SCIENCE TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE RELATED TO HUMAN BODY SYSTEMS

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ABSTRACT

SCIENCE TEACHERS' TOPIC SPECIFIC PEDAGOGICAL CONTENT KNOWLEDGE RELATED TO HUMAN BODY SYSTEMS

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This study investigated experienced science teachers' pedagogical content knowledge (PCK) and subject matter knowledge (SMK) about human body systems (HBS) (digestive, circulatory, respiratory, urinary system). Two female experienced science teachers from the same private school participated in the study. A case study, a type of qualitative methodology, is used as a research design. Data were collected from semi-structured pre-interviews including Content Representation (CoRe) questions, VNOS-C questionnaire, HBS Questions, classroom observations, teachers' documents, and post-interview. Results of the study show that participants were knowledgeable about the digestive, circulatory, respiratory, and urinary systems. They understand the human body system as a complex system by referring to integrity and cooperation among organs and systems that constitute a human body. Moreover, participant teachers had inconsistent explanations about tentative NOS by mentioning laws are unchangeable. They also did not implement NOS in the context of human body systems. Results of the PCK revealed that participants' central goals were subject matter goals and schooling goals. Moreover, they were knowledgeable about objectives and the place of the HBS in the science curriculum as well horizontal and vertical relationships. However, they went beyond the science curriculum by mentioning limitations. They were aware of the requirements of students' learning.

Participants used analogies, drawing, daily life examples, and modeling as topic-specific strategies. Teachers preferred traditional assessment methods and benefited from both formative and summative assessments. Eventually, a professional development program including NOS implementation is recommended. This program should include NOS objectives, topic-specific instructional and assessment strategies regarding NOS regarding HBS.

Keywords: Pedagogical Content Knowledge, Human Body Systems, Complex System Understanding, Science Education, Experienced Science Teachers

ÖZ

FEN BİLİMLERİ ÖĞRETMENLERİNİN VÜCUDUMUZDAKİ SİSTEMLER KONUSUNA ÖZGÜ PEDAGOJİK ALAN BİLGİLERİ

Kınık, Elif
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Bu çalışma, deneyimli fen bilimleri öğretmenlerinin vücudumuzdaki sistemler (sindirim, dolaşım, solunum ve boşaltım sistemi) konusundaki pedagojik alan bilgilerini (PAB) ve konu alan bilgilerini araştırmıştır. Araştırmaya aynı özel okuldan deneyimli iki kadın fen bilgisi öğretmeni katılmıştır. Araştırma deseni olarak nitel metodolojinin bir türü olan durum çalışması kullanılmıştır. Veriler, içerik gösterim (CoRe) soruları, bilimin doğası hakkında görüşler anketi ve vücudumuzdaki sistemler alan bilgisi sorularını içeren yarı yapılandırılmış ön görüşme sorularının yanı sıra sınıf gözlemleri, öğretmenlere ait çizimler ve son görüşme mülakatlarıyla toplanmıştır.

Çalışma, katılımcıların sindirim, dolaşım, solunum ve boşaltım sistemi hakkında bilgi sahibi olduklarını ve insan vücudunu oluşturan organlar ve sistemler arasında bir bütünlük ve işbirliği olduğunu vurgulayarak vücudumuzdaki sistemleri karmaşık bir sistem olarak algıladıklarını göstermektedir. Ayrıca katılımcı öğretmenler, kanunların değiştirilemez olduğundan bahsederek, bilimin değişebilir doğası hakkında çelişkili açıklamalar yapmışlardır ve vücudumuzdaki sistemler konusuna bilimin doğasını entegre etmekte zorlanmışlardır. PAB sonuçları, katılımcıların

temel hedeflerinin konu hedefleri ve okul hedefleri olduğunu ortaya koymuştur. Öğretmenler vücudumuzdaki sistemler konusunda müfredattaki yatay ve dikey ilişkiler hakkında bilgi sahibilerdir. Katılımcı öğretmenler vücudumuzdaki sistemlerin fen bilimleri müfredatındaki yeri ve ilgili kazanımlar hakkında bilgili olmalarına rağmen ders anlatımlarında kazanımları ve sınırlandırmaları aşan bilgiler vermişlerdir. Öğretmenler öğrencilerin öğrenme gereksinimlerinin farkındadırlar. Ayrıca, katılımcıların analojiler, konuya özgü çizim, günlük yaşam örnekleri ve modelleme kullanarak konuya özel stratejiler geliştirdikleri tespit edilmiştir. Öğretmenler geleneksel değerlendirme yöntemlerini tercih etmiş ve hem süreç hem sonuç değerlendirmesinden yararlanmıştır.

Sonuç olarak, bilimin doğası uygulamasını içeren bir mesleki gelişim programının geliştirilmesi tavsiye edilmektedir. Bu program, vücudumuzdaki sistemler kapsamında bilimin doğası hedeflerini, konuya özel öğretim ve değerlendirme stratejilerini içermelidir.

Anahtar Kelimeler: Pedagojik Alan Bilgisi, Vücudumuzdaki Sistemler, Karmaşık Sistemler, Fen Eğitimi, Deneyimli Fen Bilimleri Öğretmenleri

To my grandmother

for all her sincere efforts on my side

&

To my family

for their unconditional love

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LIST OF ABBREVIATIONS

ABBREVIATIONS

PCK: Pedagogical Content Knowledge

PCKg: Pedagogical Content Knowing

SMK: Subject Matter Knowledge

CK: Content Knowledge

NOS: Nature of Science

CoRe: Content Representation

MoNE: Ministry of National Education

CHAPTER 1

INTRODUCTION

Effective teachers are one of the influential factors in promoting students' learning process (Hanuscin, Lee & Akerson, 2011). Therefore, understanding science teachers' pedagogical content knowledge (PCK) and the relationship between subject matter knowledge (SMK) and PCK enhances the quality of science teaching (Kind, 2009). Researchers agreed with the idea that PCK is a potentially useful paradigm for understanding teachers' knowledge for instruction, but there is no unity among researchers regarding its description (Abell, 2008; Kind, 2009).

Shulman (1986, p.6) expressed that subject matter knowledge is a "missing paradigm" and distinguished content knowledge into three categories which are "(a) subject matter content knowledge, (b) pedagogical content knowledge, and (c) curricular knowledge" (Shulman, 1986, p.9). He, then, developed his categories as "(a) content knowledge, (b) general pedagogical knowledge, (c) curriculum knowledge, (d) pedagogical content knowledge, (e) knowledge of the learners and their characteristics, (f) knowledge of educational contexts, and (g) knowledge of educational ends, purposes, and values with their philosophical and historical grounds" (Shulman, 1987, p.8). How a teacher transforms content knowledge into instruction is the main idea. The relationship between content and pedagogy should not be overlooked since content and pedagogy are parts of the understanding (Shulman, 1986). According to Shulman (1986), teachers' understandings and how a teacher transforms content knowledge into instruction require a theoretical framework. Shulman (1986) scrutinized how teachers' minds combine content knowledge and pedagogy. Therefore, Shulman (1986) was the first to introduce pedagogical content knowledge and proposed PCK as a content knowledge "which goes beyond knowledge of subject matter per se to the dimension of subject matter knowledge *for teaching" (p.9).*

Shulman (1986, 1987) stated that pedagogical content knowledge includes representations of content in different ways including analogies, examples, illustrations to make topic students to more understandable by taking into account the diversity of learners such as their age, background, preconceptions, and misconceptions and curricular knowledge. After that, Shulman (1987, p.8) defined PCK as:

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

Following in the footsteps of Shulman, many researchers (Grossman, 1990; Cochran, DeRuiter & King, 1993; Veal & MaKinster, 1999; Magnusson, Borko & Krajcik, 1999; Park & Oliver, 2008; Gess-Newsome, 2015) have offered various PCK models.

Grossman (1990) supported the transformative model of PCK and categorized teacher knowledge into four domains which are subject matter knowledge, general pedagogical knowledge, pedagogical knowledge and knowledge of context (p.5). Grossman's (1990) model of teacher knowledge is given in Figure 1.1.

