the numbers of representations and activities used. For instance, Hale used both various representations such as real-life examples, figures, illustrations, animations, and activities required by the curriculum, whereas Kemal and Selda only used their own figures and limited number of examples during their teaching of biogeochemical cycles. Furthermore, they did not use any activities in the curriculum. Regarding the aspects they adverted during the instruction, although Selda and Kemal mainly touched upon the conceptual knowledge, Hale, again, differentiated in the expressions on the SD aspects. It could be obviously seen that she often mentioned the issues and phenomena of the SD during her teaching of the cycles.

Likewise, researches on teacher education had similar findings to the ones in the current study. For example, Magnusson et al. (1999) concluded that teachers did not have enough knowledge about the use of the instructional strategies. Some different studies, accordingly, argued that teachers' lack of experience on how subject-specific strategies can be implemented could be the reason of their ignorance of the use of the student-centered strategies (Aydemir, 2014; Aydin, 2012; Brown et al., 2013; Friedrichsen et al., 2007; Ingber, 2009; Karakulak & Tekkaya; 2010; Mıhlandız & Timur, 2011; Settlage, 2000; Şen, 2014). In fact, teachers' lack of knowledge about how to use topic-specific strategies could be also a reason for their level of teacher centeredness of the instruction. Especially, in the context of ESD, studies had shown that teachers' understanding of ESD specific strategies is not comprehensive and so they feel strongly that they should train about the ways to integrate of ESD into their subjects (Anyolo, Karkkainen, & Keinonen, 2018; Ravindranath, 2007; Winter, 2007). The nature of the strategies used in ESD context should be participative, interactive, reflective, experiential and based on the school context (Kadji-Beltran, Zachariou, Liarakou & Flogaitis, 2014). In other words, ESD requires implementing the learner-centered topic specific strategies such as case studies, discussion and debates, field trips, role-plays etc. Likewise, the results of the study revealed the similar findings that participated teachers did not use any ESD specific strategies to integrate SD issues into their teaching of biogeochemical cycles.

Magnusson et al. (1999) underlined that science teachers' knowledge of subject specific strategies shaped based on their orientations to science teaching (Magnusson et al., 1999). Therefore, the teachers' instructional decisions might be filtered through their orientations to teaching science. In other words, they could prefer using the strategies fitted to their orientations. Thus, as discussed in the section of science teachers' orientation to science teaching, contextual factors influencing science teachers' orientations might affect teachers' implementation of subject-specific strategies at the 8th grade, as well. That is, the exam-based educational system, type of the school (public/private), crowded classrooms, deficiency of the laboratory and the students' and their parents' concerns about the high school entrance exam could be the reasons of teachers' ignorance of the subject-specific strategies and preferences to teacher-led strategies.

One of the reasons for the differences in the level of teacher-centeredness of the topic-specific strategies could be the teachers' SMK. Although all of the teachers participated to the study had a lack of knowledge about both conceptual and syntactic (NOS) understanding, Hale was obviously knowledgeable regarding the connections between sustainable development issues and biogeochemical cycles. In other words, it can be said that Hale had more robust SMK than the other two teachers. PCK literature had already underlined the importance of SMK for developing a strong PCK (Abell, 2008; Magnusson et al, 1999; Shulman, 1986). As mentioned the discussion of teachers' substantive knowledge, especially in the subject of biology, the use of multiple representations could be a good indicator of teachers' SMK (Oh & Kim, 2013). Furthermore, in his studies, Shulman (1986; 1987) indicated that expert teachers had more knowledgeable about the ways that make specific content (in this study, SD issues) more comprehensible to the students. Again, Gess-Newsome (1992) emphasized that content expert teachers used more examples related to students' daily life. In this regard, studies conducted in the context of ESD also underlined that teachers' lack of understanding of the nature and issues of sustainable development caused them to have difficulties in integration of ESD in their practice (Cotton, Warren, Maiboroda, & Bailey,2007; Corney, 2006; Spiropoulou, Antonakaki, Kontaxaki & Bouras 2007). Likewise, in this study, it could be obviously seen that Kemal and Selda had a lack of knowledge the connections between SD issues and biogeochemical cycles and could not elaborate the issues of SD during their instruction.

Another reason of the level of teacher centeredness of the instruction might be the contextual factors. In this study, specifically, the existence of high school entrance exam was shown as an important factor affecting science teachers' topic-specific strategies. For example, Kemal and Selda emphasized that the rareness of the questions related to the topic of biogeochemical cycles asked in TEOG exam could cause them to use direct instruction. Moreover, they complained that the students' anxiety of the exam led them to teach the topic in a didactic way.

In terms of dependence on the activities suggested by the curriculum, the influence of knowledge of curriculum on science teachers' knowledge of topic-specific strategies should be discussed. In fact, Kemal and Selda used only textbooks to follow the content of the topic. They, moreover, had deficiency about the activities in the curriculum. Thus, they did not implement such activities in their teaching of biogeochemical cycles. That is, their lack of knowledge about curriculum affected their use of topic-specific instructional strategies. Most studies reported the similar findings that there was an interaction between knowledge of instructional strategies and curricular knowledge (Aydin, 2012; Hanuscin et al., 2010; Falk, 2012) study.

Most of the PCK studies also claimed that most robust interaction were found between knowledge of students' understanding and knowledge of instructional strategies (Boz & Boz, 2008; Brown et al., 2013; Demirdoğan, 2012; Hanuscin et al., 2010; Park & Chen, 2012; Soysal, 2018). As the correspondence with the results of these studies, science teachers' knowledge of students' requirements might affect their aspects elaborated (e.g. SD issues) during their teaching. For example, Hale was aware of her students' needs for developing more affective skills in the topic of environmental issues, so she stressed more the SD related issues in her teaching. Moreover, she used various topic-specific representations and activities to reach more students whose learning styles and abilities were different.

Regarding knowledge of students, participated teachers' responses were analyzed in two categories, namely; knowledge of students' requirements and knowledge of students' difficulties and misconceptions. In terms of knowledge of students' requirements, all teachers could address the pre-requisite topics such as the weather events (the formation of cloud and hail) in the 5th grade, the topic of physical and chemical changes in the 6th grade, and lastly, the topics of the properties of elements and compounds, the chemical bonds and basic building blocks of living things in the 7th grade. They were also aware of students' prior knowledge on the topic of energy flow in the food chain in the 8th grade. Thus, teachers seemed to have sufficient knowledge for students' prior knowledge on the topic of biogeochemical cycles. On the other hand, considering the students' learning styles and abilities to be able to comprehend the topic, Hale was solely concerned her students' needs. As mentioned in the discussion of instructional strategies, she gave importance to her students' different learning styles by using many topic-specific strategies. Moreover, she used project-based learning as a student-centered strategy in order to make the students active. Regarding science teachers' knowledge of students' difficulties, all of the teachers stated that students had difficulties in make their understanding actual in the environmental topics. Teachers complained that students had problems of developing attitudes awareness in such environmental topics. However, only Hale tried to help students to develop environmental awareness through discussions including real-life examples.

Especially, the reason for the similarities between science teachers' knowledge of learners, might be related to their teaching experience. Because of the experiences more than twenty years, all teachers were aware of their students' pre-requisite knowledge. Similarly, most studies addressed that the lack of classroom experiences might be the major reason for the student-teachers' lack of knowledge of students' understanding (Cochran et al., 1993; De Jong, Van Driel & Verloop, 2005; Friedrichsen et al., 2009; Veal et al., 1999).

Regarding the differences between teachers' knowledge of students, both teachers' SMK and their beliefs and orientations to science teaching also could assist for their knowledge of learners (De Miranda, 2008; Sanders et al., 1993; Van Driel, 2008). Except Hale, Kemal and Selda adopted teacher-centered orientations and aimed to transmit the curriculum objectives. Therefore, their orientations did not permit teachers to consider students' needs in the context of learning styles and abilities to comprehend the topic. Contrarily, Hale's knowledge about students might be leaded to adjust different topic-specific representations and activities to make her teaching more efficient for students (Akerson, 2005;Aydın et al., 2010; Brown et al., 2013; Demirdöğen, 2012; Hanuscin et al., 2011; Şen, 2014).

Another source of teachers' knowledge of learners could be their subject matter knowledge. Among the participated teachers, Hale was the most knowledgeable one in terms of understanding of SD issues on biogeochemical cycles. Thus, her SMK based on her expertise on biological education and informal training on science education could be most important factor influencing her understanding of students' needs. In a similar way, PCK studies (2012) stated that experienced teachers most robust SMK was knowledgeable about learners' both understanding and difficulties (Aydemir, 2014; Aydin, 2012; Şen, 2014).

Considering the knowledge of assessment, teachers' knowledge of both dimensions of science learning and methods of assessment were two sub-components analyzed. In terms of teachers' knowledge on dimensions of science learning, all participant teachers aimed to assess students' conceptual understanding and also ignored the assessment of NOS aspects on the topic of biogeochemical cycles. Teachers' emphasis on the assessment of conceptual understanding also emphasized in the previous research (Aydin, 2012; Lankford, 2010; Tekkaya & Kılıç, 2012; Şen; 2014). However, it can be seen that Hale also concerned her students' both comprehension of SD related issues and development of science process skills and/or cognitive skills such as critical thinking, problem-solving and decision making through project-based learning. Regarding the participated teachers' knowledge of methods of assessment, Kemal and Selda focused generally traditional and summative assessment techniques (informal questioning, multiple choice test) whereas Hale preferred to use authentic assessment strategies such as performance/ peer assessment (students' projects), and concept map completion tasks. Moreover, her formative assessment was coherent that go through the whole topic. She tried to provide feedbacks or re-teaching the points that learners have difficulties.

The one probable factor influencing teachers' knowledge of assessment could be their beliefs and orientations to science teaching. As Kemal and Selda held both the beliefs on transmission of the curriculum objectives and orientations including teacher-centered strategies like direct instruction (didactic orientation), their assessment was generally based on traditional assessment in order to evaluate their students' conceptual knowledge. On the other hand, Hale aimed to assess both her students' conceptual knowledge, skills and SD issues on the related topic due to the her preference on the use of student-centered orientations such as process-skill development, inquiry, project-based etc., so teacher may have chosen to focus on the authentic assessment techniques such as peer assessment and concept map.

Another reason may be the inadequate emphasis of integration and assessment on both NOS and SD issues the science curriculum (Abd-El-Khalick, 2006; Combes, 2005; Hanuscin et al., 2011; Karaaslan, 2016; Kim & Fortner, 2006). When the 8th grade science curriculum in Turkey was examined (MoNE, 2005; 2013), the lack of specific goals and objectives on development of students' NOS and SD understanding could be obviously seen. The curriculum only focused on the objectives which aim students' conceptual understanding on the related topic. Therefore, teachers did not need to intend to teach the NOS and SD aspects. In this regard, they did not attempt to assess these dimensions in their lessons. Park and Oliver (2008) also underlined that the goals and objectives in the curriculum had influence on teachers' knowledge of assessment.

Additionally, contextual factors, especially the exam-based educational system might affect teachers' knowledge of assessment. The questions asked in the high school entrance exam (TEOG) are focused on the content rather than NOS or SD issues. Even if teacher may view that NOS or SD issues should be taught, the system may force teachers to ignore the assessment of these issues. Similar situation has been emphasized in the countries having exam-based education system, for example, in China (Zhang et al., 2003) and in India (Nargund-Joshi et al., 2011). Likewise, regarding the methods of assessment, teachers heavily focused on summative assessment by preparing written exams including multiple choice items as in the national exams. The contextual factors regarding to country and school in which teachers teach has an important factor on their classroom practice (Aydin, 2012; Loughran et al., 2004; Şen, 2014).

Moreover, science teachers used traditional assessment techniques rather than alternative or authentic ones. In other words, they have lack of knowledge on the methods of assessment. Similar findings also represented in previous studies (Canbazoğlu et al., 2010; Graf et al., 2011; Kaya, 2009; Taşdere & Özsevgeç, 2012; Uşak et al., 2011; Şen, 2014). The reason of teachers' use of traditional assessment could be their lack of experience on how the authentic techniques implement through both courses in their undergraduate education and trainings in their professions. Except Hale, other two teachers participated to this study had no training on science or biology-specific professional development on alternative assessment strategies. Similarly, Kaya (2009) also emphasized the lack of emphasis on assessment in teacher education by underlying the ignorance of the related courses in undergraduate education. He concluded that the limited number of assessment courses led teachers to focus traditional assessment techniques. Therefore, teachers might have a tendency to implement such assessment strategies which they were familiar from their K-16 education.

5.3. Implications & Recommendations

In light of the results concluded and the points discussed, the study has numerous implications and recommendations for pre-service and in-service teacher educators, curriculum developers and teacher education research.

The results of the study concluded that PCK is specific to topic, context (classroom, school, parents etc.), teacher and students (Abell, 2008; Lankford, 2010; Nargund-Joshi, et al., 2011; Park & Oliver, 2008). This study aimed to investigate PCK of experienced teachers for the case of teaching biogeochemical cycles in the context of ESD. From this point, the result of the study is helpful for the understanding of the topic-specific PCK regarding the teaching of the topic of biogeochemical cycles.

This study provided the inspiration for education of both inservice and pre service teachers. As literature emphasized, teaching experience is a core source of PCK (Grossman, 1990; van Driel et al., 2002). On the other hand, it can not be inferred that robust teaching experience mean rich PCK (Friedrichsen et al., 2009). Results revealed that science teachers do not have grasp PCK and content knowledge about biogeochemical cycles in the context of SD. All teachers participated to the study complained about the deficiencies on science or topic specific training, and they stated especially their deficiencies for teaching SD and NOS. Considering the results, it was remarkable that inservice teachers should be supported on the environmental topics regarding the close connections of SD issues and NOS. The support should include not only content knowledge about environmental topics, NOS and SD but also PCK components. This means that professional development should support teachers to enrich their practice of teaching concerning students' difficulties, how to respond this difficulties by means of enriched teaching and assessment strategies. Furthermore, these professional trainings should be discipline based and specific to topic teachers taught (Nakiboğlu & Tekin, 2006). Hence, these professional support should give teachers opportunity to reflect on the specific topics (i.e. NOS and SD) with regard to how different science topics could be taught to learners because each topic has its own instructional strategies, assessments, curriculum and student difficulties.

There are some problems identified in this study that curriculum developers should cope with. First of all, curriculum developers should place specific NOS and SD objectives in biogeochemical cycles. From the point of curriculum materials, teachers should be supported in order to teach NOS and ESD effectively (Kawaga, 2009). Additional teaching resources including specific practices on instructional and assessment strategies on NOS and SD can be developed. If these suggestions are not adapted to the curriculum, science teachers may not be voluntarily to teach both NOS and SD with the connections between environmental topics because science teachers tend to teach what curricular objectives mention as it is understood by the findings of the current study.

In order to meet needs of teachers, another remedy for the development of rich PCK is to provide long-term professional development (De Jong et al., 2002; Gilbert, De Jong, Justi, Treagust, & van Driel, 2002; Hanuscin et al., 2011; Nakiboğlu & Karakoç, 2006; van Driel et al., 1998). Learning the content knowledge and curricular adaptations are not sufficient for teachers to teach NOS and SD integrated environmental topics. Therefore, theoretical framework of this study, topic specific PCK, can be used in planned development program to increase how well science teachers teach NOS and SD integrated environmental topics (Şahin, Ertepınar & Teksöz, 2009) . Firstly, in these programs, science teachers' orientation towards science should need to be changed. However, orientation towards science is multidimensional and resistant to change (Luft & Roehring, 2007). Therefore, planned PD programs should be long standing to change teachers' orientations. Otherwise, program could be unsuccessful for changing orientation towards science in shaping PCK.

Bucat (2004) argued that the profession of teaching suffers from the disease named as amnesia due to deficiency for sharing the wisdom of teaching experience. Thus, by the current PCK study, it is hoped to help other inservice or preservice teachers to have shared memory for teaching biogeochemical cycles. Concerning all PCK components; the results of the study have valuable practical information in teaching environmental topics regarding SD issues. This information recommended teacher educator to use these real-classroom experiences in professional development for both inservice and preservice education.

Lastly, there are some recommendations for further research. It was known that PCK is specific to context (e.g. both school and country level), learners, topics, and teachers. Using same topic, the studies should be conducted with one teacher which teaches in different groups of learners (e.g. high and low achievers) or different grades of learners (4,5,6 & 7th grades) to examine the PCK development. Then, the researchers should examine how the context influences teachers' PCK. For example, comparison studies in rural and urban schools or with different countries should be conducted.

Regarding orientations to science teaching, the curren research was limited to nine orientations identified by Magnusson et. Al (1999). Thus, new studies should examine how current orientations such as argumentation and STEM affect PCK development.

This study can be strengthened by connecting teachers' PCK to student achievement. Therefore further researches connecting teachers' PCK to students' learning and achievement can provide important insights into the nature of PCK. Especially, using the Gess-Newsome (2015)' PCK model, researchers should investigate the connections between teachers' PCK and their students' achievement.

In Turkey, studies specifically using PCK framework in the context of ESD is too limited. This PCK study was focused on biology topics regarding ESD. PCK studies should be implemented in both other topics of biology and different subjects such as chemistry & physics regarding ESD. Additonally, studies that will aim to delve the effect of an intervention (e.g. workshop or elective course) should be conducted to examine the teachers' PCK development in the context of ESD.