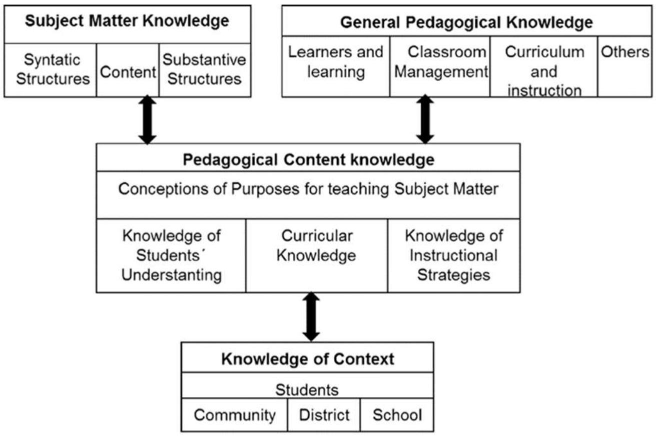

Figure 1.1 Grossman's (1990) Model of PCK (p.5)

According to Grossman's (1990) PCK model, the purpose of teaching subject matter is an overarching component for teachers to shape knowledge of students' understanding, curricular knowledge and knowledge of instructional strategies. Differently from Shulman (1986, 1987) and Grossman (1990), Cochran et al. (1993) proposed the integrative PCK model. PCK models of Grossman (1990) and Magnusson et al. (1999) were developed based on Shulman's (1986, 1987) ideas and used the term of 'knowledge' while Cochran's et. al. (1993) used the term 'knowing'. Thus, Cochran's et. al. (1993) proposed PCKg. Cochran et al. (1993) introduced that PCK development is an active process due to the constructivist perspective. Therefore, they used pedagogical content knowing (PCKg) instead of PCK. Cochran et al. 's PCKg model (1993) is given in Figure 1.2.

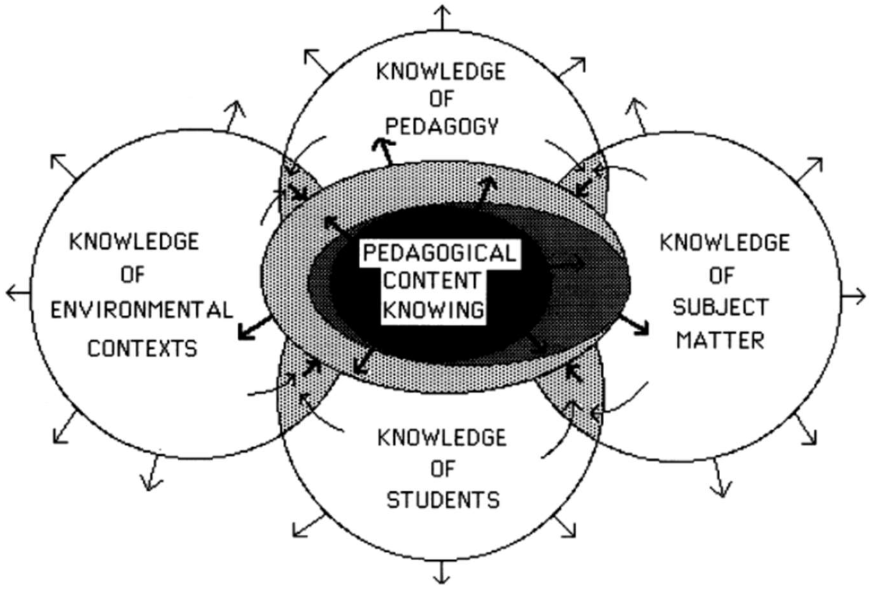

Figure 1.2 Cochran et al. ’s (1993) PCKg model (p.268)

Cochran et al. ‘s (1993) PCKg model represented the importance of teaching experience. According to PCKg model (Cochran et al., 1993) PCKg develops an integration of knowledge of pedagogy, knowledge of subject matter, knowledge of students and knowledge of context.

Another PCK model developed by Veal and MaKinster (1999) is a hierarchical model which is given in Figure 1.3.

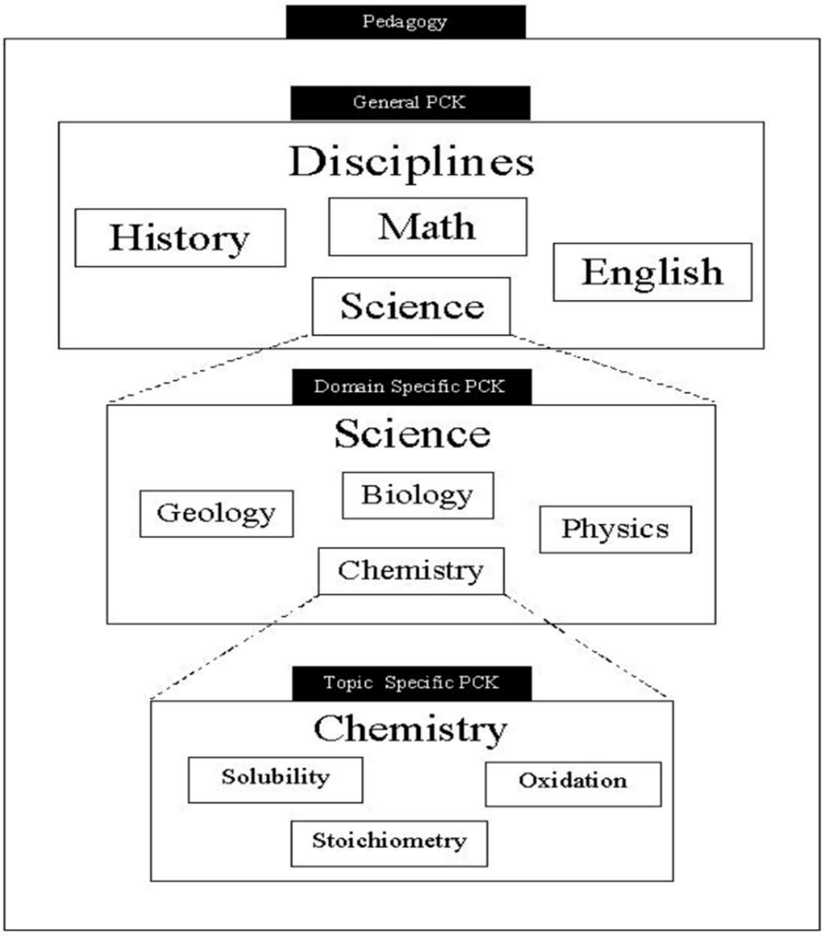

Figure 1.3 Veal and MaKinster’s (1999) Hierarchical Taxonomy of PCK (p.7)

Veal and MaKinster's Hierarchical Taxonomy of PCK (1999) shows that teachers should first developed pedagogical knowledge. This pedagogical knowledge comprises of, for instance: planning, instructional methods, assessment. This knowledge is not discipline specific. Then, general PCK, the first level of Veal and MaKinster’s (1999) taxonomy, is more specific than pedagogy. General PCK represents subject-specific strategies. Most specifically, Veal and MaKinster (1999) introduced the topic-specific PCK.

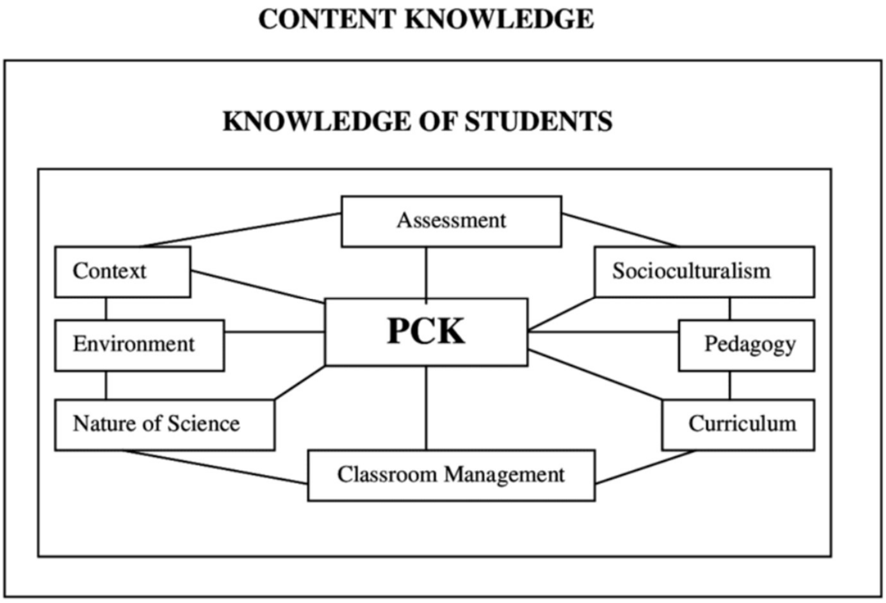

Figure 1.4 Bird's Eye View of Veal and MaKinster's (1999) Second Hierarchical Taxonomy of PCK (p.11)

Veal and MaKinster (1999)'s Hierarchical Taxonomy of PCK implies that robust content knowledge is necessary to develop PCK. Also, according to Figure 1.5, it is seen that teachers' knowledge of students is more important than pedagogy. However, the eight embedded aspects of PCK are not superior to each other since they are developed simultaneously throughout teaching.

Another transformative PCK model proposed by Magnusson et al. (1999) is given in Figure 1.6. Magnusson et al. (1999) developed their PCK model by modifying Grossman's (1990) Model.

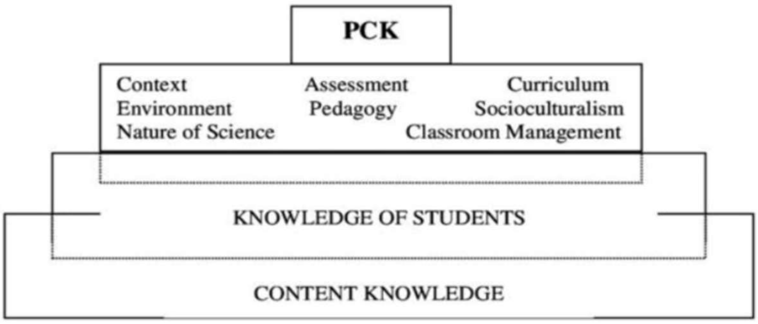

Figure 1.5 Side View of Veal and MaKinster's (1999) Second Hierarchical Taxonomy of PCK (p.11)

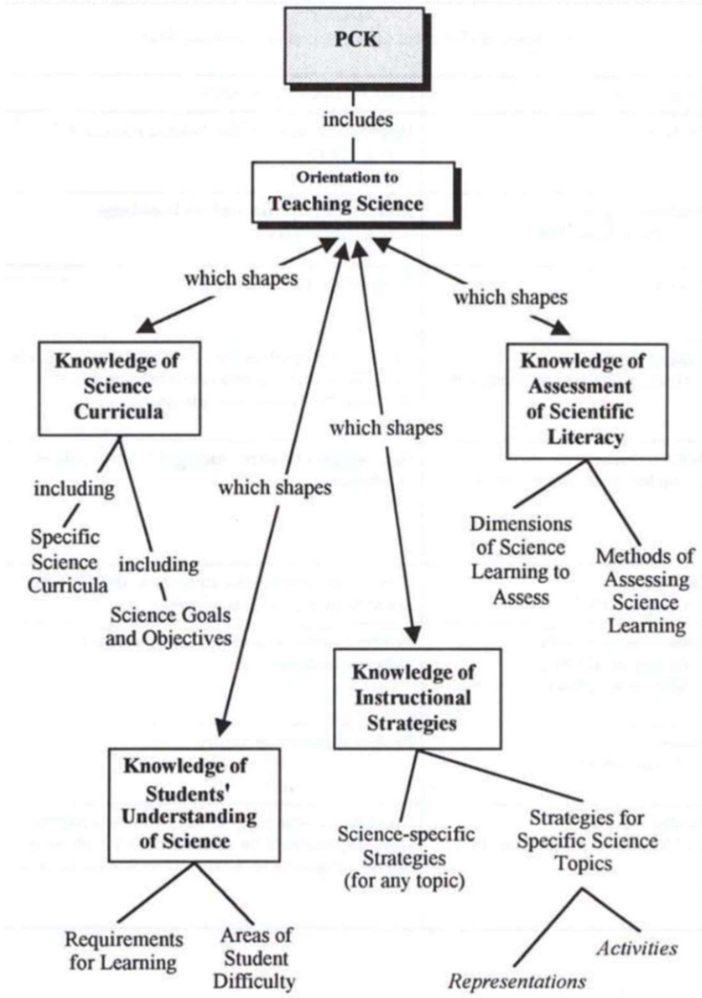

Figure 1.6 Magnusson et al. 's (1999) PCK Model (p.99)

In this model, PCK comprises of five components: orientation to teaching science, knowledge of science curricula, knowledge of assessment of scientific literacy, knowledge of instructional strategies and knowledge of students' understanding of science. Magnusson et al. (1999) defined *orientations to science teaching* as "knowledge and beliefs about the purposes and goal for teaching science at particular grade level" (p.97). They also added that orientation is "a general way of viewing or conceptualizing science teaching" (p.97). This component influences teachers' decisions about their instruction. *Knowledge of students* includes teachers' knowledge about prerequisite knowledge for students' learning and knowledge of difficulties faced by students' such as misconceptions (Magnusson et al., 1999). Teachers should be aware of what students need to know as prior knowledge to understand a particular topic. Moreover, teachers should also take into consideration the students' difficulties and misconceptions that may act as barriers for the understanding of particular topics to provide an effective learning. In this study, teachers' knowledge of students was revealed for digestive system, circulatory system, respiratory system, and urinary system. *Knowledge of curriculum* refers to two sub-categories; knowledge of aims and objectives, and knowledge of specific curricular program (Magnusson et al., 1999). Knowledge of goals and objectives consists of vertical curriculum (Grossman, 1990) and horizontal curriculum. Teachers were expected to know prescribed objectives and limitations in the context of human body systems. Knowledge of specific curricular program is not discussed in this study since the same curriculum recommended by Ministry of National Education is implemented in all schools in Turkey. However, teachers' knowledge of materials such as textbooks, and websites was examined to represent how the teacher conducts the teaching under the heading of knowledge of curriculum.

Knowledge of instructional strategies was categorized as knowledge of subject-specific strategies and knowledge of topic-specific strategies (Magnusson et al., 1999). Knowledge of subject-specific strategies represents the teachers' way of science teaching in general. It associates with teachers' orientations towards science teaching (Magnusson et al., 1999). Then, the knowledge of topic-specific strategies is more content specific. This sub-category includes topic-specific representations which include models, examples, or analogies related to specific topic and topic-specific activities including experiments, simulations and demonstrations to teach particular content. This component of PCK is also related to teachers' content knowledge (Magnusson et al., 1999). In this study, teachers' knowledge of instructional strategies was revealed for digestive system, circulatory system, respiratory system and urinary system. Finally, *knowledge of assessment* consists of two sub-dimensions which are knowledge of dimensions of science learning to assess and knowledge of methods. Effective teachers should be aware of what to assess and how to assess (Magnusson et al., 1999).

After the introduction of these models (i.e., Shulman, 1986; Grossman, 1990; Veal & MaKinster, 1999; Magnusson et al.,1999), Gess-Newsome (1999) organized PCK models as integrative and transformative (see Figure 1.7).

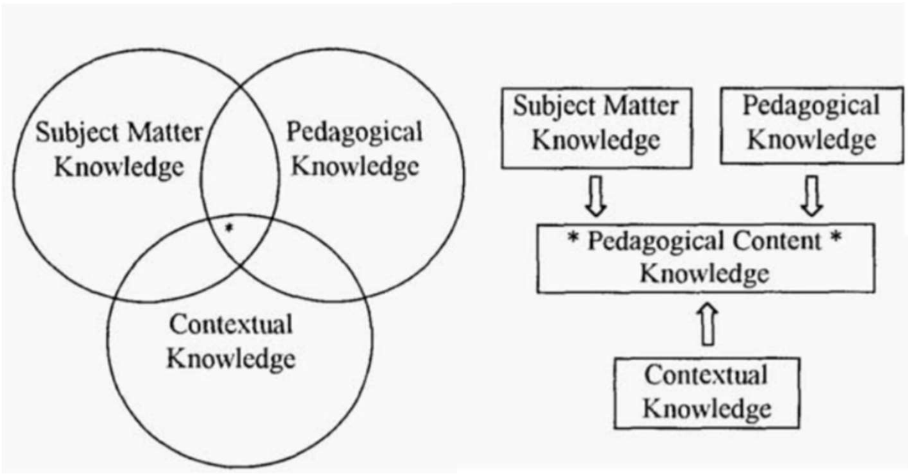

Figure 1.7 Gess-Newsome's (1999) PCK Models (p.12)

In integrative models (e.g., Veal & MaKinster, 1999), teacher knowledge emerges through the integration of subject matter knowledge, pedagogy and context. This is likened to the formation of a mixture, and just as in products that form a mixture, subject matter knowledge, pedagogy and context appear in teaching without losing their own characteristics. Therefore, PCK does not exist as a new type of domain of knowledge. Each knowledge base is developed independently of each other. On the other hand, in transformative models (e.g., Shulman, 1986; Grossman, 1990; Magnusson et al.,1999), subject matter knowledge, pedagogical knowledge and context knowledge are synthesized and transformed into pedagogical content knowledge. Transformative models are likened to the formation of compounds in chemistry and just like in the compound, the elements that make up the PCK lose their properties and form a stronger and different structure and cannot be separated from each other. The mechanism of transformative models presents the impact of SMK on generation of PCK (Kind,2009).