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APPENDICES

A.MADDE DÖNGÜLERİ VE SÜRDÜRÜLEBİLİR KALKINMA KAVRAMINA YÖNELİK GÖRÜŞME SORULARI

Ön Bilgi Soruları:

- Adınız, Soyadınız:
- Yaşınız: Cinsiyet:
- Mezun olduğunuz üniversite/Bölüm:
- Mesleki tecrübeniz (yıl/ay):
- Görev yapmakta olduğunuz okul:
- Kaç yıldır bu okulda görev yapıyorsunuz?
- Daha önce çevre ile ilgili eğitime katıldınız mı?
- Katıldıysanız, eğitimin içeriği:
- Daha önce çevre ile ilgili etkinlik/seminer/konferans vs. katıldınız mı?
- Katıldıysanız, etkinlik/seminer/konferans vs içeriği:
- Üyesi olduğunuz dernek/kurum/kuruluşlar:

Madde Döngülerine Yönelik Sorular

1) Madde döngüsü denince ne anlıyorsunuz? Sizce madde döngüsü ne demektir?
2) Madde döngüleri nelerdir? Şekil çizerek açıklayabilir misiniz?
3) Döngülerin ekosistem için önemi nedir?

Sürdürülebilir Kalkınma Kavramına Yönelik Sorular

4) Döngülerin bozulmasına neden olan faktörleri söyleyebilir misiniz? Bu faktörler o döngüyü neden/nasıl bozmaktadır?
5) Madde döngülerindeki bozulmalar sorunlara yol açar mı?

*Evet, Ne gibi sorunlara yol açabilir? Örnek vererek açıklayabilir misiniz?
*Hayır, Nedenini örneklerle açıklayabilir misiniz?

6) Madde döngülerindeki bozulmaları azaltmak için neler yapılmalıdır? Ne gibi çözümler önerirsiniz?
7) Madde döngüleri konusunu sürdürülebilir kalkınma kavramı ile ilişkilendirebilir misiniz? Nasıl/Ne açıdan ilişki kuruyorsunuz? Açıklayabilir misiniz?

B. BİLİMİN DOĞASI BİLGİSİNE YÖNELİK GÖRÜŞME SORULARI

1) Sizce bilim nedir? Bilimi; din, felsefe gibi diğer disiplinlerden ayıran özellikler nelerdir?

2) Küresel ısınma, yüzyılı aşkın süredir dünya yüzeyinde yıl boyunca kara, hava ve denizlerde görülen ortalama sıcaklıklarda görülen artış olarak tanımlanmaktadır. Bilim insanları küresel ısınmanın meydana geldiği konusunda nasıl emin olmaktadırlar? Onların bu konuda emin olmalarını sağlayan faktörler nelerdir?

3) Sera etkisi, bilimsel bir kanun mudur yoksa bilimsel bir teori midir? Nedenini açıklayabilir misiniz?

4) Bilimsel teori ve bilimsel kanun arasında bir fark var mıdır?
*Evet, Nedenini açıklayabilir misiniz?
*Hayır, Nedenini açıklayabilir misiniz?

5) Bilimsel teoriler (örn: İklim değişikliği ile ilgili bir teori) zaman içinde değişir mi?
* Evet, Teorilerin neden değiştiğini açıklar mısınız?
* Hayır, Nedenini açıklar mısınız?

6) Bilimsel kanunlar zaman içinde değişir mi?
*Evet; Neden değişirler? Açıklayabilir misiniz?
*Hayır; Nedenini açıklayabilir misiniz?

7) Bilim insanlarının araştırmalarında takip ettikleri belli bir bilimsel yöntem var mıdır?
*Evet, Bu yöntem/yöntemler nelerdir? Örnek vererek açıklayabilir misiniz?
*Hayır, Nedenini açıklayabilir misiniz?

8) 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?

9) 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?

10) 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 ve normlardan bağımsızdır.
*Bilimin sosyal, kültürel değerlere bağımlı olduğunu düşünüyorsanız, nedenini uygun örneklerle açıklayınız.
*Bilimin sosyal, kültürel değerlerden bağımsız olduğunu düşünüyorsanız nedenini uygun örneklerle açıklayınız.

C. KART GRUPLAMA AKTİVİTESİ

A. Fen ve çevre/sürdürülebilir kalkınma eğitiminin amaçlarına yönelik sorular

1. Sizce ilköğretim kademesinde fen öğretilmesinin sebepleri/amaçları nelerdir? Bu konudaki görüşünüz nedir?
2. Neden fen eğitiminin bu tür amaçları olduğunu düşünüyorsunuz? Bu kanıya varmanızı sağlayan etmenler nelerdir?
3. Sizce fen eğitimi ile sürdürülebilir kalkınma eğitimi arasında bir bağlantı var mıdır? Açıklayabilir misiniz?
4. Sizce ilköğretim kademesinde çevre ve çevre eğitimi ile ilgili konuların öğretilmesinin (sürdürülebilir kalkınma eğitimi verilmesinin) sebepleri/amaçları neler olabilir? Bu konudaki görüşünüz nedir?

B. Kartları gruplama süreci
YÖNERGE:
Araştırmacı öğretmenden örnek senaryoların bulunduğu kartları üç gruba ayırmasını ister. Öğretmenin seçtiği birinci kart grubu yaptığı öğretimi yansıtan, ikinci kart grubu yaptığı öğretimi yansıtmayan ve üçüncü kart grubu ise yaptığı öğretimi yansıtıp yansıtmadığı konusunda emin olmadığı senaryoları içeren kartlardan oluşmalıdır. Senaryolar örnek olarak verilmiştir. Senaryolar çalışmanın kapsamında olan madde döngüleri, yenilenebilir ve yenilenemez enerji kaynakları ve geri dönüşüm konularını içermektedir. Her bir senaryoda bu konular ile ilgili ifadeler bulunmaktadır. Öğretmen seçtiği karttaki öğretim yaklaşımını senaryoda belirtilen konuda kullanmayıp, araştırma kapsamındaki diğer bir konuda kullanıyor ise bunu açıkça ifade etmelidir. Bu işlem bittikten sonra, araştırmacı öğretmene yaptığı gruplamalar ile ilgili sorular sorar.

Birinci kart grubu

1. ….kartların yaptığınız öğretim ile paralel olduğunu düşünüyorsunuz. Bu kartlardaki senaryolar daha önce bahsettiğiniz amaçlara ulaşmanıza nasıl yardımcı oluyor? Başka bir deyişle, bu senaryolar öğretiminiz ile ilgili amaçlarınızla/hedeflerinizle nasıl bağdaşmaktadır? (Öğretmenin öğretimi ile paralel olan kartlar için).

2. Kendi yaptığınız öğretim ile öğretiminizi yansıtan senaryolar arasındaki benzerlikler nelerdir?

3. Seçtiğiniz birinci kart grubundaki senaryoların ortak özellikleri nelerdir?

4. Kartlardaki senaryolarda bulunan öğretim yöntemlerine ek olarak adı geçen konuları öğretme için kullandığınız başka yöntemler var mı? Var ise nelerdir? Ek olarak bahsettiğiniz bu yöntemler amaçlarınıza ulaşmanıza nasıl yardımcı olmaktadır?

İkinci kart grubu

5. ….kartlarının yaptığınız öğretim ile paralel olmadığını düşünüyorsunuz. Nedenini açıklayabilir misiniz?

6. Seçtiğiniz ikinci kart grubundaki senaryoların ortak özellikleri nelerdir?

7. Seçtiğiniz ikinci grup kartlarda bulunan senaryoları ne tür değişiklikler yaparak kullanırsınız?

Üçüncü kart grubu

8. Son olarak seçtiğiniz üçüncü kart grubunda bulunan kartların öğretiminizi yansıtıp yansıtmadığından emin olamadınız. Bunun nedenlerini açıklayabilir misiniz?

9. Bu kart grubundaki senaryoların ortak özellikleri nelerdir?

10. Eklemek istediğiniz başka bir şey var mı?

Senaryolar:

1. Öğrencilere madde döngülerini öğretmenin etkili bir yolu düz anlatım yöntemiyle tahtaya döngülerin şemalarını çizip aralarındaki farkları anlatmaktır (Didactic)

2. Laboratuar ya da sınıf için çeşitli aktiviteler/etkinlikler kullanmak geri dönüşüm konusunu öğretmek için etkili bir yoldur (Activity driven)

3. Yenilenebilir ve yenilenemez enerji kaynaklarını öğretmenin en iyi yolu, öğrencilere yenilenebilir ve yenilenemez enerji kaynaklarının kullanım alanlarına ilişkin bir etkinlik planlatmaktır (Discovery)

4. Geri dönüşüm konusunu öğretmenin iyi bir yolu öğrencilerin konu ile ilgili ön bilgilerini ortaya çıkaracak sorular sorarak sahip oldukları kavram yanılgılarını belirlemek ve sonrasında gidermeye çalışmaktır (Conceptual change)

5. Yenilenebilir ve yenilenemez enerji kaynakları öğretmenin etkili bir yolu konu ile ilgili farklı ve zor sorular çözmektir (Academic-rigor)

6. Madde döngüsünde öğretmenin etkili bir yolu öğrencilerin değişkenlerine kendilerinin karar verdikleri bir deney tasarlamalarına izin vermektir (Guided inquiry)

7. Geri dönüşüm konusunu öğretmenin etkili yollarından biri, öğrencileri çevre koruma ile ilgilenen sivil toplum kuruluşlarına katılma konusunda teşvik etmek ve sivil toplum kuruluşları ile işbirliği yaparak öğrencilerin atıklar konusunda çözüm önerileri sunmalarını sağlamaktır. (Project-based)

8. Yenilenemez enerji kaynaklarının sebep olduğu çevre sorunlarını öğretmenin etkili bir yolu, öğrencileri gruplara ayırıp, onlara yakın çevrelerinden bir senaryo vererek, öğrencilerden bu sorunlarla ilgili bir neden-sonuç ilişkisi oluşturmalarını, sonuç çıkarmalarını ve bu sonuçları oluştururken kullandıkları bilgilerin geçerliliğini değerlendirmelerini istemektir (Inquiry)

9. Karbondioksit döngüsünü öğretmenin etkili bir yolu bu konu ile ilgili yapılan araştırmalardaki verileri kullanmaktır. Daha sonra öğrencilerden neden karbondioksit döngüsü önemlidir ile ilgili hipotez kurmalarını, verileri yorumlamalarını, analiz etmelerini ve sonuçlarını sınıftaki diğer öğrencilerle paylaşmalarını istemektir (Process-Scientific skill development)

Çalışma Kapsamında Eklenen Senaryolar

10. Geri dönüşüm konusunu öğretmenin etkili yollarından biri, konu ile ilişkili kavramları inceledikten sonra, öğrencilerin bu kavramları açık bir şekilde tartışmalarını sağlayarak, kendi kavramlarını geliştirmelerine izin vermektir. (Liberation)

11. Yenilenebilir enerji alanında yapılan araştırmaların ve geliştirilen teknolojilerin çevre ve ülke ekonomisine katkılarını öğretmenin etkili yollarından biri öğrencilerden konu ile ilgili uzmanlar kişilerle (mühendisler ve bilim insanları, vb.) görüşme/mülakat yapmalarını ve araştırma sonuçlarını sınıf arkadaşlarına sunmalarını istemektir (Müfredat amacı: SPS, STSE)

12. Öğrencileri çevreye duyarlı ve sorumluluk sahibi bir vatandaş olarak yetiştirmenin etkili bir yolu, öğrencilerden insan faaliyetleri sonucu günümüzün en önemli problemlerinden biri olan atık sorununa nasıl çözüm bulunacağı üzerine araştırma yapmalarını istemektir (Müfredat amacı: STSE)

13. Bir öğretmen olarak öğrencileriniz için yapabileceğiniz en iyi şeyin onları liseye hazırlamak olduğunu düşünürsünüz. Bu yüzden, konuyu öğretip sonrasında mümkün olduğu kadar fazla soru çözmeye çalışırsınız (Eğitim Sistemi-Sınav gerçeği)

D. İÇERİK GÖSTERİMİ RÖPORTAJ SORULARI

Pedagojik Alan Bilgisine Yönelik Sorular

Öğrencilerin öğrenmesi gereken kavramlar
Ana Soru 1: "Madde döngüleri" konusundaki ana amacınız kapsamında, öğrencilerinizin neyi/ neleri öğrenmesini hedefliyorsunuz?

- Öğrencilerin bu konu ile ilgili hangi kavramları öğrenmesini bekliyorsunuz?
- Sizce öğrencilerin öğrenmesi gereken en önemli kavramlar/noktalar nelerdir? Bu noktaları/ kavramları nasıl belirliyorsunuz?
- Müfredatta bu konu ile ilgili kavramların sıralanışı nasıldır?

Öğrencilerin geliştirmesi gereken beceri/kazanımlar
Ana Soru 2: Bu ders kapsamında öğrencilerinizin öğrenmesini amaçladığınız kazanımlar neler olabilir? (Fen-Teknoloji-Toplum-Çevre (FTTÇ), Bilimsel Süreç Becerileri (BSB), Tutum ve Değerler (TD), Bilimin Doğası ve Sürdürülebilir Kalkınma ile ilgili kazanımlar)

- Bu konu ile ilgili fen ve teknoloji müfredatında öğrencilerin hangi tutum/davranış/becerileri geliştirmeleri bekleniyor?

Ana Soru 3: Bahsettiğiniz bu kazanımlar sürdürülebilir kalkınma ile ne ölçüde ilişkilidir? Neden? (Bu kazanımlar SKE hedefleri ile ne ölçüde örtüşür?)

Konuyu Bilmenin Önemi
Ana Soru 4: Öğrencilerin ''Madde döngüleri'' konusunu ve konu ile ilgili kazanımları bilmesi neden önemlidir?

- Bu konuyu öğrenmeleri öğrencilere ne gibi avantajlar sağlar?
- Öğrenciler öğrendikleri bu bilgi ve becerileri nasıl kullanabilirler? Bu bilgi ve beceriler onlara nasıl faydalı olacak? Olmayacaksa nedenini açıklar mısınız?

Öğretim ile ilgili zorluk ve sınırlılıklar
Ana Soru 5-6: "Madde döngüleri" konusuyla ilgili bu kazanımları öğretirken karşılaşacağınız zorluklar ve sınırlılıklar neler olabilir?

- Sizce bu konuyu öğretmek neden zordur?
- Bu konuyu öğretmeyi zorlaştıran ve sınırlayan etkenler nelerdir?
- Bu konuyu öğretmenin zorluklarını/sınırlılıklarını nasıl öğrendiniz? (Bu konuyu öğretmenin zor olduğuna nasıl karar verdiniz?)

Öğrencilerin anlama/kavramaları

Ana Soru 7: Madde döngüleri konusundaki öğretiminizi etkileyecek, öğrencilerin sahip olabileceği öğrenme güçlükleri (kısmi kavrama, kavram yanılgısı vb.) neler olabilir?

- Öğrencileriniz bu konuyu öğrenirken hangi noktalarda zorlanmaktadır?
- Madde döngüleri konusunda öğrencilerinizin sahip olabileceği bu öğrenme güçlüklerinin nedenleri neler olabilir?
- Öğrencilerin yukarıda bahsettiğiniz ana kavramlarla ilgili olarak sahip oldukları yanlış kavramalar neler olabilir?
- Öğrencilerin bu konuyu öğrenebilmeleri için hangi ön bilgilere ve becerilere sahip olmaları gerekir?
- Öğrencilerin bu konudaki kavram yanılgıları ve yaşadıkları zorluklar sizin öğretiminizi etkiliyor mu? Nasıl?
- Öğrencilerin zorlandıkları noktaları ve yanlış kavramaları düşünerek ders planınızda ne gibi değişiklikler yapıyorsunuz?

Öğretim Yöntem ve Stratejileri

Ana Soru 8: Öğretim sürecinizi (dersin işlenişi), hangi yöntem ve öğrenme stratejilerini neden kullanacağınızı belirterek ayrıntılarıyla açıklayınız.

- Günlük hayat ile ilişkili anlatıyorsanız, nasıl bir ilişki kuruyorsunuz?
- Bu öğretim stratejilerini kullanmayı tercih etmenizin nedenleri nelerdir?
- Bu stratejileri kullanmayı nasıl öğrendiniz? Bu stratejileri kendiniz mi geliştirdiniz yoksa başka kaynaklardan mı (kişi, kaynak, vb) öğrendiniz?
- Konuyu öğretirken öğrencilerin konu ile ilgili yanlış kavramalara sahip olduklarının farkına varsanız ne yaparsanız?
- Yapmayı planladığınız bu aktivite/stratejinin etkili olduğunu/olacağını nasıl öğrendiniz/nereden biliyorsunuz?
- Yaptığınız öğretimin etkili olup olmadığını nasıl anlarsınız? (Öğretim esnasında)

Öğrencilerin anlama/kavramalarını değerlendirme yöntemleri

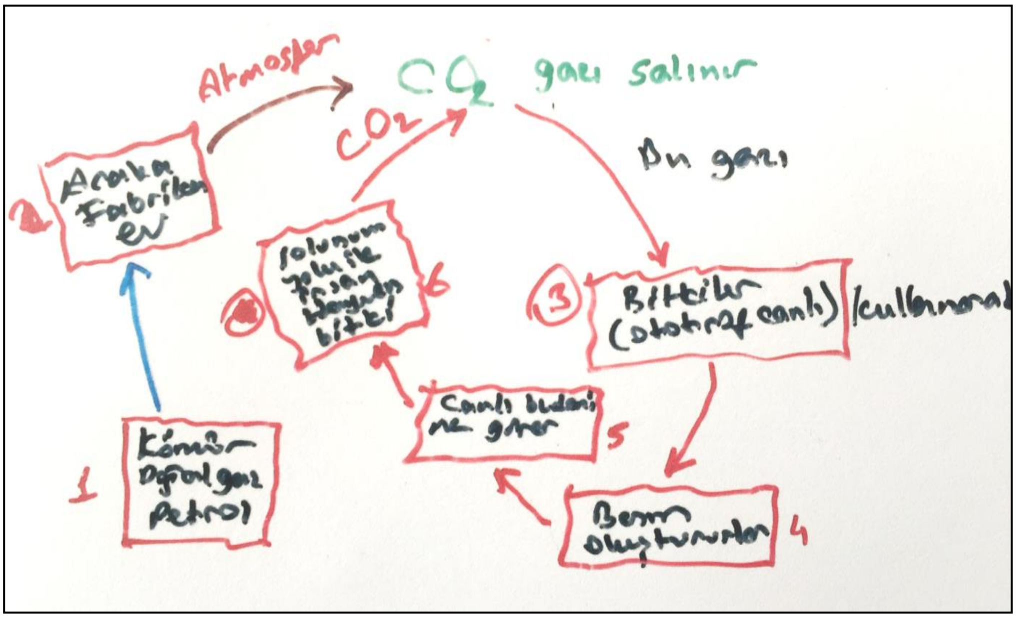
Ana Soru 9: Öğrencilerinizin ne öğrendiğini değerlendirmek için kullanacağınız özel yol ve araçlar nelerdir, açıklayınız?