Different from integrative and transformative models, Park and Oliver (2008) developed a hexagonal model of PCK (see Figure 1.8).

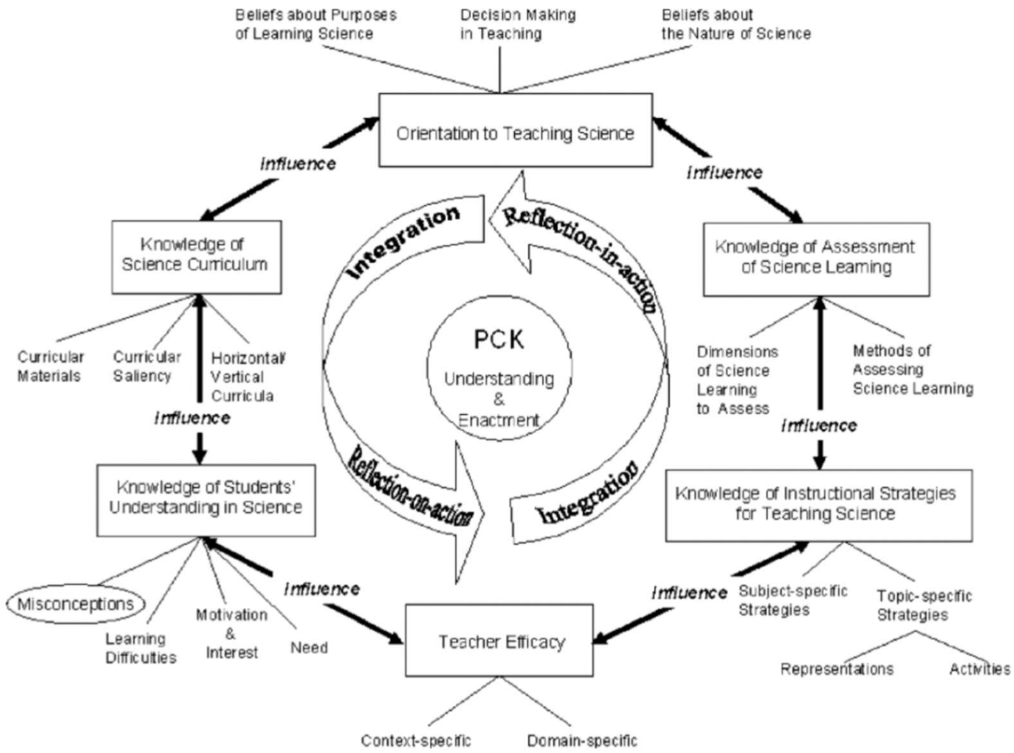

Figure 1.8 Park and Oliver’s (2008) Hexagonal Model of PCK (p.279)

Park and Oliver (2008) revealed in their research that PCK is developed both in action and on action. They introduced an affective component “teacher efficacy in addition to Magnusson et al. (1999)’s PCK model. This has an impactful role for teachers to solve the problems and shape their knowledge. Park and Oliver (2008) also put forward that teachers’ PCK is mostly shaped by students’ misconceptions.

Finally, Gess-Newsome (2015) presented the consensus model (see Figure 1.9). In the consensus model, teacher professional knowledge bases include five knowledge domains: a) assessment knowledge, b) pedagogical knowledge, c) content knowledge, d) knowledge of students, e) curricular knowledge. Then, Gess-Newsome (2015) introduced topic-specific professional knowledge in the consensus model.

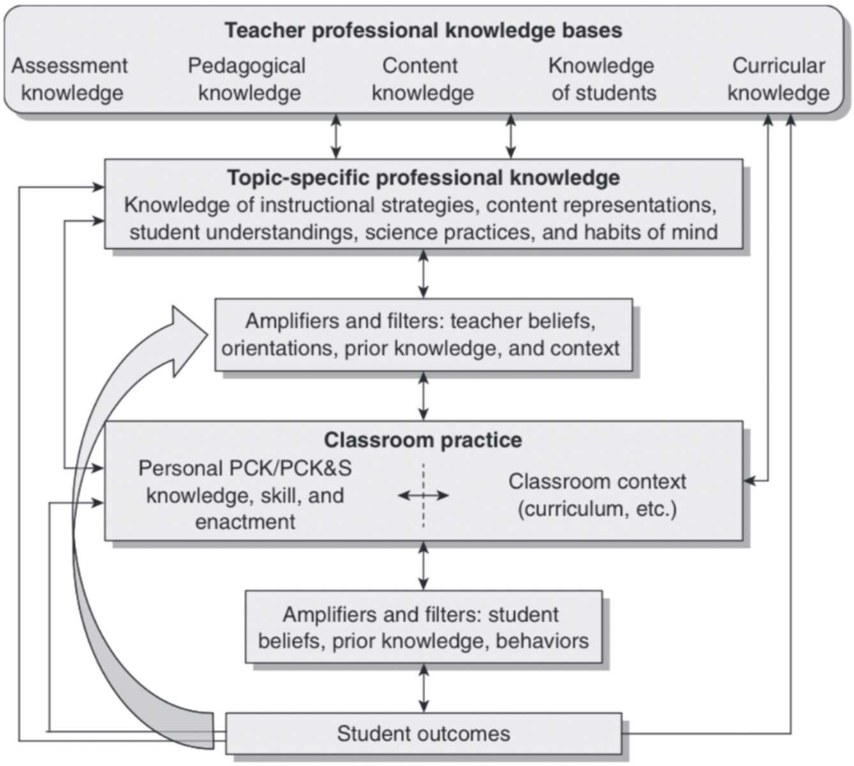

Figure 1.9 Gess-Newsome's (2015) Consensus Model (p.31)

In consensus model, the role of student outcomes and classroom practice is apparent. Moreover, two-way interactions are seen among elements of the consensus model. Topic-specific professional knowledge (TSPK) is linked to classroom practice. Similar to Magnusson et al. (1999)'s PCK model, teachers' orientations and beliefs seem to be an overarching component. Teacher beliefs, orientations, prior knowledge, and context act as amplifiers and filters between TSPK & classroom practice, classroom practice & student outcomes. In other words, these filters shape the decision-making process of teachers in the classroom.

Recently, Refined Consensus Model (RCM) is proposed by Carlson and Daehler (2019). One of the important features of this model is identification of collective PCK (cPCK), personal PCK (pPCK), and enacted PCK (ePCK). In this model, enacted PCK (ePCK) represents teachers' knowledge and skills in a particular environment to reach students outcomes. In this process, teachers need time to plan, teach and reflect on learners' need, instructional strategies and representations, and integration of several factors in pedagogical reasoning. On the other hand, personal PCK (pPCK) represents teachers' cumulative and dynamic PCK and skills in collaboration with students, colleagues, and others. A teachers' pPCK is unique to each teacher and developed and refined over time along with teaching experiences, education and professional sharing. Learning context (i.e., classroom environment, museum) is another important feature and serves as an amplifier of pPCK. On the other hand, cPCK represents an amalgam of more than one science educators' contribution in addition to teacher's own professional knowledge. The cPCK includes discipline-specific PCK, topic-specific PCK and concept-specific PCK.