- Niçin bu ölçme tekniklerini kullanmayı tercih ediyorsunuz?
- Değerlendirme sonuçları size nasıl yardımcı olmaktadır? Bu sonuçlar size neler anlatmaktadır?
- Öğrencilerin bu konudaki yanlış kavramalarını ve zorlandıkları noktaları anlamak için kullandığınız değerlendirme teknikleri var mı? Bunları nasıl öğrendiniz/Kaynaklarınız nelerdir?

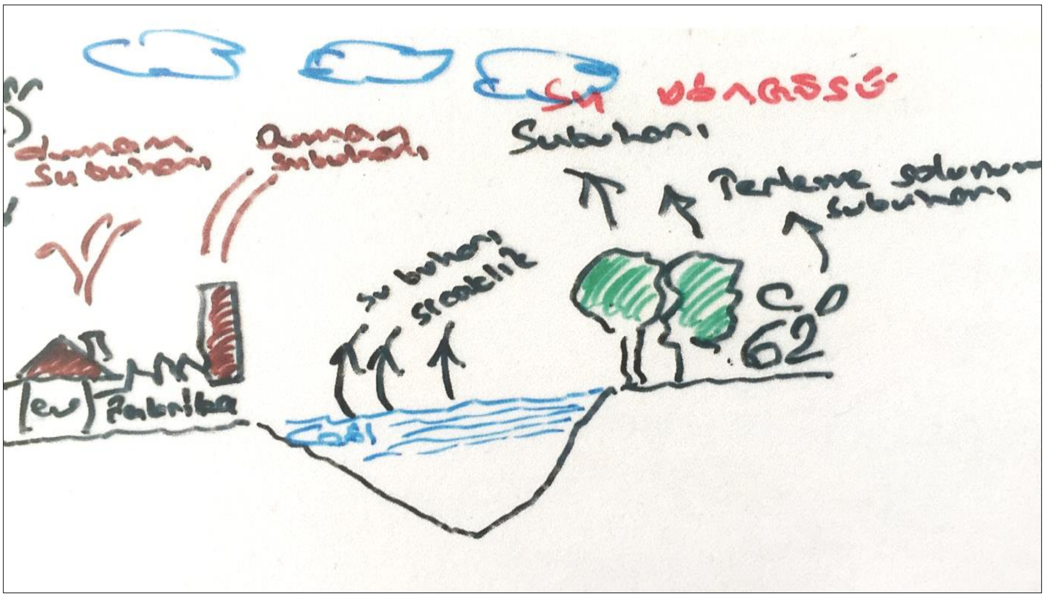
E. ORIJINAL DRAWINGS OF SCIENCE TEACHERS

DRAWNGS OF KEMAL

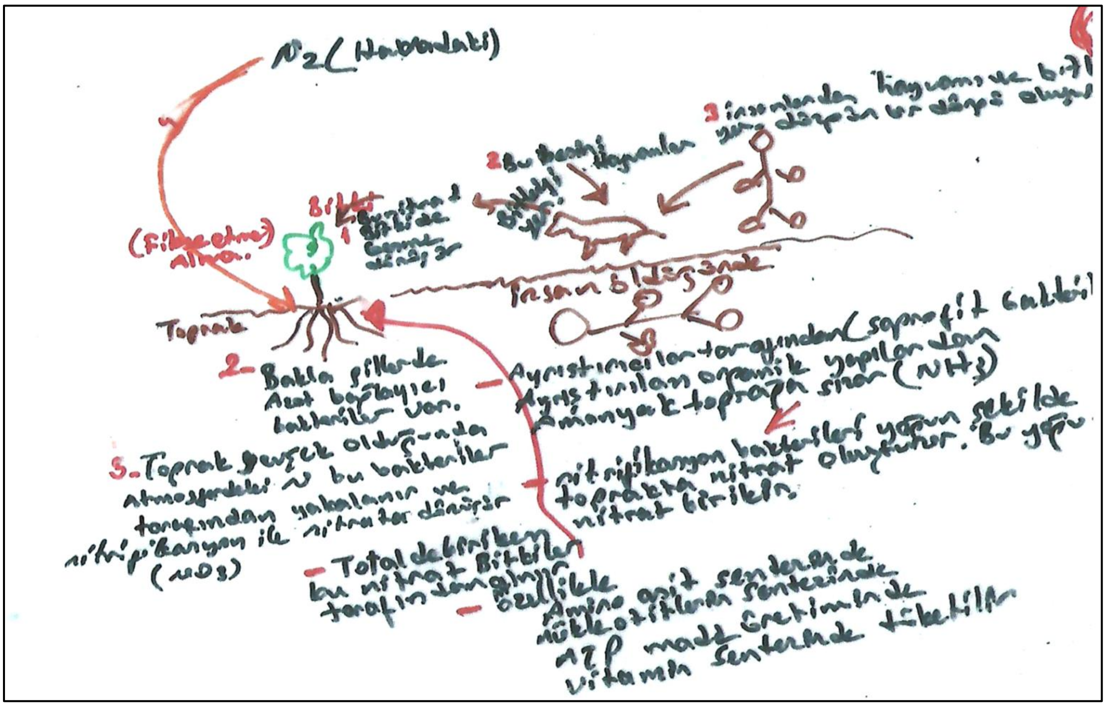
Kemal's drawing of carbon cycle



Kemal's drawing of hydrological cycle



Kemal's drawing of nitrogen cycle

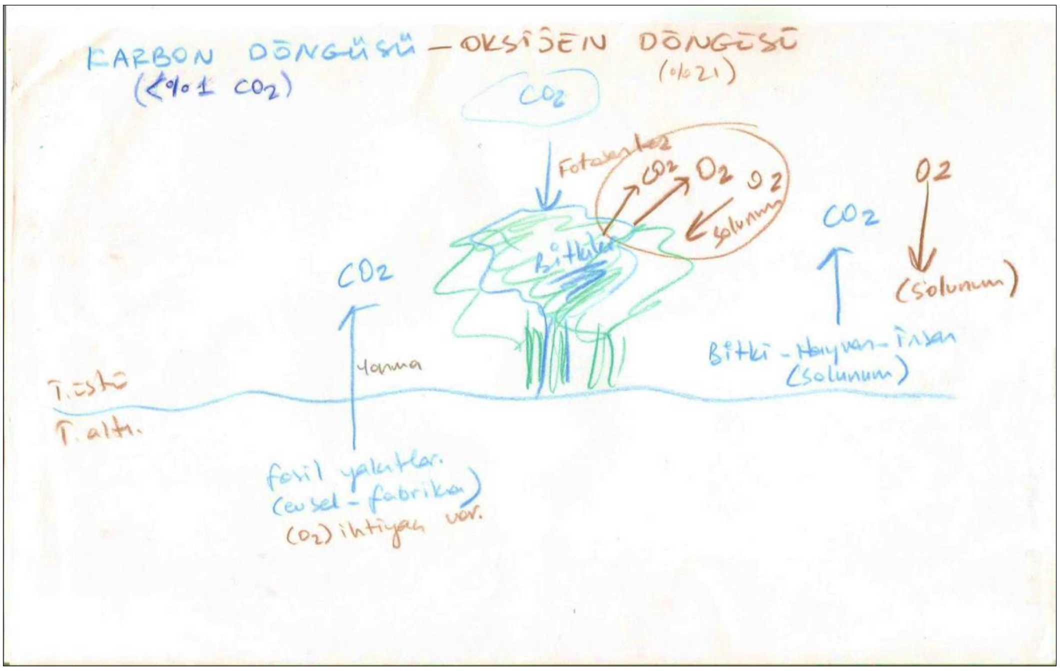


Kemal's drawing used to teach the carbon cycle

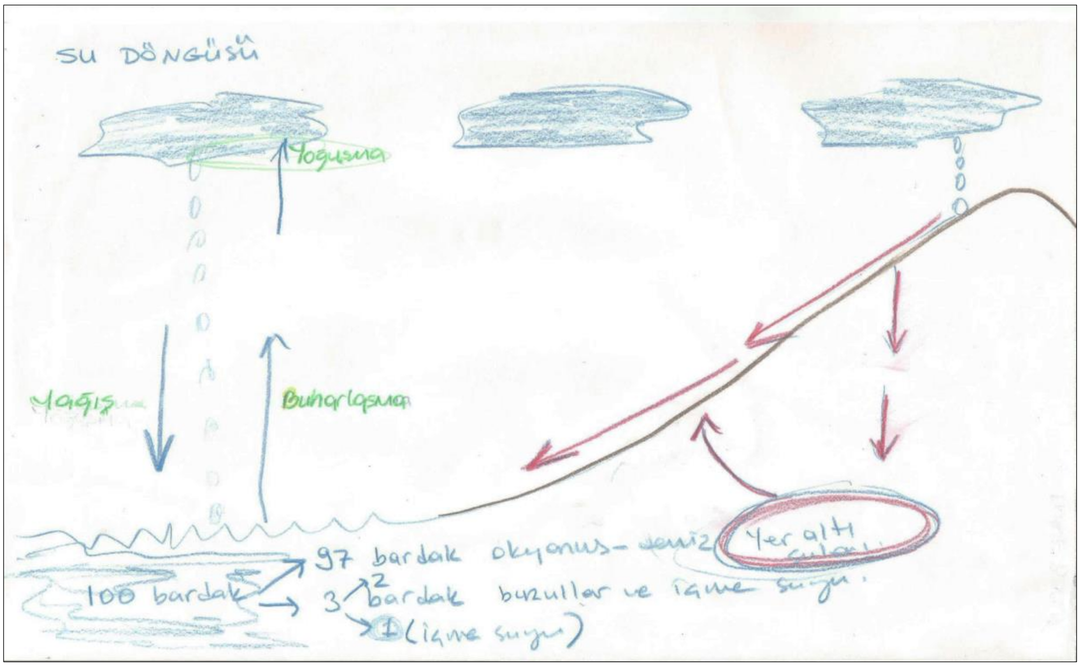
Kemal's drawing used to teach the nitrogen cycle

DRAWINGS OF HALE

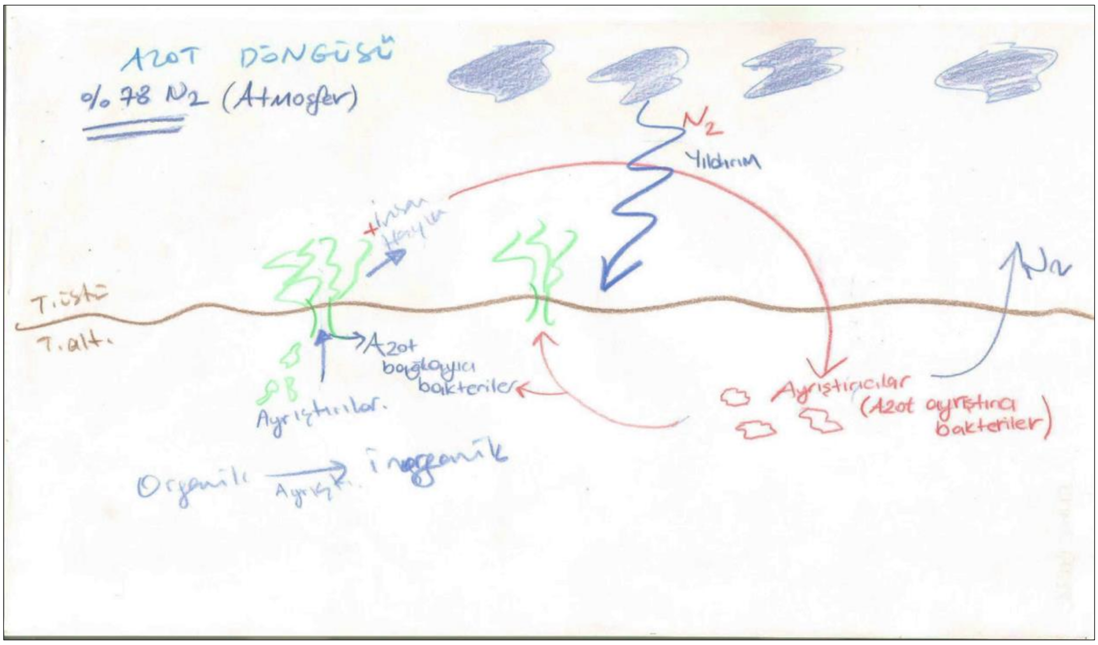
Hale's drawing of carbon cycle



Hale's drawing of hydrological cycle

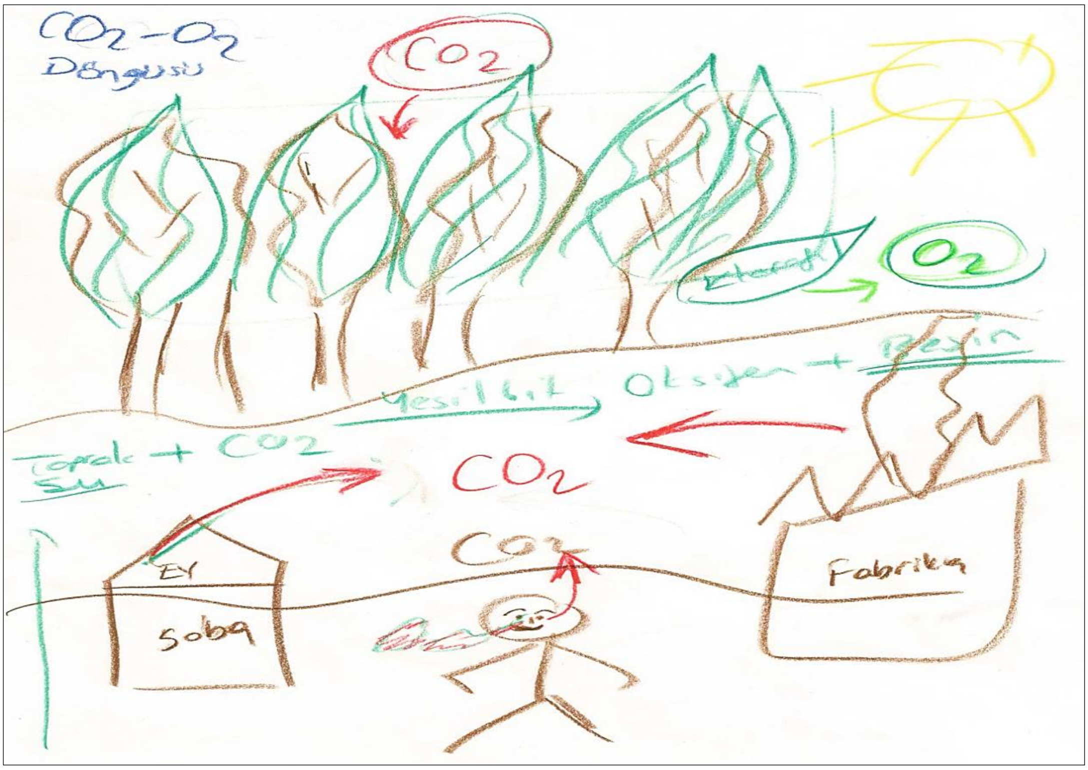


Hale's drawing of nitrogen cycle

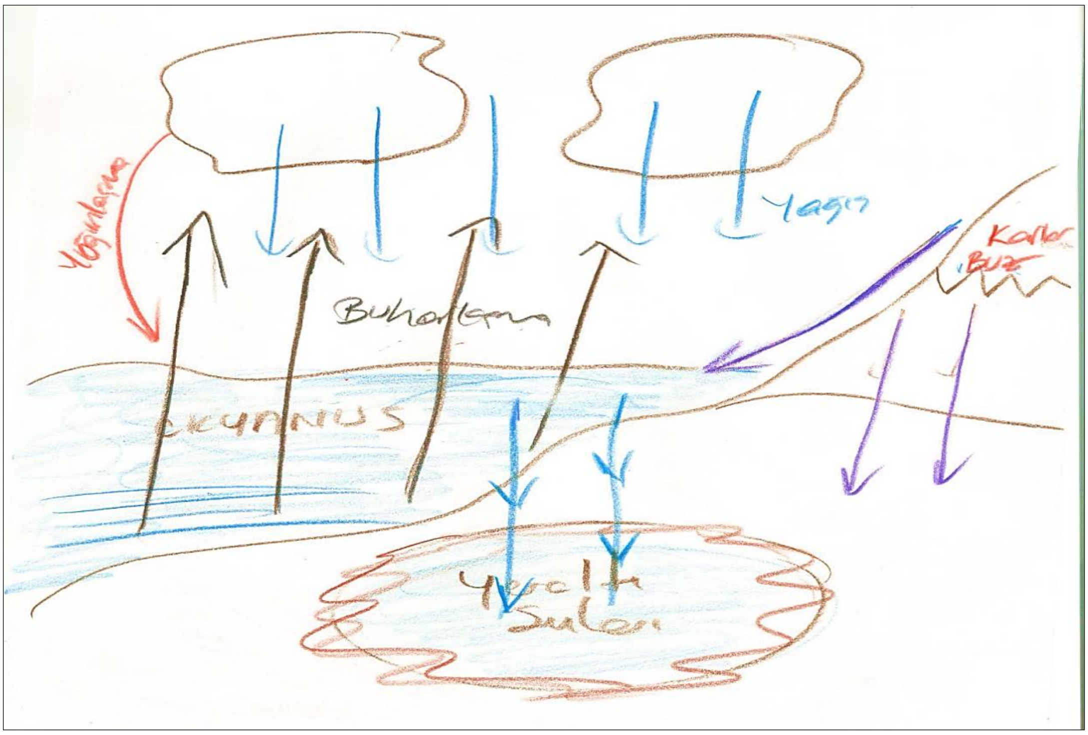


DRAWINGS OF SELDA

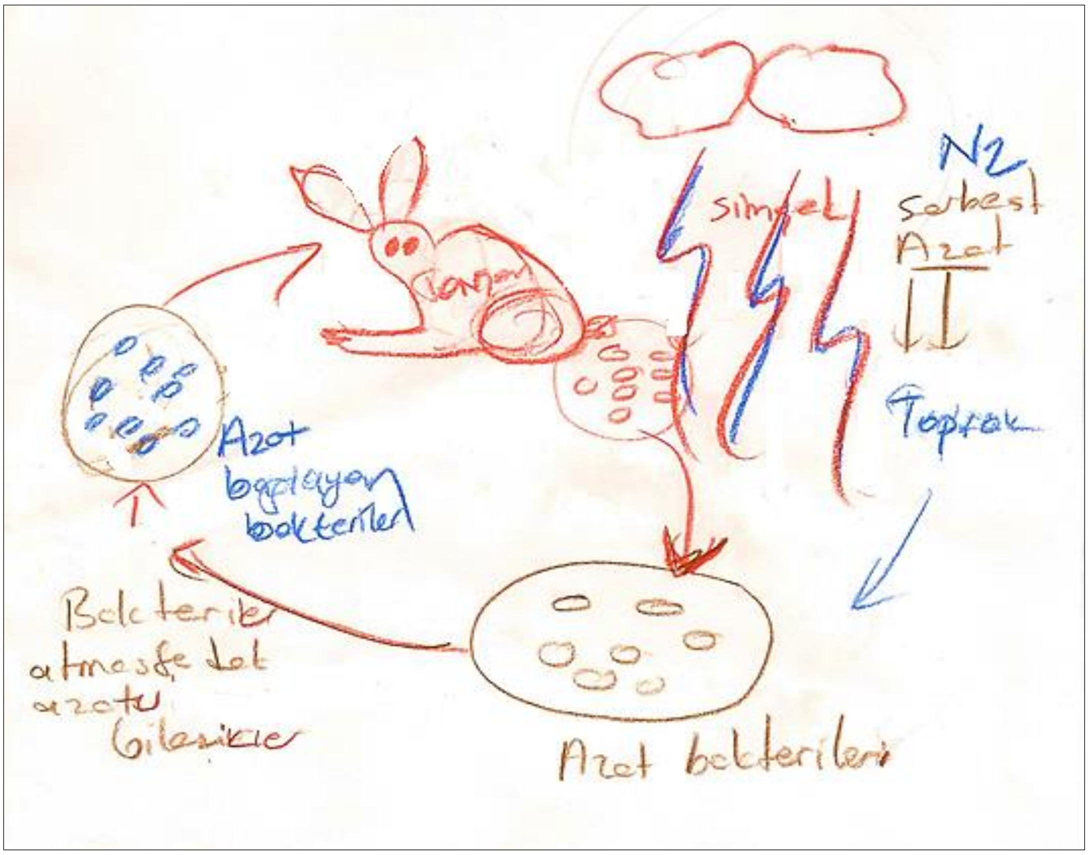
Selda's drawing of carbon cycle



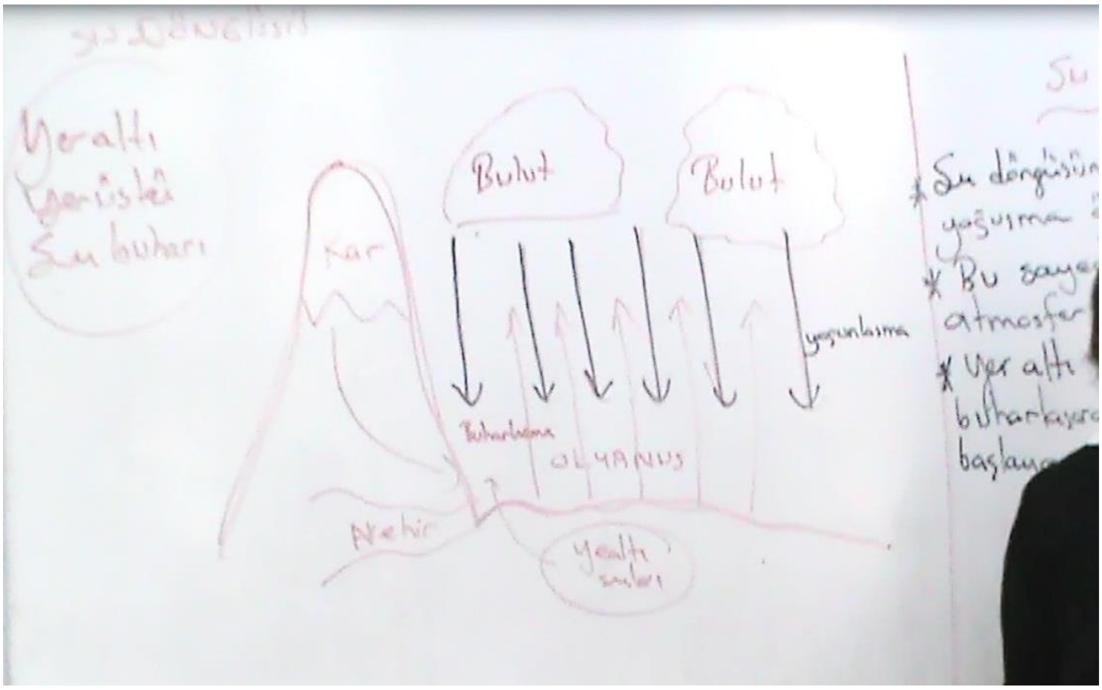
Selda's drawing of water cycle



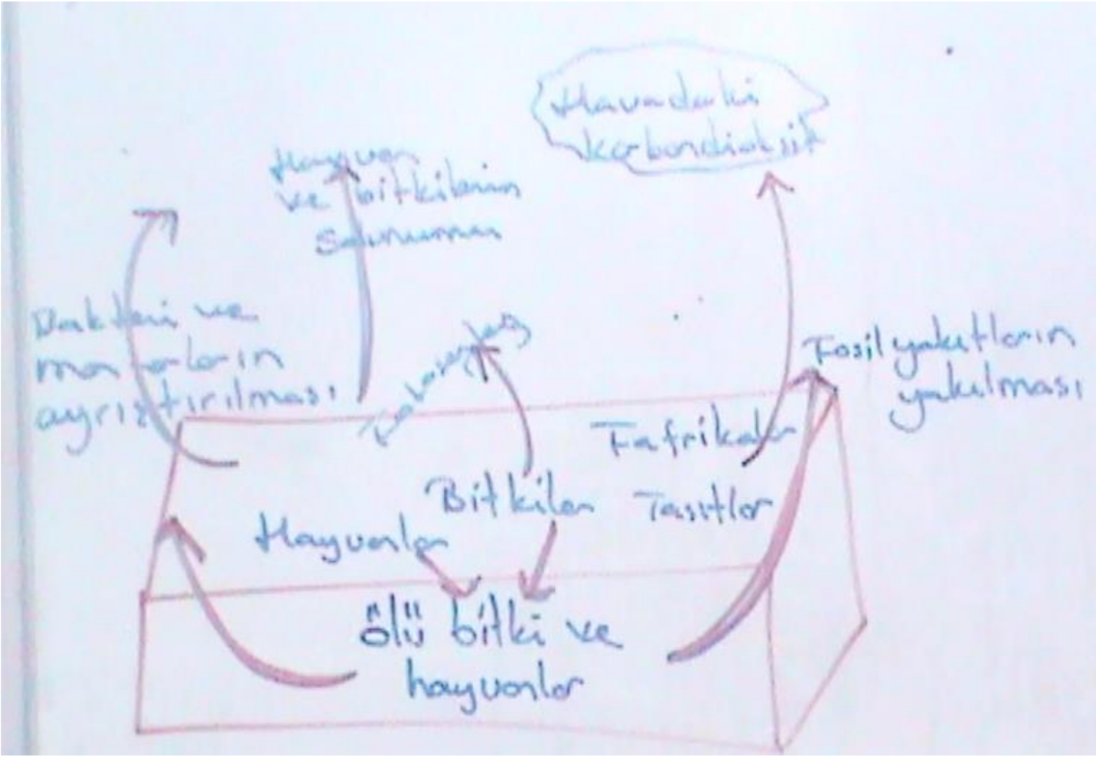
Selda's drawing of nitrogen cycle



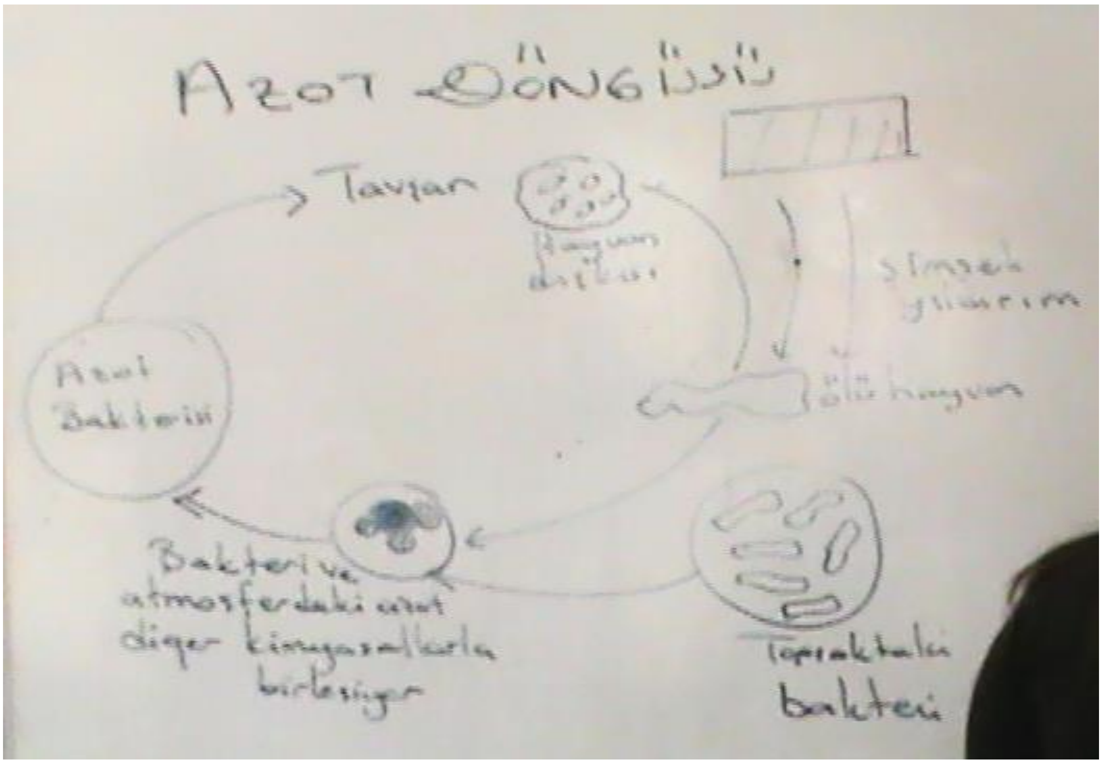
Selda's drawing used to teach the hydrological cycle



Selda’s drawing used to teach the carbon cycle



Selda’s drawing used to teach the nitrogen cycle



F. RUBRIC USED FOR INFORMED NOS VIEWS

NOS Aspects and Descriptions (Lederman, Schwartz, Abd-El-Khalick & 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.

G. PERMISSION OF METU HUMAN SUBJECTS ETHICS COMMITTEE

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
APPLIED ETHICS RESEARCH CENTER

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
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25 Mart 2013

Gönderilen: Prof.Dr.Ceren Öztekin
İlköğretim Bölümü

Gönderen : Prof. Dr. Canan Özgen
IAK Başkanı

İlgi : Etik Onayı

Danışmanlığını yapmış olduğunuz İlköğretim Bölümü Araştırma Görevlisi Bahar Yılmaz Yendi'nin "Fen Bilgisi Öğretmenlerinin Sürdürülebilir Kalkınma Eğitimi Kapsamında Pedagojik Alan Bilgilerinin İncelenmesi" isimli araştırması "İnsan Araştırmaları Komitesi" tarafından uygun görülerek gerekli onay verilmiştir.

Bilgilerinize saygılarımla sunarım.

Etik Komite Onayı

Uygundur

25/03/2013

Prof.Dr. Canan ÖZGEN
Uygulamalı Etik Araştırma Merkezi
(UEAM) Başkanı
ODTÜ 06531 ANKARA

H. PERMISSION OF MINISTRY OF NATIONAL EDUCATION

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

ÖĞRENCİ İŞLERİ DAİRESİ BAŞKANLIĞI
Ev. Ar.

Sayı : 14588481/605.99/869909 08/05/2013
Konu: Araştırma İzni
(Bahar YILMAZ YENDİ)

ORTA DOĞU TEKNİK ÜNİVERSİTESİ
(Öğrenci İşleri Daire Başkanlığı)

İlgi : a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2012/13 nolu genelgesi
b) 17/04/2013 tarih ve 2047 sayılı yazınız.

Üniversiteniz İlköğretim Ana Bilim Dalı Doktora Programı öğrencisi Bahar YILMAZ YENDİ'nin "Fen Bilgisi Öğretmenlerinin Sürdürülebilir Kalkınma Eğitimi Kapsamında Pedagojik Alan Bilgilerinin İncelenmesi" konulu tez önerisi kapsamında uygulama yapma isteği Müdürlüğümüzce uygun görülmüş ve araştırmanın yapılacağı İlçe Milli Eğitim Müdürlüğüne bilgi verilmiştir.

Anketlerin uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde iki örneğinin (CD ortamında) Müdürlüğümüz Strateji Geliştirme-1 Şube Müdürlüğüne gönderilmesini arz ederim.

İlhan KOÇ
Müdür a.
Şube Müdürü

Güvenli Elektronik
Aslı İle Aynıdır
08/05/2013

...aşar SUBAŞI
Şef

13.05.2013-7701

Bu belge, 5070 sayılı Elektronik İmza Kanununun 5 inci maddesi gereğince güvenli elektronik imza ile imzalanmıştır
Evrak teyidi http://evraksorgu.meb.gov.tr adresinden 80f0-1ed5-37f9-b939-9b65 kodu ile yapılabilir.

I. CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Yılmaz Yendi, Bahar
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Date and Place of Birth: 12.01.1982, Kavak/Samsun
Marital Status: Married
Phone: +90 454 310 12 50
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EDUCATION

Degree	Institution	Year of Graduation
PhD	Middle East Technical University (METU), Education Faculty Elementary Education	2008-
BS	Ondokuz Mayıs University (OMU), Education Faculty, Elementary Science Education	2005
High School	Tülay Başaran Anatolian Lycee	2000

WORK EXPERIENCE

Year	Place	Enrollment
2018-	Giresun Universitesi, Education Faculty, Department of Elementary Science Education	Research Assistant
2007- 2018 Ocak	METU, Education Faculty, Department of Elementary Science Education	Research Assistant
2006-2007	OMU, Education Faculty, Department of Elementary Science Education	Research Assistant

FOREIGN LANGUAGES

Advanced English

J. TURKISH SUMMARY / TÜRKÇE ÖZET

Deneyimli Fen Bilimleri Öğretmenlerinin Sürdürülebilir Kalkınma Eğitimi Kapsamında Madde Döngüleri Konusuyla İlgili Konu Alan ve Pedagojik Alan Bilgileri

GİRİŞ

Eğitimin alt alanlarında, öğretimin temel amacı, öğrencilerin öğrenmelerini ve anlamalarını sağlamaktır. Ancak, öğretmenlerin öğretme konusundaki yetenekleri (Kind, 2009) sınıf içi öğrenmede en etkili faktördür (Lumpe 2007). Bu nedenle, öğretmenlerin, öğrencilerin anlamaları ve başarılarına muazzam bir etkisi vardır (Aydın, 2012; Brown, Friedrichsen ve Abell, 2013; Lumpe, 2007; Miller, 2001; Sanders, 2000; van Driel, Beijaard ve Verloop, 2001). Bu nedenle, 1980'lerden bu yana, eğitim araştırmacıları, öğretmenlerin sahip oldukları bilgi ve uygulamaların öğrencilerin başarısı üzerindeki etkilerini açıklamak ve bu alanda zengin ve değerli veriler sağlamak için " öğretmen bilgisi " ve " öğretmenlerin uygulama bilgisi " gibi konulara odaklanmışlardır (Abell, 2007; Aydın, 2012; Carter, 1990; Friedrichsen, 2008; Grossman, 1990; Hashweh, 2005; Magnusson, Krajcik ve Borko, 1999; Shulman, 1986, 1987; Şen, 2014; Zembylas, 2007; Rollnick ve diğerleri, 2008).