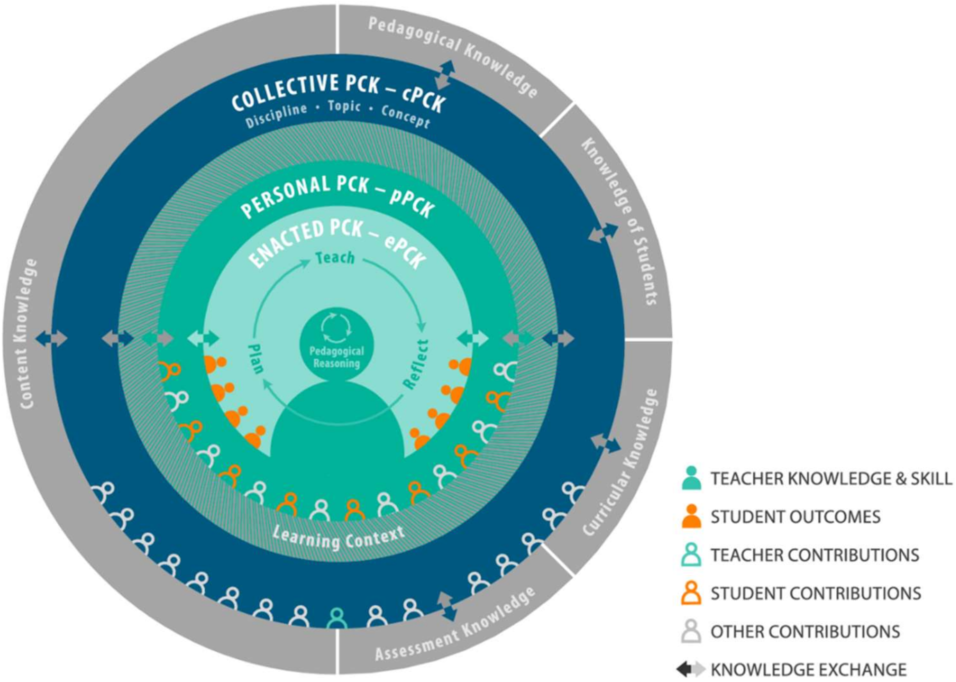

Figure 1.10 Carlson & Daehler's (2019) Refined Consensus Model of PCK (p.83)

Among those models, the current study adopted Magnusson et al. (1999) model since it is not only more common in PCK studies (i.e., Lankford, 2010; Şen, 2014; Schultze & Nilsson, 2018) but also provides a more extensive view on specific topics to identify teacher knowledge (Abell, 2007). Moreover, Also, the model of Magnusson et al. (1999) PCK is topic-specific in its nature (Veal & MaKinster, 1999; Friedrichsen, Boz, & Hanuscin, 2014). Thus, to investigate the in-service science teachers' pedagogical content knowledge (PCK), human body systems, as one of the complex system were selected in the current study. Therefore, this study addressed the experienced science teachers' PCK regarding human body systems.

1.1 Significance of the Study

Overall, this study is significant in that it uncovers experienced in-service science teachers' PCK in the context of human body systems. First significance is related to the topic it covers. Human body is a complex system as it consists of sub-systems that interact with each other (Hmelo-Silver and Azevedo, 2006; Ben-Zvi Assaraf, Dodick, & Tripto, 2013). Learning complex systems (i.e., the respiratory system) is important to handle real world problems (Hmelo, Holton, & Kolodner, 2000) and teachers' PCK is corelated to students' achievements (Gess-Newsome, 2015). Therefore, teachers should be aware of the nature of complex systems to support an effective learning experience for students (Hmelo-Silver, Marathe & Liu, 2017). Additionally, human body systems occupied an important place in middle school science and high school biology curriculum. In the middle school, science teachers are required to teach Muscular and Skeletal System, Digestive System, Circulatory System. Respiratory System, Urinary System, Endocrine System, Nervous System to their 6th grade students and Reproductive System to7th graders. So, human body systems as core topics located in national science curriculum and are taught at all levels of the education, including middle and high school. Accordingly, understanding complex systems and facilitating their learning are important part of science learning (Hmelo-Silver & Azevedo, 2006; Tripto, Assaraf, Snapir & Amit, 2013). Despite of its curricular importance, teachers had difficulties in establishing the connection among human body system organs (Patrick & Tunnicliffe, 2010) which in turns may prevent coherent understanding of the complex nature of HBS. This may be the reason why HBS have still remaining among the topics in which students have learning difficulties (e.g., Ramadas & Nair, 1996; Teixeria, 2000) as well as possess misconceptions, such as for circulatory system (Fančovičová & Prokop, 2019; Aydın & Balım, 2009); respiratory system (Aydın & Balım, 2009) and breathing (Fančovičová & Prokop, 2019); Furthermore, teachers had misunderstanding about gas exchange (Pelaez et al., 2005), and digestion (Prokop & Fančovičová, 2006). Moreover, when PCK studies are examined, studies in the field of chemistry are dominant, so there is a need to enlighten science teachers' PCK regarding biology and physics topic (Aydın & Boz, 2012). The present research, by addresses abovementioned issues, intended to extend current understanding of teachers' PCK in the context of human body systems.

Working with teachers can be considered as another sig. of the study. Previous studies mostly focused on pre-service teachers (Aydın & Boz, 2012) and showed that pre-service teachers do not have sufficient subject matter knowledge as well as PCK (Aydın & Boz, 2012). They also stated that PCK develops with experience due to interaction with students in classroom environment (Cochran et al., 1993). thus, more research on science teacher PCK is needed especially with expert teachers (Abell, 2008) who have well-structured and well-organized subject matter knowledge (Gess-Newsome, 1999). Therefore, studying with experienced teachers, current study has implications for teacher education

The present study conducted to unveil experienced science teachers' PCK regarding human body system by taking all components of Magnusson et al. (1999) model into consideration without ignoring overarching component, which is orientation toward science (Friedrichsen et al., 2011; Aydın & Boz, 2012; Abell,2007; Friedrichsen, van Driel & Abell, 2011). Considering the important role of orientation toward science for developing PCK (Brown et al., 2013) it is necessary to do further research on science teaching orientations (Friedrischen & Dana, 2005) which have an. Besides, along with substantive knowledge, current research examined the syntactic knowledge as a part of SMK.

One of the factors that makes this study significant is the use of multiple data sources (i.e., pre-interview, classroom observations, post-interview). This enables collecting and analyzing data in a detailed way to reveal PCK which is hidden construct in teachers' mind (Abell, 2008).

Finally, findings of this study may have contributions to the studies conducted especially in the field of the experienced science teachers' PCK in regarding HBS as one of the complex systems in science. At the same time, it may provide teachers with important clues for teaching of the complex systems like HBS.

1.2 Statement of the Problem

To purpose of this study is to reveal experienced science teachers' pedagogical content knowledge in the context of human body systems. Although human body systems include seven sub-systems, only the digestive system, circulatory system, respiratory system, and urinary system were selected as topics of the study. The participating teachers' nature of science (NOS) understanding as syntactic knowledge and substantive knowledge were examined as subject matter knowledge. The theoretical framework of this study is based on Magnusson et al. (1999)'s PCK model. Therefore, the participating teachers' orientation toward science, knowledge of students, knowledge of curriculum, knowledge of instructional strategies, and knowledge of assessment strategies in terms of human body systems were revealed. In the light of these considerations, the following research questions and sub-research questions were addressed.

1. What are the experienced science teachers' PCK regarding human body systems?
    1.1. What are the experienced science teachers' orientation toward science teaching?
    1.2. What are the experienced science teachers' knowledge of students regarding human body systems?
    1.3. What are the experienced science teachers' knowledge of curriculum regarding human body systems?
    1.4. What are the experienced science teachers' knowledge of instructional strategies regarding human body systems?
    1.5. What are the experienced science teachers' knowledge of instructional strategies regarding human body systems?
2. What are the experienced science teachers' subject matter knowledge regarding human body systems?
    2.1 What are the experienced science teachers' substantive knowledge regarding human body systems?
    2.2 What are the experienced science teachers' syntactic knowledge regarding human body systems?

2.3 What are the experienced science teachers' system understanding in the context of human body systems?

1.3 Definition of Important Terms

Content Knowledge: Shulman (1986, p.9) explained content knowledge as "the amount and organization of knowledge per se in the mind of the teacher". In this study, content knowledge is examined as substantive and syntactic based on Schwab (1964)'s categorization (Abell,2007). Human body systems including digestive system, respiratory system, circulatory system, and urinary system were examined as substantive content knowledge. Moreover, teachers' nature of science understanding was investigated as syntactic content knowledge based on And-El-Khalick and BouJade (1997).

Human Body Systems: The human body consists of several subsystems which interacts with each other in the body (Hmelo-Silver & Azevedo, 2006). There are eleven organ systems (i.e., digestive, muscular, endocrine, respiratory systems) in human body (Simon, Dickey & Reece, 2018). Each of them works together to fulfill body functions. The four of these organs systems which are digestive, circulatory, respiratory, and urinary system were selected within the scope of this study.

PCK: Shulman (1986) defined PCK as "the ways of representing and formulating the subject that make it comprehensible to others" (p.9). Therefore, it related to teachers' teaching strategies such as analogies, activities and examples to provide effective teaching environment by using knowledge of students' difficulties and misconceptions.