20. yüzyılın ilk yarısında araştırmacılar, öğretmenlerin içerik bilgisinin, nitelikli öğretmenlerin en önemli göstergesi olduğu sonucuna vardılar. 20. yüzyılın ikinci yarısında ise, araştırmalar, öğretmenlerin pedagoji bilgileri üzerinde yoğunlaşmıştır (Shulman, 1986). Ancak, Shulman, öğretmenlerin konu alan ve pedagoji bilgilerinin bağlantılı olduğunu iddia etmiştir. Bu nedenle, öğretme ve öğretmenlerin sahip olması gereken bilgiler ile ilgili sorunlar, Shulman'ın "pedagojik alan bilgisi (PAB)" yapısını tanıtmasına neden olmuştur (Shulman, 1987). Shulman'a (1987) göre, PAB hem içerik hem de pedagoji bilgisini içermekte ve "öğrencilerin farklı ilgi alanlarına

ve becerilerine göre düzenlenmiş ve uyarlanmış; öğretilen konuya özgü içerik bilgisinin ve pedagojik bilginin özel birleşimi" (s.8) olarak tanımlanmaktadır.

Shulman'ın PAB yapısı, başarılı öğretmenlerin öğrencilerin anlamalarını sağlamak için hangi bilgileri bilmeleri gerektiği sorusuna açıklık getirmiştir (Grossman, 1990; Lederman, Gess-Newsome ve Latz, 1994; Mulhall ve Loughran, 2003). PAB, öğretmenlerin hem konu alan hem de öğrencilerin önceki bilgi ve güçlükleri, değerlendirme ve öğretim stratejileri kullanımı ve de müfredat kaynakları gibi genel pedagoji hakkındaki detaylı bilgileri olarak görülmektedir (Abell, 2007; Magnusson ve diğerleri, 1999; Tobin ve McRobbie, 1999). Sonuç olarak, PAB etkili öğretme ve öğrenmenin merkezi olarak kabul edilmektedir (Cochran, DeRuiter ve King 1993; Magnusson, Krajcik ve Borko 1999). Teorik bir yapı olarak, PAB, fen eğitimi araştırmacıları için de ayrıca farklı bir bakış açısı sunmaktadır. Özellikle, Magnusson ve arkadaşlarının (1999) PAB modeli, fen bilgisi eğitimi alanındaki PAB çalışmalarının çoğunda kullanılmıştır (Abell, 2008; Kind, 2009). Bu modelde, araştırmacılar, öğretmenlerin konu alan bilgisi (KAB), pedagojik bilgi (PB), eğitimsel bağlam bilgisi ve PAB olarak dört ana alanda bilgi sahibi olduğu sonucuna varmışlardır. Teorik çerçeve olarak bu modelin kullanıldığı bu çalışma, fen eğitimi disiplininde PAB'ın uygulamaları hakkında fikir vermek adına öğretmenlerin konu alan bilgisi ve PAB'larına odaklanmıştır.

Fen Eğitimi ve Sürdürülebilir Kalkınma için Eğitim

21. yüzyılda, bilim ve teknolojinin hızla ilerlemesi sonucu, çevresel sorunlardaki artış, bireylerin hem etik hem de ahlaki kaygılarında değişimlere neden olmuştur. Bu nedenle, araştırmacılar fen eğitiminde özellikle çevresel sorunlar ve sürdürülebilir kalkınma konularının dikkate alınması gerektiğini vurgulamaktadırlar. 1950'lerden bu yana, fen eğitiminin hedefi, öğrencileri bilimsel okuryazar vatandaşlar olarak eğitmek olmuştur. Ancak, günümüzde birçok araştırmacı, bilimsel okuryazarlığın daha sürdürülebilir bir dünya yaratmak için, 21. yüzyılın ihtiyaçlarını karşılaması gerektiğini (Choi, Lee, Shin, Kim ve Krajcik, 2011)

savunmaktadır (Hodson, 2011; McFarlane, 2011). Bu ihtiyaçtan yola çıkarak, fen eğitiminin yeniden kavramsallaştırılması gerektiği sonucuna varılmaktadır (Carter, 2008; Colucci-Gray, Perazzone, Dodman ve Camino, 2013; Feldman ve Nation, 2015). Carter (2008), fen eğitiminin 21. yüzyıldaki amacının, hem öğrencilerin bilim hakkında eleştirel yargılarda bulunmalarına yardımcı olmak hem de daha sürdürülebilir bir dünya için sorumlu vatandaşlar olabilmeleri adına gereken bilgi ve becerilerini geliştirmek olduğunu iddia etmiştir. Dolayısıyla, fen eğitimi, gelişmekte olan toplumların ihtiyaçlarına cevap verebilmek için, öğrencilerin sürdürülebilir kalkınma konusu hakkında bilgi ve bakış açılarını geliştirmeli (Feldman ve Nation, 2015); sosyal ve küresel sorunlarla ilgili harekete geçebilmeleri için gereken becerilerini, ilgi alanlarını ve motivasyonlarını arttırmalı (Feldman ve Nation, 2015; Tytler, 2007) ve sürdürülebilir bir gelecek sağlamak adına değer yargıları ve tutumlarını değiştirmelidir (Stratton, Hagevik, Feldman ve Bloom, 2015). Bu bağlamda, Türkiye'deki fen bilgisi müfredatı, sürdürülebilirlik konularını mevcut programa dâhil etmek için yenilenmiştir (MEB, 2013). Ancak, müfredattaki değişiklikler ya da düzeltmeler, eğitimin sorunlarına çözüm getirmeyi ve sürdürülebilir bir gelecek oluşturmak için sorumlu vatandaşlar yetiştirmeyi garanti etmemektedir. Yeni müfredat, öğretim ve değerlendirme için yeni stratejiler ve yöntemler önerse bile, öğretmenler müfredatı uygulamakta ve öğretimlerine yansıtmakta zorlanabilmektedirler (Aydın ve Çakıroğlu, 2010).

Eğitim, daha sürdürülebilir toplumlar yaratmada öncü bir faktör olarak görülmektedir (UNCED, 1992); bu nedenle okul öncesi eğitiminden yükseköğretime kadar tüm eğitim programlarında öğretmenlerin sürdürülebilir kalkınma eğitimi konusundaki yeterlikleri tartışılmaktadır (örneğin, Rieckmann, 2012; UNECE, 2011). Yukarıda belirtildiği üzere, fen eğitiminin perspektifindeki değişimler nedeniyle, fen bilgisi öğretmenlerinin sürdürülebilir kalkınma eğitimindeki (SKE) rolü özellikle tartışma konusudur. Diğer bir deyişle, fen eğitiminin yeniden kavramlaştırılması, öğretmenlerin sürdürülebilir kalkınma (SK) konularını öğretebilmek için hem konu alan bilgileri hem de PAB ile ilgili yaklaşımlarını değiştirmeleri gerektiği anlamına gelmektedir. Bu nedenle, SK konularını sanattan, fen ve matematiğe kadar bütün disiplinlere dâhil edebilmek için öğretmenler, sürdürülebilir kalkınma eğitiminin uygulanabilmesi için gerekli olan bilgi, beceri, değer yargıları ve uygun pedagoji bilgisine sahip olmalıdır (McKeown ve Hopkins, 2003). Dolayısıyla, müfredat değişimleri sonucu ortaya çıkan zorluklar göz önüne alındığında, fen bilgisi öğretmenlerinin sürdürülebilirlik için eğitim bağlamında gerekli konu alan ve pedagojik alan bilgileri ile ilgili araştırma yapma ihtiyacı kaçınılmazdır (Kadji-Beltran, Zachariou, Liarakou ve Flogaitis, 2014). Bu ihtiyaca cevap olarak, deneyimli fen bilgisi öğretmenlerinin konu alan ve PAB'larını inceleyen mevcut araştırmanın, SKE bağlamında, fen eğitimi alan yazınına değerli teorik ve pratik bilgiler sağlaması beklenmektedir.

Çalışmanın Önemi

PAB alanında yapılan çalışmalar, öğretmenlerin farklı konularda PAB'larına yönelik araştırma yapılması gerektiğini vurgulamaktadırlar. Ayrıca, birçok eğitim araştırmacısı çalışmalarında ya öğretmenlerin konu alan bilgilerini ya da pedagojik bilgilerini incelemeyi seçmiştir. Bu araştırma öğretmenlerin hem KAB'larını hem de PAB'larını birlikte ele alması açısından PAB alan yazınına katkıda bulunmuştur. Ayrıca fen eğitiminde, PAB alanında yapılan araştırmalar çoğunlukla kimya konularına odaklanmıştır (Aydın ve Boz, 2012; Aydın; 2012). Biyoloji konularıyla ilgili PAB araştırması nadir olduğundan (Aydemir; 2014; Aydın ve Boz, 2012; Tür, 2009; Şen, 2014), henüz PAB alan yazında çalışılmayan madde döngüleri konusu çalışma için seçilmiştir. Ek olarak, mevcut araştırma, fen bilgisi öğretmenlerinin PAB'larını sürdürülebilir kalkınma için eğitim (SKE) bağlamında tanımlamayı amaçlamıştır. Spesifik olarak, çevresel bir konu olması nedeniyle, madde döngüleri, öğretmenlerin sürdürülebilir kalkınma konusundaki anlayışlarını ve SKE için pedagojik alan bilgilerini araştırmak için de önemli bir konudur. Bu nedenle, bu çalışmanın sonuçları, fen bilgisi öğretmenlerinin madde döngüleri ve sürdürülebilir kalkınma kavramlarını nasıl ilişkilendirdiklerine dair değerli kanıtlar sağlaması nedeniyle önemlidir.

PAB alan yazındaki çalışmalar, öğretmenlerin bu bilgiyi sınıf içi uygulamalarında nasıl kullandıklarını gösteren sınırla sayıda araştırma olduğunu göstermektedir (Mthethwa-Kunene, Onwu ve de Villiers, 2015; Park ve Chen, 2012; Rollnick ve diğerleri, 2008). Ayrıca, SKE alan yazını da, bu eğitime ilişkin sınıf içi uygulamaları gösteren çalışmaların sayısının az olduğuna vurgu yapmaktadır (Anyolo, 2015; Birdsall, 2015; Corney ve Reid, 2007). Dolayısıyla, bu araştırma, öğretmenlerin madde döngüleri konusuna özgü PAB'larını nasıl geliştirdiklerine dair kanıtları, gerçek sınıf ortamlarından uygulamaları gözler önüne sererek sağlamayı amaçlamıştır. Ek olarak, Van Driel, Veal ve Janssen (2001), deneyimli öğretmenlerin belirli konulardaki PAB'larının gerçek sınıf ortamında uygulamaları üzerine yapılan çalışmaların önemli olduğuna dikkat çekmişlerdir. Özellikle, Loughran ve arkadaşları (2004), öğretmenlerin PAB'larına yönelik somut örneklerin sunulduğu çalışmaların sınırlı olduğunu vurgulamıştır. Dolayısıyla, gerçek uygulayıcıların somut örneklerini içeren bu çalışmanın, fen bilgisi öğretmenlerinin ve öğretmen adaylarının ilgili konuda sınıf içi öğretim uygulamalarını zenginleştirebilmeleri amacıyla düzenlenen mesleki gelişim programlarına (örn. hizmet-öncesi ve hizmet-içi eğitimler) zengin ve değerli veriler sağlaması beklenmektedir.

Araştırma Soruları

Çalışmanın temel amacı, deneyimli fen bilgisi öğretmenlerinin madde döngüleri konusunda KAB ve PAB'larının sürdürülebilir kalkınma için eğitim bağlamında incelenmesidir. Bu nedenle, çalışmayı yön vermek adına aşağıdaki araştırma soruları ortaya konmuştur:

- Fen bilgisi öğretmenlerinin, sürdürülebilir kalkınma bağlamında madde döngüleri öğretmek için konu bilgisi nedir?
    - Fen bilgisi öğretmenlerinin madde döngüleri hakkındaki kavramsal bilgileri nelerdir?
    - Fen bilgisi öğretmenlerinin madde döngüleri konusunda bilimin doğasına yönelik bilgileri nelerdir?

- Fen bilgisi öğretmenlerinin madde döngüleri konusundaki SD bilgileri nelerdir?
- Fen bilgisi öğretmenlerinin madde döngülerini öğretmek için pedagojik alan bilgileri nelerdir?
  - Fen bilgisi öğretmenlerinin fen öğretimine yönelimleri nelerdir?
  - Fen bilgisi öğretmenlerinin madde döngüleri ile ilgili müfredat bilgileri nelerdir?
  - Fen bilgisi öğretmenlerinin madde döngüleri ile ilgili öğretim stratejileri nelerdir?
  - Fen bilgisi öğretmenlerinin madde döngüleri ile ilgili için öğrenci bilgileri nelerdir?
  - Fen bilgisi öğretmenlerinin madde döngüleri ile ilgili değerlendirme bilgileri nelerdir?

YÖNTEM

Araştırma Deseni

Mevcut çalışmada, deneyimli öğretmenlerin PAB'ları hakkında yoğun ve ayrıntılı bilgiler elde etmek adına nitel araştırma yaklaşımı benimsenmiştir. Nitel araştırmalarda en yaygın kullanılan araştırma desenlerinden biri durum çalışmalarıdır (Flick, 2007). Durum çalışmalarında amaç, iyi tanımlanmış olan bağlam çerçevesinde, durumla ilgili derinlemesine, ayrıntılı ve yoğun bilgi üretmektir (Burton, Brundrett & Jones, 2008; Taylor, Sinha ve Ghoshal, 2013). Dolayısıyla, ele alınan araştırma sorularının amacı ve niteliği göz önüne alınarak, bu çalışmada çoklu durum çalışması araştırma deseni olarak seçilmiştir.

Katılımcılar

Amaçlı örneklem yöntemi aracılığı ile önceden belirlenmiş kriterler ışığında, zengin ve kapsamlı bilgiye ulaşılabilecek dört deneyimli fen bilgisi öğretmeni katılımcı olarak seçilmiştir. Ancak, katılan öğretmenlerden biri idari nedenlerden dolayı çalışmadan ayrılmıştır. Sonuç olarak, bu çalışmaya en az 5 yıllık mesleki deneyimi olan üç fen bilgisi öğretmeni katılmıştır. Araştırmacı, katılımcı öğretmenler için Kemal, Hale ve Selda takma isimlerini kullanmıştır.

Veri Toplama Araçları

Bu çalışmada veriler, 2013-2014 yılı bahar döneminde, 8.sınıflarda görev yapan fen bilgisi öğretmenlerinden elde edilmiştir. Nitel araştırmalarda, görüşmeler, belgeler ve gözlemler, incelenen olayların ayrıntılı tanımını sunmak için üç temel veri toplama aracıdır (Merriam, 2009). Araştırmacı, bu görüşü dikkate alarak, çalışmada röportajlar, kart gruplama aktivitesi, video kaydı aracılığıyla sınıf içi gözlemler ve öğretmen dokümanlarını veri toplama aracı olarak kullanmıştır.

Verilerin Analizi

Bu çalışmada öğretmenlerden elde edilen veriler, hedeflenen bilgi türlerine göre ayrı ayrı kategorilere ayrılarak analiz edilmiştir. Katılımcıların madde döngülerine yönelik kavramsal bilgilerini (substantive knowledge) analiz etmek için araştırmacı, madde döngüleri konusunun içerdiği kavram ve süreçlerin bilimsel tanımlarından oluşan bir değerlendirme listesi hazırlamıştır. Ayrıca, her bir döngü içindeki bileşenleri ve süreçleri içeren genel bir değerlendirme listesi hazırlanmıştır. Simpson ve Marek (1988) 'in derecelendirme ölçeği kullanılarak, katılımcı öğretmenlerin madde döngüleri ile ilgili kavramsal bilgileri ilgili kategorilere ayrılmıştır. Katılımcı öğretmenlerin bilimin doğasına yönelik bilgilerini (syntactic knowledge) toplamak için VNOS-C ölçeği kullanılmıştır. Öğretmenlerin VNOS-C'ye yönelik görüşlerinin değerlendirilmesinde Lederman, Schwartz, Abd-El-Khalick ve Bell (2001) tarafından geliştirilen değerlendirme tablosu kullanılmıştır. Katılımcı öğretmenlerin madde döngüleri ve sürdürülebilir kalkınma (SK) kavramı arasındaki bağlantıları ile ilgili anlayışlarını belirleyebilmek için Koutalidi ve Scoullos (2016, s.14) tarafından geliştirilen tematik bağlantılar esas alınmıştır. Ayrıca, öğretmenlerin SK ile ilgili temel kavramlarının belirlenebilmesi için Kılınç ve Aydın (2013)'a ait yedi temel kategori kullanılmıştır.

Son olarak, fen bilgisi öğretmenlerinin PAB'larını analiz etmek için, bu çalışmada Magnusson, Krajcik ve Borko (1999) tarafından geliştirilen model kullanılmıştır. Model, fen öğretimine yönelimler, müfredat bilgisi, öğretim stratejileri bilgisi, öğrencilerin fen bilgisi anlayışı ve değerlendirme bilgisini içeren beş bileşenden oluşmaktadır. Bu modele göre her bir bileşen ve ilgili bileşenlerin alt boyutları, kategorileri ve alt kategorileri temsil ederken, kodlar ilgili alan yazından ve öğretmenlerin cevaplarından çıkarılmıştır.

SONUÇLAR ve TARTIŞMA

Bu bölümde, hem çalışmadaki hem de alan yazındaki bulgular dikkate alınarak; deneyimli fen öğretmenlerinin madde döngüleri konusundaki konu alan bilgileri ve PAB'leri sürdürülebilir kalkınma eğitimi bağlamında tartışılmaktadır.

Fen Bilgisi Öğretmenlerinin Konu Alan Bilgileri

Sürdürülebilir kalkınma için eğitim (SKE) bağlamında deneyimli fen bilgisi öğretmenlerinin konu alan bilgilerini ortaya çıkarmak için, öğretmenlerin hem temel kavramsal anlayışları, hem bilimin doğası anlayışları hem de madde döngülerine yönelik ilgili SK anlayışları incelenmiştir. Bu nedenle, bu bölümde, katılımcı öğretmenlerin KAB'larına yönelik bulgular, alan yazındaki sonuçlar dikkate alınarak tartışılmıştır.

Bu çalışmada, madde döngülerine yönelik kavramsal bilgi anlamında, katılımcı fen öğretmenlerinin madde döngüleri konusunda bilgi eksikliğinin olduğu sonucuna varılabilir. Öğretmenlerin spesifik olarak karbon, su ve azot döngülerinde kavramsal olarak eksiklikleri olduğu gözlemlenmiştir. Diğer taraftan fen öğretim müfredatı incelendiğinde, öğretmenlerin eksik bilgilerinin programdaki eksikliklerle benzer olduğu saptanmıştır.

Bu şartlar ışığında, katılımcı öğretmenlerin temel bilgilerinin fen müfredatından etkilenebileceği sonucuna varılabilir. Bu çalışma, özellikle, 8. sınıf fen ders kitaplarının sınırlı içeriğinin öğretmenlerin temel bilgileri üzerinde etkili olabileceğini göstermektedir. Bu sonuç, öğretmenlerin, deneyimli olsalar bile, zaman içinde kullanılmayan bilgiyi unutabileceklerini ortaya çıkarmıştır. Öğretmenlerin içerik bilgisine zaman içinde ne olduğunu anlamayı amaçlayan Arzi ve White (2007) 'nin çalışmaları da bu sonucu desteklemektedir. On yedi yıllık boylamsal çalışmalarında, Arzi ve White (2007) yirmi iki öğretmeni öğretmenliğe ilk başladıkları yıldan itibaren takip etmiştir. Çalışmalarının bulgularına dayanarak, öğretimde hem rehber hem de bilgi kaynağı olarak başvurulan müfredatların, öğretmenlerin içerik bilgisini önemli şekilde etkilediği sonucuna varmışlardır. Böylece, kullanılmayan içerik bilgisinin unutulduğunu ve zaman içinde çok az yeni bilginin geliştirildiğini savunmaktadırlar. Bu nedenle öğretmenlerin, müfredat bilgisini öğretmede uzmanlaşarak, akademik ve bilimsel bilgiyi bir kenara bırakabilecekleri sonucu ortaya çıkmıştır.

Çalışmada, katılımcı öğretmenlerin temel bilgileriyle ilgili göze çarpan bir başka bulgu da temel bilgi düzeyleridir. Hale ve Selda'nın uzmanlık alanı biyoloji olduğundan, bir biyoloji konusu olarak madde döngüleri hakkındaki kavramsal anlayışlarının Kemal'in anlayışından daha fazla olması beklenmiştir. Bununla birlikte, öğretmenlerin döngülerle ilgili kavramsal bilgileri incelendiğinde, Kemal'in madde döngüleri hakkındaki temel bilgilerinin Selda'dan daha iyi olduğu açıkça görülmektedir. Örneğin, azot döngüsünde Selda, ayrıştırıcıları ve azot bağlayıcı bakterileri ayırt edememiş, dahası, azot ayrıştırıcı bakterileri ise azot bakterilerinden biri olarak belirtmemiştir.. Bu nedenle azot döngüsündeki süreçlerle ilgili bilgisi yetersizdi. Bu bağlamda, Kemal'in, uzmanlık alanı dışındaki madde döngüleri konusunu anlama ve öğretme konusunda Selda'dan daha başarılı olduğu sonucuna varılabilir. Kind (2009), bu sonucu, fen bilgisi öğretmenlerinin uzmanlıklarının dışında bir konunun öğretilmesine nasıl tepki verdiklerini araştırdığı çalışmasında göstermiştir. Böylece, fen bilgisi öğretmenlerinin uzmanlık alanları dışındaki derslerinin, uzmanlıkları dâhilinde öğretilenlerden daha başarılı olduğunu göstermiştir. Ayrıca bu öğretmenler, uzmanlık dışı fen konularını öğrenmek için daha fazla çaba harcamaktadırlar.

İkinci olarak, fen bilgisi öğretmenlerinin bilimin doğası hakkındaki anlayışı da bu çalışmada sözdizimsel bilgi olarak araştırılmıştır (Schwab, 1964). Önceki araştırma bulguları ile tutarlı olarak (Abd-El-Khalick ve Lederman, 2000; Akerson ve Abd-El-Khalick, 2003; Brickhouse, 1990; Cullen, Akerson ve Hanson, 2012; Doğan ve Abd-El-Khalick 2008; Lederman, 1992) Lederman, 1999; Liu ve Lederman, 2007; Schwartz, Westerlund, García ve Taylor, 2010; Shim, Young ve Paolucci, 2010; Tairab, 2001) hizmet içi öğretmenlerin bu çalışmada bilimin doğasına ilişkin yetersiz görüşlerine sahip oldukları saptanmıştır. Özellikle öğretmenlerin ifadeleri, bilimsel bilginin geçici doğası, teoriler ve yasalar arasındaki farklılıklar, bilim adamlarının öznelliği ve bilimsel bilginin sosyo-kültürel yapısına ilişkin naif açıklamalar içermektedir. Ayrıca, fen bilgisi öğretmenlerinin belirtilen bilimin doğası boyutlarına ilişkin mitleri, yine öğretmenlerin bilimin deneysel, çıkarımsal ve yaratıcı boyutlarına ilişkin görüşlerini etkilemiştir.

Bu koşullar ışığında, bu çalışmada, katılımcı öğretmenlerin bilimin doğası görüşleri, ilköğretim, ortaöğretim ve lisans eğitimini içeren eğitim geçmişleriyle ilişkili olabilir. Özellikle, fen ders kitaplarındaki fen bilimi yaklaşımı ve eğitim yaşamları ile birlikte deneyimledikleri laboratuar faaliyetlerinin yapısı ve bilimin doğasına yönelik derslere lisans eğitimlerinde aşinalıklarının olmaması, katılımcıların bilimin doğası hakkındaki yanlış fikirlerinin önemli nedenleri olabilir. Her şeyden önce, öğrenci olarak, katılımcı öğretmenlerin önceki eğitimleri sırasında laboratuar deneyimleri yanlış NOS görüşlerine yol açmış olabilir. Ne yazık ki, laboratuar etkinlikleri gibi birçok yaygın fen öğretimi yöntemi, bilimde yaratıcılığa karşı çalışmaya hizmet etmektedir (Abd-El-Khalick, 2005; McComas, 1998). İlköğretim seviyesinden lisans seviyesine kadar, laboratuvar çalışmalarının çoğu doğrulama faaliyetleridir. Laboratuvar el kitabı adım adım yönergeler sağlar ve öğrencilerden etkinlik yapmaları, gözlemler yapmaları ve daha sonra belirli bir sonuca varmaları beklenir. Oluşan sonuçların hem kendine özgü hem de tek tip olacağı beklentisi vardır. Sonuç olarak, laboratuar faaliyetleri bilimin nesnel olduğu yanılgısını arttırmaktadır (Bilican, 2014; Clough, 2006). Tobias (1990), laboratuarlarda bilimin öğrencilere heyecan verici ve yaratıcı bir süreç olarak görme fırsatı verilmediğini savunmuştur.

Ders kitaplarında bilimin gösterimi de katılımcı öğretmenlerin bilimin doğası hakkındaki yetersiz görüşlerine neden olabilir (Abd-El-Khalick, Waters & Le, 2008; Bilican, 2014; Clough, 2006; İrez; 2009; Vesterinen, Aksela ve Lavonen, 2011).). Çalışmalar bilim ders kitaplarında gösterilen bilimin doğası ve yönlerinin birçok sorunu olduğunu gösterniştir. Ders kitapları bilimi, gerçekleri arayan bir süreç olarak tanıtmıştır. Ek olarak, bilimin doğası yönlerini ihmal ederek yanlış NOS görüşlerini yansıtmaktadırlar (Irez, 2009; Vesterinen, Aksela ve Lavonen, 2011). Bu nedenle, herhangi bir eğitim seviyesinde tanıtılan fen ders kitaplarıyla ilgili bu sorunlar, katılımcı öğretmenlerin bilimin doğası hakkında sağlam bir anlayışa sahip olmalarını engellemiştir. Ayrıca, bilimin doğasına yönelik derslerin lisans eğitiminde olmayışı, öğretmenlerin bilimin doğası anlayışını geliştirmelerini engelleyen bir başka neden olabilir. Bilindiği gibi, bilim tarihi ve doğası ile ilgili dersler, son zamanlarda Türkiye'deki öğretmen eğitimi programlarına entegre edilmiştir. Fen bilgisi öğretmenliği eğitiminde iyi organize edilmiş yöntem veya seçmeli dersler boyunca öğretmenlere, bilimin doğasının farklı bağlamlardaki çeşitli yönlerini tartışma ve yansıtma fırsatları sunulmaktadır. Böylece, bilimin doğası öğretmen eğitimi ile öğretmenler için yaygın bir tema haline getirilmiştir (Abd-El-Khalick, 2000; Bilican, 2014). Mevcut araştırmaya katılan öğretmenlerin yirmi yıldan fazla deneyimleri olduğundan, lisans seviyesindeki bu derslerle ilgili bir aşinalık eksikliği olabilir.

Son olarak, mevcut araştırmada, fen bilgisi öğretmenlerinin SK hakkındaki düşünceleri ayrı bir konu bilgisi türü olarak incelenmiştir. Çalışma, SK kavramının disiplinlerarası niteliğine dayanarak, fen öğretmenlerinin, çevre, toplum, ekonomi, politika, teknoloji, eğitim ve enerji gibi SK'nın yedi ana yönü ile madde döngülerini nasıl ilişkilendirdiklerini araştırmıştır. Fen öğretmenlerinden SK kavramlarını tanımlamak için, biyojeokimyasal döngülerin bozulmasının nedenlerini, sonuçlarını ve çözümlerini açıklamaları istenmiştir.. Bulgulardan anlaşılacağı gibi, Kılınç ve

Aydın (2013) tarafından belirlenen yedi temel kavramsal alan ortaya atılmıştır: 'çevre', 'ekonomi', 'toplum', 'politika', 'enerji', 'teknoloji' ve 'eğitim '. Bu sonuç, SK konularının yalnızca çevre veya SK'nın üç popüler ayağı (çevre, toplum ve ekonomi) açısından anlaşılmadığını göstermiştir. Bununla birlikte, Hale ve Selda temel olarak sırasıyla SD'nin çevresel, toplumsal ve ekonomik yönlerine odaklanırken, Kemal siyasi meseleleri SD'nin üçüncü yönü olarak ele almıştır. Bu nedenle, bazı araştırmalar insanların SD hakkında düşünürken politik yönünü dikkate almadıklarını varsaymasına rağmen (örneğin, Gil-perez ve diğerleri, 2003), bu çalışma fen bilgisi öğretmenlerinin SK tanımında siyasi argümanlar kullandıklarını göstermiştir. Ek olarak, öğretmenler SK kavramşarını en çok karbon döngüsüyle ilişkilendirmişlerdir. Özellikle Selda ve Kemal azot ve su döngüsünde SD kavramlarını yansıtmakta başarılı olamamışlardır.

Hem fen bilgisi öğretmenlerinin hem mesleki deneyimlerinin hem de yazılı ve dijital medya (TV, gazeteler ve internet) yoluyla gayrı resmi eğitimlerinin bu tür SD kavramlarından sorumlu olabileceği söylenebilir. Örgün eğitim açısından, katılımcı öğretmenler eko-okullar projesini uygulayan ortaokullarda eğitim verdikleri için, SD'nin tüm kavramlarına aşina olabilirler. Öte yandan, Türkiye'deki fen bilgisi müfredatı ve ekookullar programının her ikisi de temel olarak çevrenin biyofiziksel ve ekolojik yönlerine dayanmaktadır. Sonuçta fen bilgisi öğretmenlerinin SD'yi çevre açısından tanımladığı ortaya çıkmıştır. Bu bağlamda, Summers ve Childs (2007), fen öğretmenlerinin ortaöğretime yönelik bir eğitim kursunda anket kullanarak sürdürülebilir kalkınma kavramlarını araştırmıştır. Çalışmanın sonucu doğrultusunda, çok sayıda fen bilgisi öğretmeninin sürdürülebilir kalkınmayı açıklarken çevresel faktörlere odaklandığını iddia etmişlerdir.

Gayri resmi eğitimleri ilgili olarak, araştırmalar hem öğrencilerin hem de öğretmenlerin çoğunlukla çevresel konularla ilgili bilgileri yazılı ve görsel medya aracılığıyla öğrendiklerini; göstermektedir (Kılınç ve diğerleri, 2008; Öztaş ve Kalıpçı, 2009). Örneğin, Kemal, küresel ısınma ve sera etkisi gibi çevresel kaygıları açıklamak için Al Gore hakkındaki belgesellere ve Green Peace ile ilgili haberlere değinmiştir. Bu nedenle, 5 yıllık kalkınma planları, GAP ve çevresel bozulma ile ilgili haber veya belgesellerin fen bilgisi öğretmenleri arasında farkındalığa yol açabileceği söylenebilir. Kılınç ve Aydın (2013) da yaptıkları çalışmada, Türk medyasında kalkınma planlarının siyasi ve çevresel tartışmalara dikkat çektiği sonucuna varmıştır. Mesela Hale, projenin yerel topluma katkısını açıklamak için GAP'tan bahsederek, SK'nın bileşenlerine vurgu yaptı. Bu nedenle, bu tarz güzel örneklerin öğretmenlerin SK'yı tüm yönleri ile tartışmasına yardımcı olabileceği söylenebilir.

Ek olarak, fen bilgisi öğretmenlerinin SK ile ilgili görüşleri, Türkiye bağlamına özgü olabilir. Güçlü hükümete sahip olmak, yabancı ticarete bağımlı olmak, yeni teknolojilerin üretimi, üretim için endüstriyel gelişim, toplumun yaşam standartlarını iyileştirmek ve yeni iş olanakları yaratmak gibi ifadeleri, fen bilgisi öğretmenlerinin Türkiye'nin gelişmekte olan bir ülke olarak şu anki sorunlarıyla karşı karşıya olduğunu göstermiştir. Bu nedenle, ülke merkezli bağlamsal nedenlerin öğretmenlerin görüşlerini etkileyebileceği söylenebilir.

Fen Bilgisi Öğretmenlerinin Pedagojik Alan Bilgileri

Fen Bilgisi Öğretmenlerinin Fen Öğretimine Yönelimleri

Bu çalışmada Kemal ve Selda, 8. sınıfta fen öğretmenin amacını; müfredat kazanımlarını aktarma ve öğrencileri liseye ve liselere giriş sınavına (TEOG) hazırlama olarak belirtmişlerdir. Katılımcı öğretmenler, aynı zamanda öğrencilerin fen ve günlük yaşamla bağlantı kurmalarına ve çevresel farkındalık geliştirmelerine yardımcı olmak gibi amaçlarının da olduğunu ifade etmelerine rağmen, sınıf içi uygulamaları sırasında bu hedeflerini görmezden gelmişlerdir. Öte yandan, Hale öğrencilerin katılımcı ve aktif olmasını sağlamak için proje merkezli öğrenmeyi bir yönelim olarak tercih etse de, bütün öğretmenlerin sınıf içi fen eğitimi yönelimlerinin sınırlı olduğu gözlemlenmiştir. Genel olarak katılımcılar, madde döngüleri konusunda öğretmen merkezli ve düz anlatım yaklaşımına uygun bir öğretim sergilemişlerdir.

Öğretmenlerin fen öğretimine yönelimleri; yoğun müfredat, konu alan bilgisindeki yetersizlikler ve bağlamsal faktörler (sınav temelli eğitim sistemi, okul bağlamı gibi…) gibi birçok faktörle açıklanabilir (Avraamidou, 2012; Feierabend ve diğerleri, 2011; Friedrichsen ve diğerleri, 2011; Friedrichsen ve Dana, 2005; Samuelowicz ve Bain, 1992). Türkiye'de, nitelikli bir Fen ya da Anadolu lisesinde öğrenim görebilmek için, ortaokul öğrencileri lise giriş sınavına (TEOG [şu anda bilinen ismiyle LGS]) girmek ve iyi puanlar almak zorundadır. Bu sınav odaklı sistem nedeniyle, özellikle 8. sınıflarda çoktan seçmeli sorulara dayanan bir öğretim sergilenmektedir. Ayrıca, okul yönetimleri de sınava dayalı öğretime önem vermektedir, çünkü ülkemizde öğretmenler ve okullar hakkındaki kalite değerlendirmeleri, öğrencilerin TEOG sınavlarından aldıkları puanlara dayanarak şekillenmektedir. Özellikle, bu çalışmada öğretmenler, öğrencilerin katılımcı ve etkileşim içerisinde oldukları proje tabanlı, sorgulama gibi yönelimlerin yararlı olduğunun farkında olmalarına rağmen, okul türü (kamu / özel), kalabalık sınıflar, laboratuvarın yetersizliği ve de öğrencilerin ve ailelerinin TEOG sınavı ile ilgili endişelerinin olması gibi bağlamsal faktörlerin öğretimlerini etkilemesinden şikâyet etmektedirler. Sonuç olarak, yukarıda belirtilen bu bağlamsal faktörler, öğretmenleri ideal öğretme hedeflerini değiştirmeye zorlayabilmekte ve böylece öğretmenin öğretmen merkezli yönelimleri tercih etmesine sebep olabilmektedir (Friedrichsen ve diğerleri, 2011; Friedrichsen ve Dana, 2005; Samuelowicz ve Bain, 1992).