CHAPTER 2

LITERATURE REVIEW

This study aims to reveal experienced science teachers' pedagogical content knowledge (PCK) in the context of human body systems (HBS). Participants' subject matter knowledge (SMK) was categorized into substantive and syntactic knowledge. The knowledge of human body systems and teachers' understanding of human body as complex systems were examined as substantive knowledge while their nature of science (NOS) understanding were presented as syntactic knowledge. In accordance with this view, PCK studies followed by human body system both foreign and Turkish were summarized.

2.1 Studies on Pedagogical Content Knowledge

Studies on PCK were organized in several different science disciplines. Studies focusing on life science/biology, chemistry and physics were represented in this section respectively. Each heading was further categorized in the following order: i) studies on PCK either in abroad or in Turkey, ii) PCK development. First, studies on life science/biology are summarized. Then, PCK for NOS studies are presented.

Studies on Life Science/Biology

The studies conducted on biology field were generally based on Magnusson et al. (1999)'s model and the relevant data for them were collected from experienced secondary biology teachers and middle school science teachers through interviews and classroom observations. For example, Chapoo, Thathong and Halim (2014) studied in the context of nature of organisms. CoRe questionnaire about the nature of organisms, and classroom observation were used. Interviews were conducted 52 students of her after teaching. The results of the study showed that her purpose and goals to teach science was related to NOS understanding. Moreover, she addressed the students' needs and prior knowledge. Regarding the knowledge of instructional strategies, she used questioning, discussion, and pictures. She was knowledgeable about the curriculum since she was one of the members of school-based science curriculum developers. Finally, considering her knowledge of assessment, she used formative assessment and applied several assessment methods (i.e., multiple choice tests, observation, concept mapping).

Similarly, Lankford (2010) conducted a study to elicit six teachers' PCK in terms of diffusion and osmosis. In addition to interviews and classroom observations, lesson plans and documents were used to collect data. The results of the study indicated that most of the participant teachers had constructivist orientation toward science teaching due to their own teaching experience and school context. Moreover, participant teachers used demonstrations, analogies, and laboratory investigations as topic-specific instructional strategies. Five out of six teachers followed 5E instructional strategies. Furthermore, the participating teachers recognized students' difficulties and facilitated their learnings with diagrams and computer animations. In addition, teachers also gave importance to the determination of students' prior knowledge before teaching. Other than that, the teachers used formative assessment to evaluate their students' understanding through learning process. Also, the teachers created horizontal and vertical relationships related to the curriculum. Moreover, the teachers exceeded the curriculum by mentioning out of curriculum concepts. Finally, participating teachers' PCK were well integrated due to their teaching experiences.

On the other hand, Lucero et al. (2017) only investigated the relationship between teachers' SMK and students' knowledge of conceptions (KOSC) about the evolution by natural selection. Data were collected from four biology teachers whose experience levels differed between 1 to 7 years through interviews by using Conceptual Inventory of Natural Selection (CINS) questionnaire. In the interview, participant teachers were asked about their students' thinking on natural selection. Also, students' responses to the CINS and classroom observations were used as data. The CINS included 20 close-ended questions about students' alternative conceptions. The classroom observations were video recorded. Firstly, the participants were asked about their SMK about natural selection to identify their previous knowledge, and then they were requested to predict the incorrect answers which were possible for students to choose in the CINS by providing rationale behind them. Then, CINS was applied to 392 students (grade 9-12) in total who were selected from the classes of the participating teachers. Finally, and participant teachers' instructions and students were examined by taking into consideration the interaction between students and teachers during the classroom. The results of the study showed that the teachers' SMK and KOSC were independent from each other according to their responses. However, researchers indicate that there was a minimum threshold of SMK to recognize students' alternative conceptions. Moreover, participants in this study showed strong KOSC. However, they were unaware of better instructional strategies that might be implemented during their instruction for the improvement of students' learning. Researchers believe that teachers who had less experience with lower SMK are less likely to have strong KOSC and they may not apply effective instructional strategies to draw the attention towards alternative conceptions.

In addition to studies revealing teachers' PCK, studies examining the relationship between PCK components have also been conducted. For instance, Park and Chen (2012) examine the interaction among PCK components in terms of heredity and photosynthesis by using Pentagon Model (Park & Oliver, 2008b) as theoretical framework of the study. Another purpose of this study was to develop a tool to make PCK more visible. The study was conducted with four high school biology teachers who were working at the same school and using the same curriculum. All the participants had a master's degree, and their years teaching experiences were different from one another. The researchers utilized semi-structured interviews, classroom observations, lesson plans and samples of students' work such as their lab reports, assignments, and poster presentations as data collection tools. There were three types of interviews in this study: i) background interviews, ii) pre-observation interviews, iii) post-observation interview. The purpose of the background interview was to identify teachers' background knowledge, their orientation toward science teaching and their knowledge regarding heredity and photosynthesis. Moreover, the purpose of pre-observation interview was to reveal teachers' planned actions, including curriculum objectives about teaching heredity and photosynthesis. The purpose of post-observation interview, on the other hand, was to elicit teachers' ideas about lessons by also considering the observer field notes. Data was analyzed through in-depth PCK analysis, enumerative approach, and the constant-comparative method. The results of the study revealed that each teacher had a different PCK Map, and each teacher had a different PCK Map in terms of heredity and photosynthesis. At the end of the study, researchers found that the interaction among PCK components were topic-specific and unique. In addition, it was revealed that the knowledge of students (KSU) and the knowledge of instructional strategies (KISR) were the key components to guide teachers' PCK. The lowest interaction was found between knowledge of curriculum and other components. Knowledge of assessment strategies had closer relationship with the knowledge of students and knowledge of instructional strategies than orientation toward science teaching. Finally, didactic orientation toward science teaching caused the interaction between knowledge of instructional strategies and other PCK components to hinder.

In addition to studies including in-service teachers as participants, there are also studies which investigated pre-service teachers (e.g., Käpylä, Heikkinen, & Asunta, 2009). Käpylä et al. (2009) conducted a study to show the effect of subject matter knowledge on pedagogical subject matter knowledge in the context of photosynthesis and plant growth. Data were collected from 10 primary and 10 secondary pre-service biology teachers. Lesson plans, interviews and questionaries were used to as data collection tools. The findings of the subject matter knowledge were presented under three categories: i) knowledge on starting materials and products of photosynthesis, ii) the connection of photosynthesis and plant growth, iii) main source of the mass of the plant. The results showed that primary student-teachers had limited understanding when compared to secondary pre-service biology teachers. In addition to the subject matter knowledge, the teachers' PCK was examined through knowledge on conceptual difficulties of the students, knowledge on curriculum, teaching methods, and orientation to teaching. The analysis of the data showed that, the biology student-teachers were more knowledgeable than primary student-teachers with regard to the knowledge of students. Primary student-teachers were not familiar with students' conceptual difficulties. On the other hand, pre-service biology teachers were aware of the fact that students had challenges in understanding the main sources of plant growth and mass. Then, in terms of the main teaching goals, pre-service biology teachers indicate more essential content when compared to elementary teachers. Moreover, both groups of teachers indicated that knowledge of basic ecology was the most crucial one. Furthermore, with regard to the educational activities, pre-service biology teachers preferred direct activities (i.e., examining plan structure). However, pre-service primary teachers chose indirect activities (i.e., writing manuscript for animation). Also, both groups had limited knowledge of topic-specific strategies. Therefore, it could not be related with subject matter knowledge. Finally, in terms of teaching orientation, pre-service primary teachers' orientation seemed constructivist while pre-service biology teachers' orientation seemed as if a combination of both constructivist and conceptual change orientation. In summary, Käpylä et al. (2009) concluded that subject matter knowledge is partially impactful on pedagogical subject matter knowledge.

In addition to the studies carried out abroad, there are additional studies in the context of Turkey as well. A number of researchers studied with experienced science teachers. (Şen, 2014; Caylak, 2017; Şen, Öztekin and Demirdöğen, 2018; Tıraş, 2019; Yılmaz-Yendi, 2019; Sagbilge & Öztekin, 2021). Similar to the studies above, the researchers collected data through multiple sources including interviews, classroom observations and documents from experienced middle school science teachers. Moreover, Magnusson et al. (1999)'s model was preferred as the framework of these studies. Each study given below examined five components of Magnusson et al. (1999)'s model.