Öğretmenlerin fen öğretimine yönelik yönelimlerini etkileyen bir başka olası faktör, aşırı yoğun müfredat olabilmektedir. Lise giriş sınavının takvimi nedeniyle katılımcı öğretmenler, müfredatta yetişmesi gereken konuları tamamlayabilmek için sürelerinin kısıtlı olduğundan yakınmaktadırlar. Müfredatın bu yoğunluğunun yanında, öğrenci merkezli etkinliklerin hazırlanması ve derecelendirilmesi için ayrıca ek süre gerektiğini belirtmişlerdir. Aynı şekilde araştırmalar, öğretmenlerin öğrencilerine yönelik zihinsel aktiviteleri hazırlamak için gereken zaman (Friedrichsen ve Dana, 2005) ve öğretim çalışmalarının aşırı yüklü olması (Nargund-

Joshi, vd., 2011) gibi nedenlerle didaktik öğretimi tercih ettiklerini ortaya koymaktadır.

Son olarak, fen bilgisi öğretmenlerinin fen öğretimine yönelimlerini, konu alan bilgileri ile ilgili huzursuzlukları olabilmektedir (Avraamidou, 2012; Feierabend ve diğerleri, 2011; Friedrichsen ve diğerleri, 2011; Friedrichsen ve Dana, 2005). Çalışmanın bulguları, tüm öğretmenlerin madde döngüleri konusunda sınırlı konu alan bilgisine sahip olduğunu ortaya çıkarmıştır. Özellikle, Kemal ve Selda'nın bilimin doğası ve SK'ya yönelik anlayışlarında eksiklikler gözlemlenmiştir. Özellikle, SKE bağlamında yapılan birçok araştırma, öğretmenlerin sürdürülebilir kalkınma ve çevre konuları ile ilgili anlayışlarının, sürdürülebilir kalkınma eğitimini öğretimleriyle bütünleştirmeye yönelik inançları açısından çok önemli olduğunu doğrulamıştır (Corney, 2006; Spiropoulou, Antonakaki, Kontaxaki ve Bouras, 2007; Summers ve ark. , 2005). Bu nedenle, konu alan bilgilerindeki bu eksiklik, öğretmenleri kavramsal bilgileri didaktik bir şekilde aktardıkları, öğretmen merkezli yönelimleri tercih etmeye zorlayabilmektedir.

Fen Bilgisi Öğretmenlerinin Müfredat Bilgisi

Katılımcı fen öğretmenlerinin müfredat bilgisi, müfredat amaç ve hedefleri bilgisi açısından, yeterli bulunmuştur. Öğretmenler, madde döngülerle ilgili müfredat kazanımlarını doğrudan ifade etmişlerdir. Ayrıca, ilgili konunun hem 8. Sınıftaki diğer konularla hem de alt sınıflardaki ilgili konularla bağlantılarının farkındadırlar. Fen bilgisi öğretmenlerinin müfredat kazanımları ile ilgili bilgilerinin deneyimleriyle ilgili olabileceği düşünülmektedir. Katılımcı öğretmenler on yıldan fazla deneyime sahip olduklarından, madde döngüleri konusundaki müfredat kazanımlarına ve öğretilmesi için gerekli ön bilgiye sahiptirler. Aynı şekilde, deneyimsiz öğretmenlerle yapılan PAB çalışmaları da, bu öğretmenlerin müfredat ile ilgili yeterli bilgiye sahip olmadıklarını ortaya koymaktadır. Bu çalışmalar, öğretmen adaylarının ilgili konuların öğretilebilmesi için hem gerekli kazanımların hem de ön bilgi ve koşulların farkında olmadıklarını göstermektedir (Graf ve diğerleri, 2011; Hanuscin ve diğerleri, 2010; Mıhlandız ve Timur, 2011; Özcan ve Tekkaya, 2011; Tekkaya ve Kılıç; 2012; Uşak, 2009).

Tartışılması gereken bir diğer husus, öğretmenlerin müfredat ile ilgili yaptıkları değişikliklerdir. Müfredatta yer alan kazanımlar dışında, tüm öğretmenler, döngülerin devamlılığının sağlanabilmesi için, öğrencilerde çevre bilinci ve farkındalık oluşturma gibi tutumlar geliştirmeyi amaçladıklarını belirtmişlerdir. Ek olarak, Hale ve Selda, gerektiğinde konunun alt başlıklarını değiştirebileceklerini belirtirken, Kemal madde döngülerini anlatırken ilk olarak karbon döngüsünü anlatmayı tercih etmiş, yani konu sıralamasını değiştirmiştir. Yapılan PAB çalışmalarına dayanarak, öğretmenlerin fen öğretime yönelik inançları (yönelimleri) ve öğrenci bilgileri gibi faktörlerin, müfredatta yaptıkları değişiklikleri açıklayabileceği söylenebilir (De Miranda, 2008; Friedrichsen et al., 2011; Friedrichsen & Dana, 2005; Rollnick et al., 2008). Özellikle, bu çalışmada, katılımcı öğretmenlerin fen öğretimine yönelik inançları, tutum geliştirmeye yönelik ek hedefleri olması açısından müfredatı ihlal etmelerinin nedeni olabilir (Friedrichsen ve diğerleri, 2011; Friedrichsen ve Dana, 2005). Son olarak, öğretmenlerin müfredata yönelik değişiklikleri ile öğrenci bilgileri arasında bir etkileşim olabilmektedir. Eğer öğretmenler, öğrencilerinin ön bilgilerinin farkındalarsa, ders kitaplarını (De Miranda, 2008) ve müfredat kaynaklarını (Bayer ve Davis, 2012) öğrencilerin özel ihtiyaçlarına ve özelliklerine cevap verecek şekilde değiştirebilmektedirler. Örneğin, bu çalışmada, Kemal, öğrencilerin fotosentez ve solunum konularına aşina olmaları nedeniyle, karbon döngüsünü önce anlatarak müfredatta değişiklik yapmıştır.

Son olarak, bu çalışma, tüm öğretmenlerin öğretim programını takip etmek için ders kitaplarını kullandığını ortaya koymuştur. Diğer taraftan, ders kitapları ve öğrenci çalışma kitabındaki etkinliklerin kullanımı bakımından, öğretmenler yetersiz kalmışlardır. Örneğin, Kemal ve Selda, madde döngüleri anlatırken müfredatta yer alan aktiviteleri kullanmak yerine, daha fazla soru çözmeyi veya konuyu tekrar etmeyi tercih etmişlerdir. Öğretmenlerin müfredatta yer alan etkinlikleri görmezden gelmelerinin nedenleri, müfredatla ilgili yapılan değişikliklerin sıklığı ve sınav temelli eğitim sistemi gibi bağlamsal faktörler olabilir. 1923 yılında Türkiye Cumhuriyeti'nin kuruluşundan beri, fen bilgisi öğretim programı 11 kez yenilenmiş veya geliştirilmiştir (Çalık ve Ayas, 2008). Hatta 2013 ve 2018 yıllarında da fen bilgisi öğretim programında değişiklikler yapılmıştır. Araştırmacılar, yeni bir müfredat geliştirildiğinde, öğretmenlerin henüz mevcut müfredatı tamamen uygulayamadıklarını vurgulamaktadır (Çalık ve Ayas, 2008). Yeni müfredat, öğretim ve değerlendirme için yeni stratejiler ve yöntemler önerse bile, öğretmenler yeni müfredatı öğretimlerine yansıtmakta büyük zorluklar yaşamaktadırlar (Aydın ve Çakıroğlu, 2010). Sonuç olarak, yeni müfredatta yer alan stratejilere uymak yerine, önceki öğretim şekillerine devam etmektedirler (Coll ve Taylor, 2012). Böylece, müfredatta sık sık yapılan değişiklikler fen bilgisi öğretmenlerinin bu değişiklikleri görmezden gelmelerine neden olabilmektedir. Liseye Giriş Sınavı (TEOG), öğrencileri sınava hazırlamak için, öğretmenlerin öğretimleri esnasında soru çözme etkinliklerine daha fazla yer vermelerine neden olabilmektedir. Mıhlandız ve Timur (2011), çalışmalarında, yukarıda bahsi geçen bağlamsal faktörlerin fen bilgisi öğretmenlerinin müfredat bilgilerini etkilediği sonucunu desteklemektedirler.

Fen Bilgisi Öğretmenlerinin Öğretim Stratejileri Bilgisi

Fen bilgisi öğretmenleri arasında öğretim stratejileri bilgisi açısından hem farklılık hem de benzerlikler mevcuttur. Katılımcı öğretmenler, derse özel öğretim stratejileri açısından benzer özelliklere sahiplerdir. Tüm öğretmenler, fen bilgisini derslerinde düz anlatım ve soru sorma gibi öğretmen merkezli öğretim stratejilerini baskın bir şekilde kullanmışlardır. Her ne kadar Hale, döngüleri öğretirken öğrenci merkezli, problem ve proje tabanlı öğretim stratejilerini benimsemiş olduğunu belirtse de, öğretimini genel olarak soru sorma stratejisine dayandırdığı gözlemlenmiştir. Diğer taraftan öğretmenlerin öğretim stratejileri bilgilerindeki farklılık ise, öğretimlerinin öğretmen merkezliliğinin seviyesidir. Bu durum, fen bilgisi öğretmenlerinin konuya özgü öğretim stratejileri tercihlerini etkileyen ayırt edici faktör olmuştur. Başka bir deyişle, fen bilgisi öğretmenleri madde döngülerini öğretirken, hem vurguladıkları hususlar (örneğin; kavramsal bilgi, SK kavramları gibi…) hem de kullanılan betimleme ve faaliyetlerin sayısında farklılıklar göstermişlerdir. Örneğin, Hale, gerçek hayattan örnekler, çeşitli şekiller, resimler, animasyonlar ve müfredatta yer alan etkinlikleri kullanırken; Kemal ve Selda sadece kendi çizdikleri şekilleri ve sınırlı sayıdaki gündelik örnekleri kullanmışlardır. Yine Selda ve Kemal sadece kavramsal bilgilere değinirken, Hale özellikle SK kavramlarına ve konuyla ilişkilerine ağırlık vermiştir.

Öğretmen eğitimi ile ilgili yapılan araştırmalar, bu çalışmanınkilerle benzer bulgulara sahiptir. Özellikle, Magnusson ve diğ. (1999) öğretmenlerin öğretim stratejileri ve kullanımı hakkında yeterli bilgiye sahip olmadıklarını vurgulamaktadır. Bazı araştırmalar, öğretmenlerin derse özel stratejilerin nasıl uygulanabileceği konusundaki deneyim eksikliğinin, öğrenci merkezli stratejilerin kullanımına ilişkin yetersiz bilgiye sahip olmalarına neden olabileceğini savunmaktadır (Aydemir, 2014; Aydın, 2012; Brown ve ark. ., 2013; Friedrichsen ve diğerleri, 2007; Ingber, 2009; Karakulak ve Tekkaya; 2010; Mıhlandız ve Timur, 2011; Settlage, 2000; Şen, 2014). Öğretmenlerin disipline özel stratejilerin nasıl kullanılacağına ilişkin sahip oldukları bilgi eksikliği, aynı zamanda öğretimin öğretmen merkezliliğinin düzeyini de belirleyebilmektedir. Özellikle, SKE bağlamında yapılan araştırmalar, öğretmenlerin SKE'ne özgü stratejiler ile ilgili bilgilerinin eksik olduğunu ve bu nedenle SK kavramlarını mevcut konularla bütünleştirmeye yönelik öğretim stratejileri ile ilgili eğitim almaları gerektiğini göstermiştir (Kanyimba, 2002). SKE bağlamında kullanılan stratejiler, katılımcı, etkileşimli, yansıtıcı, deneysel ve okul yapısı ve bağlamına uygun nitelikte olmalıdır (Kadji-Beltran, Zachariou, Liarakou ve Flogaitis, 2014). Diğer bir deyişle, SKE, vaka çalışmaları, tartışmalar, alan gezileri, rol yapma gibi öğrenci merkezli özel stratejilerin uygulanmasını gerektirmektedir. Çalışmanın sonuçları, katılan öğretmenlerin madde döngülerini anlatırken, SK kavramlarını mevcut konuya entegre etmek için, SKE'ye yönelik hiçbir özel stratejiyi kullanmadığını göstermiştir.

Magnusson ve diğ. (1999), fen bilgisi öğretmenlerinin fen öğretimine yönelimlerine dayanarak belirli öğretim stratejilerine sahip olabileceklerinin altını çizmektedir (Magnusson ve ark., 1999). Başka bir deyişle, öğretmenler fen eğitimi ile ilgili yönelimlerine uygun stratejileri kullanmayı tercih edebilmektedirler. Bu nedenle, fen öğretimine yönelimlerle ilgili bölümde tartışıldığı üzere, fen öğretmenlerinin yönelimlerini etkileyen bağlamsal faktörler, öğretmenlerin 8. sınıftaki fen eğitimine özel stratejilerini etkileyebilmektedir. Yani, sınava dayalı eğitim sistemi, okul türü (devlet / özel), kalabalık derslikler, laboratuvarın yetersizliği ve öğrencilerin ve ebeveynlerinin lise giriş sınavı ile ilgili kaygıları öğretmenlerin öğretmen merkezli öğretim stratejilerini tercih etmelerinde etkilidir.

Öğretmenlerin öğretmen merkezli stratejilerinin düzeyindeki farklılık, öğretmenlerin konu alan bilgilerindeki farklılık ile açıklanabilir. Araştırmaya katılan tüm öğretmenler hem kavramsal hem de bilimin doğası açısından bilgi eksikliğine sahip olsa da, sadece Hale'nin sürdürülebilir kalkınma kavramları ile madde döngüleri arasındaki bağlantılar anlamında yeterli bilgiye sahip olduğu gözlemlenmiştir. Başka bir deyişle, Hale'nin SK kavramına yönelik konu alan bilgisi diğer öğretmenlerinkinden daha güçlüdür. PAB alan yazını, güçlü bir PAB geliştirmek için konu alan bilgisinin önemini sürekli olarak vurgulamaktadır (Abell, 2008; Magnusson ve diğerleri, 1999; Shulman, 1986). Öğretmenlerin, özellikle de biyoloji konularında farklı betimlemeler, örnekler, şekiller kullanması, konu alan bilgilerinin iyi bir göstergesi olabilmektedir (Oh ve Kim, 2013). Ayrıca, Shulman (1986; 1987) çalışmalarında, deneyimli öğretmenlerin belirli bir konuyu (bu çalışmada, SD kavramlarını) öğrenciler için daha anlaşılır hale getirme yöntemleri ile ilgili daha bilgili olduklarını belirtmiştir. Yine, Gess-Newsome (1992), konu alan bilgisi iyi olan öğretmenlerin, öğrencilerin günlük yaşamıyla ilgili daha fazla örnekler kullandıklarını vurgulamıştır. Bu bağlamda, SKE alanında yapılan çalışmalar da, öğretmenlerin sürdürülebilir kalkınma kavramı ile ilgili bilgi eksikliklerinin, SKE'nin uygulamaları ile ilgili zorluklar yaşamalarına sebep olduğunun altını çizmektedir (Corney, 2006; Spiropoulou, Antonakaki, Kontaxaki ve Bouras 2007). Bu çalışmada da, diğer çalışmalarda görüldüğü üzere, Kemal ve Selda'nın SK kavramları ile madde döngülerini ilişkilendirme konusunda bilgi eksikliği olduğu ve sonuç olarak öğretimleri sırasında SK kavramlarını yeterince detaylandıramadıkları açıkça görülmektedir.

Öğretmenlerin öğretim stratejileri ile ilgili bilgisi üzerinde bağlamsal faktörler de etkili olabilmektedir. Bu çalışmada özellikle liseye giriş sınavı, fen bilgisi öğretmenlerinin konuya özgü öğretim stratejilerini etkileyen önemli bir faktör olarak ortaya çıkmaktadır. Örneğin, Kemal ve Selda, TEOG sınavında madde döngüler konusuyla ilgili nadir soru çıktığı için, konuyu düz anlatım yoluyla öğretmeyi tercih ettiklerini belirtmişlerdir. Ayrıca, öğretmenler öğrencilerin sahip olduğu sınav kaygısının, konuları didaktik bir şekilde öğretmelerine yol açtığından şikâyet etmektedirler.

Ayrıca, öğretmenlerin müfredat bilgisinin, konuya özel öğretim stratejileri üzerindeki etkisi tartışılmalıdır. Örneğin, Kemal ve Selda ders kitaplarını sadece öğretim programını takip etmek için kullanmışlardır. Bu durum, madde döngüleri konusunu anlatırken, müfredatta önerilen etkinlikleri göz ardı etmelerine neden olmuştur. Başka bir deyişle, öğretim programı ilgili bilgi eksiklikleri, ders esnasında kullandıkları öğretim stratejileri etkilemiştir. Aynı şekilde, PAB çalışmalarının çoğunda bulgular, öğretmelerin öğretim stratejileri bilgisi ile müfredat bilgileri arasında bir etkileşim olduğunu göstermektedir (Aydın, 2012; Hanuscin ve diğerleri, 2010; Falk, 2012).

PAB çalışmalarının birçoğu, PAB bileşenleri arasında en güçlü etkileşimin, öğretim stratejileri bilgisi ve öğrenci bilgisi arasında bulunduğunu iddia etmektedir (Akerson, 2005; Boz ve Boz, 2008; Brown ve diğerleri, 2013; Demirdoğan, 2012; Hanuscin ve ark., 2010; Park ve Chen, 2012; Soysal, 2018). Bu çalışmaların sonuçlarında da belirtildiği üzere, fen bilgisi öğretmenlerinin "öğrencilerin gereksinimleri hakkındaki bilgileri", öğretimleri sırasında vurguladıkları konuları (örneğin, SD konuları) etkileyebilmektedir. Örneğin, bu çalışmada, Hale, madde döngüleri konusunda, öğrencilerinin çevresel tutum ve beceri geliştirmeleri gerektiğini düşünerek, öğretiminde SK ile ilgili konuları daha fazla vurgulamıştır. Ayrıca, öğrencilerin farklı öğrenme biçimlerini ve yeteneklerini dikkate alarak, daha fazla öğrenciye ulaşmak adına konuya özel örnekler, sunumlar ve aktiviteler kullanmayı tercih etmiştir.

Fen Bilgisi Öğretmenlerinin Öğrenci Bilgisi

Katılımcı öğretmenlerin, öğrencilerin gereksinimleri ile ilgili yeterli düzeyde bilgi sahibi oldukları gözlemlenmiştir. Bütün öğretmenler, madde döngülerini daha kolay öğrenmeleri için öğrencilerin 5. sınıftaki hava olayları (bulut ve dolu oluşumu), 6. sınıftaki fiziksel ve kimyasal değişiklikler, 7. sınıftaki elementlerin ve bileşiklerin özellikleri, kimyasal bağlar ve canlıların temel yapı taşları ve son olarak 8. sınıftaki besin zincirinde enerji akışı konularında bilgi sahibi olmaları gerektiğinin farkındaydılar. Öte yandan, öğrencilerin öğrenme biçimleri ve yetenekleri göz önüne alındığında, sadece Hale’nin öğrencilerinin bu ihtiyaçlarına yönelik bir öğretim sergilediği ortaya çıkmıştır. Öğretim stratejileri ile ilgili bölümde tartışıldığı üzere, konuya özgü farklı öğretim stratejileri kullanarak, öğrencilerinin farklı öğrenme biçimlerine hitap etmeye çalışmıştır. Ayrıca, öğrencilerin daha aktif olabilmesi için öğrenci merkezli olan proje tabanlı öğrenmeyi öğretimine yansıtmayı tercih etmiştir. Öğrencilerin karşılaştıkları zorluklar ile ilgili olarak, tüm öğretmenler öğrencilerin bu ve buna benzer çevre konularında tutum ve farkındalık geliştirme konusunda sorun yaşadıklarını belirtmişlerdir. Ancak, sadece Hale’nin gerçek hayattan örnekler içeren tartışmalarla öğrencilerinin çevre bilincini geliştirmelerine yardımcı olmaya çalıştığı gözlemlenmiştir. Yapılan çalışmalar da, öğretmenlerin öğrencilerle ilgili sahip oldukları bilgilerin, öğretimi daha verimli hale getirmek için öğretmenleri konuya özel farklı sunumlar ve etkinlikler düzenlemeye yönlendirilebileceğini göstermektedir (Akerson, 2005; Aydın ve diğerleri, 2010; Boz ve Boz, 2008; Brown ve diğerleri, 2013). ; Demirdöğen, 2012; Hanuscin ve diğerleri, 2010; Şen, 2014).

Fen bilgisi öğretmenlerinin öğrenci bilgilerini, özellikle öğretmenlik deneyimleri etkileyebilmektedir. Yirmi yılı aşkın deneyimleri, bu çalışmadaki tüm öğretmenlerin öğrencilerinin ön bilgileri ile ilgili bilgili olmalarına neden olmaktadır. Benzer şekilde, çoğu çalışma, sınıf içi deneyimin, öğretmenlerin öğrencilere yönelik bilgilerine etkisinin çok büyük olduğunu göstermektedir. (Cochran ve diğerleri, 1993; Friedrichsen ve diğerleri, 2009; Gullberg ve diğerleri, 2008; Jong, Van Driel ve Verloop, 2005; Veal ve diğerleri, 1999);

Öğretmenlerin öğrenci bilgileri arasındaki farklılığı, öğretmenlerin farklı konu alan bilgileri ve de fen öğretimine yönelik farklı inançları ve yönelimleri ile açıklanabilir (De Miranda, 2008; Sanders ve diğerleri, 1993; Van Driel, 2008). Hale dışında, Kemal ve Selda öğretmen merkezli yönelimleri benimsedikleri ve genel olarak müfredat kazanımlarını aktarmayı amaçladıkları gözlemlenmiştir. Bu nedenle, fen eğitimine yönelimleri, öğrencilerinin ihtiyaçlarını, öğrenme stillerini ve becerilerini göz önünde bulundurmalarına izin vermemiştir. Yine, Hale'nin, SK kavramları ile madde döngüleri arasındaki ilişkiler anlamında bilgili olması, öğrencilerinin ihtiyaçlarını anlamasına imkân sağlamıştır. Çalışmanın bulguları ile benzer şekilde, PAB çalışmaları, deneyimli öğretmenlerin konu alan bilgilerinin, öğrencilerinin hem anlamaları hem de yaşadıkları zorlukları bilme konusunda öğretmenlerin bilgilerini etkilediğini göstermektedir (Aydemir, 2014; Aydın, 2012; Şen, 2014).

Fen Bilgisi Öğretmenlerinin Değerlendirme Bilgisi

Katılımcı öğretmenler fen öğreniminin değerlendirme boyutları bağlamında, öğrencilerin yalnızca kavramsal öğrenmelerini değerlendirmeyi amaçlamış ve aynı zamanda madde döngüleri konusundaki bilimin doğası boyutlarının değerlendirilmesini göz ardı etmişlerdir. Önceki araştırmalarda da öğretmenlerin sadece öğrencilerinin kavramsal öğrenmelerini değerlendirdiklerine vurgu yapılmaktadır (Aydın, 2012; Lankford, 2010; Tekkaya ve Kılıç, 2012; Şen; 2014).

Öğretmenlerin değerlendirme bilgisini etkileyen muhtemel faktörlerden biri, fen öğretimine olan inanç ve yönelimleri olabilir. Kemal ve Selda, fen eğitiminin genel amacının müfredat kazanımlarının aktarılması olduğunu düşünmekte ve öğretmen merkezli stratejileri içeren (örneğin; düz anlatım) yönelimleri tercih etmektedirler. İfadeleri ile doğru orantılı olarak, ders esnasında genellikle öğrencilerin kavramsal öğrenmelerini değerlendirmek üzere geleneksel değerlendirmeye yönelmişlerdir. Öte yandan, Hale ek olarak öğrencilerinin madde döngüleri kapsamında SK ile ilgili sorunları anlamalarını ve de proje tabanlı öğrenme yoluyla eleştirel düşünme, problem çözme ve karar verme gibi bilişsel becerilerini geliştirmeyi amaçlamıştır. Fakat seçtiği değerlendirme yöntemleri bu amaçlara hizmet etmekten uzaktır. Kemal ve Selda genel olarak geleneksel ve sonuca dayalı değerlendirme tekniklerine (soru-cevap, çoktan seçmeli test) yoğunlaşırken; Hale, performans / akran değerlendirme (öğrenci projeleri) ve kavram haritası gibi otantik değerlendirme stratejilerini kullanmayı tercih etmiştir. Bu yöntemlerle öğrencilerin yanıtlarına geri bildirimde bulunmaya ve öğrencilerin zorluk yaşadığı noktaları yeniden öğretmeye çalışsa da, öğrencilerin öğrenmelerini biçimlendirmek üzere kullandığı yöntemler, amaçlarına hizmet etmemiştir. Diğer bir deyişle, fen bilgisi öğretmenleri değerlendirme yöntemlerini kullanma konusunda sıkıntı yaşamaktadırlar.

Fen bilgisi öğretmenlerinin alternatif veya otantik yöntemlerden ziyade geleneksel değerlendirme tekniklerini kullandıkları ve değerlendirme bilgisi yönünden eksik olduğu birçok çalışmada da vurgulanmaktadır (Canbazoğlu ve ark., 2010; Graf ve ark., 2011; Kaya, 2009; Taşdere ve Özsevgeç, 2012; Uşak ve ark., 2011; Yarden ve Cohen, 2009; Şen, 2014). Öğretmenlerin daha çok geleneksel değerlendirmeyi kullanmalarının nedeni, otantik değerlendirme yöntemlerinin nasıl uygulandığı konusunda ne lisans eğitimlerinde ne de mesleki gelişim eğitimlerinde (hizmet-içi eğitimler) hiçbir deneyime sahibi olmamalarıdır. Hale, alternatif değerlendirme stratejileri konusunda fen eğitimine özel mesleki gelişim eğitimi almamış olmasına rağmen, uygulama konusunda deneyimsizdir. Benzer şekilde, Kaya (2009) lisans eğitimindeki ilgili derslerin altını çizerek, öğretmen eğitiminde değerlendirme stratejileri bakımından eksiklikler olduğunu vurgulamıştır. Ayrıca, sınırlı sayıda düzenlenen değerlendirmeye yönelik hizmet içi eğitimlerin öğretmenleri geleneksel değerlendirme tekniklerine yönlendirdiği sonucuna varmıştır. Bu nedenle, öğretmenler öğrenim hayatları boyunca aşina oldukları bu tarz geleneksel değerlendirme stratejilerini uygulama eğiliminde olmaktadır. PAB alan yazını da, özellikle değerlendirme bilgisindeki gelişimin, diğer bileşenlerin geliştirilmesinden daha fazla zaman ve emek gerektirebileceğini vurgulamaktadır (Hanuscin ve diğerleri, 2011; Henze ve diğerleri, 2008).

Fen bilgisi öğretim programında hem bilimin doğası hem de SK konularının değerlendirilmesine yönelik vurgunun yetersiz olması (Abd-El-Khalick ve diğerleri, 1998; Hanuscin ve diğerleri, 2011; Karaaslan, 2016), öğretmenlerin sadece kavramsal öğrenmeyi değerlendirmelerine neden olabilmektedir. Türkiye'deki 8. sınıf fen bilgisi müfredatı incelendiğinde (MEB, 2005; 2013), öğrencilerin bilimin doğası ve SK anlayışlarının geliştirilmesine yönelik özel amaç ve hedeflerin eksikliği açıkça görülebilmektedir. Müfredat, genel olarak öğrencilerin konularla ilgili kavramsal öğrenmelerini amaçlayan kazanımlara odaklanmaktadır. Bu nedenle, öğretmenler, bir kazanım olarak ele alınmayan bilimin doğası ve SK konularını öğretme ya da değerlendirme amacı gütmemektedirler. Bu bağlamda, Park ve Oliver (2008), müfredatta yer alan amaç ve kazanımların öğretmenlerin değerlendirme bilgilerini son derece etkilediğinin altını çizmektedirler.

Ek olarak, bağlamsal faktörler, özellikle sınav temelli eğitim sistemi, öğretmenlerin değerlendirme bilgilerini etkileyebilmektedir. Liseye giriş sınavında (TEOG) sorulan sorular bilimin doğası veya SK konularından ziyade kavramsal içerik bilgisine odaklanmaktadır. Öğretmeler bilimin doğası veya SK kavramlarının öğretilmesi gerektiğini düşünse bile, sınav odaklı bu eğitim sistemi, öğretmenleri bu konuları değerlendirmekten alıkoymaktadır. Örneğin Çin (Zhang ve ark. 2003) ve Hindistan (Nargund-Joshi ve ark., 2011) gibi sınava dayalı eğitim sistemine sahip ülkelerde de benzer durumların yaşandığı vurgulanmaktadır. Aynı şekilde, değerlendirme yöntemleriyle ilgili olarak, öğretmenler, ülke genelinde yapılan sınavlarda olduğu gibi, çoktan seçmeli maddeleri kullanarak yazılı sınavlar hazırlayarak öğrencilerin öğrenmelerini değerlendirmektedirler. Buradan hareketle, öğretimin yapıldığı ülke ve okula ilişkin bağlamsal faktörlerin öğretmenlerin değerlendirmelerine yönelik sınıf içi uygulamaları üzerinde önemli bir etkiye sahip olduğu söylenebilir (Aydın, 2012; Loughran ve ark., 2004; Şen, 2014).

Öneriler

PAB üzerine yapılan çalışmaların sonuçları, bu kavramın konuya, öğretmene, öğrencilere ve bağlama (sınıf, okul ortamları, öğrencilerin ebeveynleri vb.) özgü olduğunu göstermiştir (Abell, 2008; Lankford, 2010; Nargund-Joshi, et. ve diğerleri, 2011; Park ve Oliver, 2008). Bu noktadan hareketle, PAB'ın konudan konuya, öğretmenden öğretmene, sınıftan sınıfa değiştiği iddia edilebilir. Sadece bir PAB çalışmasının sonuçlarından, bir konunun nasıl öğretileceğine dair bir cevaba ulaşılamaz (Park ve Oliver, 2008). Bu çalışma, SKE bağlamında madde döngüleri konusunda deneyimli öğretmenlerin PAB’larını araştırmayı amaçladığından, öğretmenlerin madde döngüleri konusuna özgü PAB'larının, SKE bağlamında anlaşılması açısından faydalı bilgiler içermektedir.

Bu çalışma, aynı zamanda geleceğin öğretmenleri olan öğretmen adaylarına faydalı bilgiler sunmaktadır. Çalışmaların, öğretmen adaylarının da bu çalışmadaki öğretmenlerle benzer sorunlarının olduğunu göstermesi, tüm öğretmenler için SKE bağlamında mesleki gelişim programlarına ihtiyaç olduğunu göstermektedir. Öğretmenlere ve öğretmen adaylarına SKE bağlamında verilmesi gereken mesleki gelişim eğitimlerinin sadece çevresel konular, bilimin doğası ve sürdürülebilir kalkınma kavramlarını değil, PAB bileşenlerini de içermesi gerektiği vurgulanmaktadır.

Öğretmenlik deneyimi, PAB’ın temel dayanağıdır (Grossman, 1990; van Driel ve ark. 2002). Öte yandan, yalnızca öğretim deneyimi, zengin bir pedagojik alan bilgisi anlamına gelmez (Friedrichsen ve diğerleri, 2009). Çalışmanın sonuçları, öğretmenlerin, öğrencilerin zorluklarını anlama ve bu zorluklara farklı ve zengin öğretim ve değerlendirme stratejileriyle cevap verebilme konusunda profesyonel gelişim programları ile desteklenmesi gerektiğini vurgulamaktadır. Bu destek, disipline ve öğretilen konuya özel olmalıdır (Nakiboğlu ve Tekin, 2006). Sonuçlar, fen bilgisi öğretmenlerinin SKE bağlamında madde döngüleri konusunda yeterli konu alan ve pedagojik alan bilgisine de sahip olmadığını ortaya çıkarmıştır. Bu nedenle; özellikle iyi bir SKE için, mevcut müfredatta SK ile bağlantısı olan fen konularına odaklanılmalı, SK kavramları mevcut konularla bağlantılı verilmelidir.

Bu çalışma, eğitimcilere madde döngülerinin sürdürülebilir kalkınma bağlamında nasıl öğretilebileceği konusunda bilgiler vermesi ve bu bilgileri farklı konulara yansıtabilmeleri açısından faydalıdır. Özellikle çalışmanın sonuçları, madde döngülerinin SK bağlamında öğretilmesine yönelik değerli pratik bilgilere sahiptir. Bu gerçek sınıf içi bilgiler, öğretmen yetiştirme programlarında (lisans eğitimleri ya da hizmet içi eğitimler) gerçek ve somut örnekler olarak gösterilerek, öğretmenlerin deneyimlerini birbirleri ile paylaşmaları bakımından faydalı olabilir.

Çalışmada fen bilgisi öğretmenlerinin SK bağlamında konu alan bilgilerinin yetersiz olduğunu ve bu bilgileri öğretimlerine yansıtamadıklarını ortaya çıkmıştır. Her şeyden önce, fen bilgisi öğretim programı geliştirme uzmanlarının bilimin doğası ve SD kavramlarını dikkate alarak, özellikle kazanımlar anlamında programda konu bazında düzenlemeler yapması gerektiği açıktır. Ayrıca öğretim materyalleri açısından da program geliştirilmeli ve öğretmenler desteklenmelidir. Bilimin doğası ve SK'ya özel öğretim ve değerlendirme stratejileri üzerine uygulamaları içeren müfredat kaynakları geliştirilebilir. Çalışmanın bulguları öğretmenlerin öğretim programında yer alan kazanımları öğretmeye ve müfredat kaynaklarını izlemeye eğilimli olduğunu gösterdiğinden, önerilen değişiklikler öğretim programına uyarlanmadığı takdirde, fen bilgisi öğretmenleri hem bilimin doğası hem de sürdürülebilir kalkınma kavramını mevcut konularla bütünleştirmekte sorunlar yaşamaya devam edecektir.

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