For instance, Şen (2014) investigated teachers' PCK about cell division. The researchers collected data from pre-interviews with CoRe questions (Loughran et al., 2004), VNOS-C questionnaire (Lederman et al., 2002), post-interviews, classroom observations and teacher documents. Multiple case study design was followed, and the participants were three experienced science teachers who graduated from elementary science education in Turkey. The findings were categorized as syntactic knowledge, substantive knowledge and PCK. First, in terms of syntactic knowledge, participant teachers had either adequate or informed views of empirical NOS, inferential NOS, and creative imaginative NOS. Also, while one of the teachers had informed views of subjective NOS, the other had inadequate views. The teachers were categorized as having inadequate views about tentative NOS, socio-cultural NOS, theories and laws aspect. Second, in relation to substantive knowledge, the participant teachers' knowledge of basic cell division terms, cell cycle, mitosis, and meiosis were categorized as partial and sound understanding. Participant teachers touched upon subject matter goals, schooling goals and affective goals either in pre-interviews or classroom observations. Moreover, all participating teachers were aware of the place of cell division in the curriculum. They could mention vertical and horizontal relationship. Moreover, they were knowledgeable about the instructional objectives. Researcher revealed that participating teachers were knowledgeable about students' misconceptions, and they were also aware of the sources of misconceptions (i.e., daily life language, textbooks, teachers). However, teachers did not use constructivist-based strategies (i.e., conceptual change) to eliminate misconceptions. Furthermore, participating teachers focused on conceptual understanding when they assessed their students. They used both alternative assessment techniques (i.e., concept map, poster) and traditional assessment techniques (i.e., matching, short answer) while applying both formative and summative assessments strategies. Moreover, in terms of knowledge of instructional strategies, participating teachers preferred to use visuals, videos, illustrations as topic-specific strategies. However, they did not use student centered subject specific strategies due to time limitations and their lack of knowledge about strategies.

By utilizing same sets of data, Şen et al., (2018) investigated the effect of subject matter knowledge on PCK about cell division. The findings of the study showed that the teachers' orientation toward science was similar to each other albeit they had different levels of subject matter knowledge. Participants were categorized as content-experts, curriculum-led and content-novice based on their subject matter knowledge. It was seen that being content-expert teacher brought about both advantages and disadvantages regarding the knowledge of the science curriculum. For instance, content-expert teacher was more knowledgeable about horizontal relationship and the importance of cell division in the curriculum. However, she violated the curriculum by giving extra-curricular knowledge about the topic. Similarly, content-novice teacher also exceeded the curriculum by mentioning the high school biology concepts. Yet, curriculum-led teachers stayed loyal to the curriculum. In terms of the awareness of students, teachers who had rich subject matter knowledge seemed more knowledgeable. For example, content-expert and curriculum-led teachers were aware of prerequisite knowledge that students must have to understand cell division better. The content-expert teacher was more knowledgeable about students' difficulties and gave many examples unlike other teachers. All participants addressed the curriculum objectives when they were addressing their students. However, while content-expert teacher and content-novice teacher used only traditional assessment techniques, curriculum-led teacher preferred both alternative and traditional methods. Lastly, researchers asserted that rich subject matter knowledge led teachers to develop topic specific strategies. Specifically, participant teachers had limited knowledge about subject-specific strategies and preferred didactic teaching. Besides, content-expert teacher presented more analogies than the others. Also, only content-expert teacher used modelling. In conclusion, researchers revealed that the teachers' knowledge of students' understanding, and knowledge of instructional strategies were influenced by subject matter knowledge. In addition, teachers' orientation toward science were not affected by teachers' subject matter knowledge. Moreover, it was realized that rich subject matter knowledge may bring about curriculum violation.

Similar to Şen (2014), Tıraş (2019) PCK in the context of ecosystems. Data were collected from two in-service experienced teachers who were teaching at public schools in Turkey. Multiple data sources including pre-interviews, classroom observations and field notes were used to reveal teachers' subject matter knowledge and PCK. The researchers found that science teachers had limited understanding of substantive knowledge. Participating teachers' beliefs were mostly on subject matter goals by transmitting prescribed objectives related to ecosystems although they touched upon the schooling goals and affective goals. Then, in terms of curriculum knowledge, the teachers were not aware of all the objectives and could not connect horizontal and vertical relationships. Moreover, although the teachers addressed students' difficulties, they did not prefer using constructivist strategies to determine and remediate students' misconceptions through their instructions. Teacher mentioned that the sources of students' difficulties emerged from the daily life language. In addition, the teachers seemed aware of the subject specific strategies (i.e., field trip) as they presented didactic instruction by using questioning methods. Moreover, participating teachers used traditional assessment techniques instead of alternative assessment. The teachers assessed students' conceptual understanding. However, they did not aim at evaluating students' science process skills.

In a similar line, Yılmaz-Yendi (2019) studied experienced science teachers' SMK and PCK about biochemical cycles in the context of education for sustainable development. Three experienced science teachers participated in this study. Multiple case study design was applied, and data were gathered from semi-structured interviews, classroom observations, card sorting activity, and documents including teachers' drawings and exam papers. The results of the subject matter knowledge showed that while two teachers exceeded the curriculum, the other one had limited knowledge considering the scope of the curriculum. Researcher found that participating teachers were aware of the curricular objectives, and they connected vertical and horizontal relationships. Besides, they were aware of the prerequisite knowledge for students to facilitate their understanding of biochemical cycles. Furthermore, it was seen that the teachers had deficiencies in the understanding of subject-specific and topic-specific strategies. Their instructions were didactic, and they evaluated their students with traditional assessments.

Recently, Sagbilge and Öztekin (2021) conducted a study to reveal three experienced science teachers' PCK in the context of seasons, weather, and climate. The relevant data were collected from semi-structured interviews and classroom observations. The results of this study showed that the teachers preferred direct instruction, questioning and discussion to reveal their students' prior knowledge. They utilized drawings, simulations, videos, and analogies as topic-specific representations. Moreover, they also mentioned the use of experimentation and modelling as topic-specific activities. Furthermore, teachers were aware of pre-requisite knowledge for students to understand the target topic in a better way. Also, the participants were knowledgeable about the place of this topic in the science curriculum, prescribed objectives, vertical and horizontal curriculum. Regarding the knowledge of materials, all teachers preferred to use textbook as the main source while some of them used online simulations and additional books. Finally, all the participating teachers assessed students' conceptual understanding about related topic based on prescribed objectives in the curriculum by using written examination and questioning methods.

In the context of Turkey, there are also studies which investigated pre-service teachers as well as in-service teachers. For example, Usak (2009) explored pre-service science teachers' PCK about the cell. The data were collected from six teachers via lesson plans, interview, and concept mapping. Findings revealed that participants had high self-efficacy about their SMK. They were knowledgeable enough about cell to teach students. Most of the participants' knowledge of the curriculum was inadequate regarding the time planning. Moreover, they mostly preferred teacher centered instruction. Concerning assessment strategy, participants were familiar with traditional (i.e., Open-end question, Multiple choice, Gap-filling) and alternative assessment techniques (i.e., Performance evaluation Structured grid, Concept map).

To be brief, when the studies in the field of biology are examined, it is seen that there are studies that reveal all aspects of teachers' PCK, the effect of SMK on PCK, and the relationship between PCK dimensions. Researchers mostly used Magnusson et al. (1999) model of PCK. Previous studies regarding PCK were reported for both in-service and pre-service teachers. As a result, experienced in-service teachers mostly had well integrated PCK. Moreover, having a strong SMK of teachers may have caused them to go beyond the curriculum or having a limited SMK may cause insufficient student knowledge.

Researchers also examined the development of PCK regarding teaching biology (e.g., Mthethwa-Kunene, Onwu and de Villiers, 2015; Brown et al.2013). For instance, in the context of teaching basic school genetic concepts, a study related to biology teachers was conducted by Mthethwa-Kunene et al., (2015). This study aimed at revealing the experienced successful biology teachers' PCK and its development. Participant teachers' PCK was examined according to their topic-specific subject matter knowledge, pedagogical knowledge and knowledge of students' pre-conceptions and learning difficulties. There were several data collection tools which included interviews supported with concept maps, documents including lesson plan and students' work sample, and classroom observations. Researchers categorized subject matter knowledge as declarative, procedural and conditional knowledge as explained by Juttner et al. (2013) by asking questions of 'What", "Why", and "How". Purposeful sampling strategy was utilized and four teachers who taught biology to Grade 11-12 students in Switzerland were selected, and they had 5 to 22 years of experiences. The analysis of concept maps was done quantitatively according to the rubric based on number of concepts and its hierarchical and sequential relationship. In addition to that, classroom observations were analyzed through iterative coding and categorization of teachers' actions. The results showed that each teacher had 85% or above score of their concept maps and they were categorized as having adequate content knowledge about genetics provided in the curriculum. When it came to their instructional strategies, they adopted different instructional strategies such as peer teaching, analogies, and illustrative diagrams. All of them started their lesson by questioning strategies to create a relationship between students' prior knowledge about new topic. However, participant teachers did not use any structured activities such as experiments, and simulations. Data related to teachers' knowledge of students' pre-conceptions and learning difficulties indicated that teachers did not plan their lectures according to students' difficulties and misconceptions. Teachers thought that abstract nature of genetics was one of the sources of students' difficulties. Moreover, courses in the university, textbooks, curriculum, teaching experiences and in-service professional development biology workshops were found to be the sources of development of PCK. Finally, at the end of the study, it was revealed that post-reflection guideline helped participant teachers to refine their PCK.

Similarly, Bravo and Cofré (2016) explored two biology teachers' PCK development about the theory of evolution (TE). Those teachers attended a professional development program (PDP). PDP aimed at developing teachers' understanding of NOS and evolution as well as accompanying teachers through their instruction of evolution. Multiple case study design was followed in the study, and the participating teachers studied in the same teacher-training program at the same university. However, their experience levels (i.e.,10 years and 4 years) were different from each other. The study investigated how the PCK elements for evolution developed with the participation of two biology teachers in the PDP, which aspects of the PCK for evolution of the biology teachers were modified due to the PDP, and which PDP elements were influential in the changes of teachers' PCK for evolution according to the teachers. The first stage of PDP was about updating the content of evolution and teaching NOS explicitly as well as discussing the relationship between NOS and evolutionary theory. It also included misconceptions and learning difficulties about evolution. At the beginning of the PDP, participating teachers had insufficient understanding of NOS and evolution. However, participating teachers' NOS understanding and knowledge of evolution were developed at the end of the first part of the PDP. In the second stage of the PDP, teachers planned lessons about evolution by addressing instructional strategies they would use. In addition, teachers prepared additional lesson materials. Then, the teachers implemented their plans in these lessons. Their instructions were video recorded. There were two lessons which were about the NOS aspects related to human evolution. Data were collected with semi-structured interviews (CoRe before the PDP, a group interview, CoRe after the PDP). In this study, Magnusson et al. (1999)'s model except orientation towards science was used to capture teachers' PCK. Data analysis conducted with Atlas.ti 6.2. software. PaP-eR (Loughran et al., 2012) was used to reflect on teachers' thinking. The findings of the study showed that the teachers' knowledge of instructional strategies was modified. For instance, one of the participating teachers had traditional teaching styles previously. She modified her teaching by creating connections with NOS aspects (i.e., the difference between theory and law after the PDP). The teachers became aware that teaching NOS affects students' understanding of TE positively. The teachers' knowledge of students in terms of students' difficulties and misconceptions was also observed to improve during this process.

In addition to the PCK development of in-service teachers, studies have also dealt with pre-service teachers. For instance, Brown et al. (2013) conducted a longitudinal multiple case study to examine the development of four pre-service biology teachers' PCK. Development of those teachers' science teaching orientations, knowledge of students' understanding of science and instructional sequence and their interaction throughout certification program were revealed at the end of the study. All participant teachers had undergraduate degrees in biology and attended a science teacher preparation program. Courses that students attended focused on inquiry based and conceptual change approach and instructors emphasized using 5E instructional model. To provide a holistic understanding, multiple data collection was used and these included interviews, observation field notes, classroom documents and lesson plans. The results of this study showed that the sources of pre-service biology teachers' science teaching were their K-16 learning experiences, and their other backgrounds. The teachers had strong orientations and they were heavily resistant to change. According to those teachers, teaching was mostly about delivering science content while the role a teacher was that of a guide. Secondly, participant teachers' knowledge of learners developed through the internship. In other words, it could be seen that science method courses helped prospective teachers to be aware of students' difficulties. With regard to the knowledge of instructional sequence, they started with transmitting scientific knowledge since they believed that learning begins with the teacher presenting the information first. Although, they became more competent regarding instructional strategies, none of them could follow 5E learning cycle phase. Finally, researchers revealed that the participant teachers' knowledge of learners and instructional sequences were consisted with their science teaching orientations.

Nugraha (2017) investigated pre-service science teachers' developing PCK about the digestive system by using CoRe. Data were obtained from 20 pre-service teachers in teacher education program via CoRes, interviews, reflective journals, and field notes. According to the participant pre-service teachers, students should know (1) digestive system organs and accessory digestive system organs, (2) the food processing including ingestion, digestion, absorption, and elimination, (3) digestive deficiency. Participant teachers aimed at delivering the content of the curriculum. They thought that teaching digestive system was important to maintain a healthy life. Moreover, pre-service teachers thought that students may have difficulties regarding the digestive system. For example, according to teachers, students were not aware of accessory digestive system organs, and four stages of food processing. Participant teachers thought that daily life experiences may be the reason for students' pre-conceptions. In addition, they proposed a student-centered teaching method which includes role playing, experiments, and games to teach the digestive system. Finally, the teachers planned to use only test to assess their students. The researcher concluded that CoRe is useful tool to develop pre-service teachers' PCK.

Researchers were interested not only in biology but also in chemistry context. Similar to studies on biology, studies on chemistry were also conducted to elicit both in-service and pre-service teachers' PCK, the role of SMK on PCK (e.g., Rollnick et al., 2008). While some studies revealed all aspects of PCK (e.g., Gencer & Akkus, 2021), some of them presented only one dimension of PCK (e.g., Boz & Boz, 2008).

Studies on Chemistry

In Sweden, Drechsler and Van Driel (2008) also revealed nine experienced chemistry teachers' PCK about acid-base chemistry. The aims of this study were to reveal participants' PCK about students' difficulties and how they cope with students' difficulties. Moreover, participants' perception about their PCK regarding acid and bases were also presented. Two years before the interview, participants attended a course on students' difficulties and models related to acid-base chemistry. A semi-structured interview including three phases (the briefing and warm-up phase, the main phase and the debriefing phase) was conducted to collect data. For the first phase, participants' ideas about the teacher training course were discussed. Then, for the main phase, teachers' planning about their teaching and how their teaching changed in time, the textbooks the participants used, the teachers' opinion about students' difficulties in acid-base topic were discussed. Finally, participants were requested to draw storylines to represent their satisfaction with their teaching of acid-base through the years. Findings showed that teachers were aware of students' difficulties. For example, participants believed that students had difficulty in calculations, writing and interpreting equations and bases (more than acids). All participants were aware of the fact that the students had difficulty in models (Boyle, Arrhenius, and Brønsted model) of acids and bases. However, few of them preferred to show different models. They believed that students would overcome these difficulties in upper secondary education. Furthermore, regarding teaching, five of participants show student-oriented teaching and reflected students' difficulties when they plan their lesson by using demonstrations, experimental material, and simpler calculations. They also discussed the use of models of acids and bases in their teaching. Other four teachers did not mention the use of models of acids and bases although they were aware of the models. Moreover, results from story-lines show that six out of nine teachers' level of satisfaction increased over the years.

Differently, the study conducted by Rollnick et al. (2008) presented two South African case studies to reveal the role of subject matter knowledge on PCK by adopting Gess-Newsome (1999)'s model. While one of the cases was about teaching of a mole, the other one focused on teaching of chemical equilibrium. Data were collected through CoRes, PaP-eRs, pre-interview, classroom observations, post-interviews, documents including textbooks, and the exam papers that the teachers had. Classroom observations were videotaped during the teaching of chemical equilibrium at a tertiary institution. For the case of teaching a mole at the high school context, the classroom observations were audiotaped, and field notes were also used. Data were collected from two experienced teachers for the case about the mole, and from an experienced teacher for the case of chemical equilibrium. For the first case study, the mole concept, teachers attended a workshop which provided them some activities related to the mole. Findings of the first case study showed that the participants had limited SMK. Thus, they had difficulty in providing effective teaching. For example, although they used analogies, they did not provide well-organized connections. They also had difficulty in constructing a connection between big ideas due to the lack of understanding of subject matter knowledge. With regard to the second case which was about chemical equilibrium in an access program, the participant showed well-established SMK contrary to the teachers in the first case study. Thus, the participant presented strong PCK during the lectures although his interview did not make the issue clear earlier.

Similar to PCK studies in abroad, there are also several studies conducted in Turkey focusing on teachers' PCK. Recently, Gencer and Akkus (2021) investigated the topic-specific nature of experienced secondary chemistry teachers' PCK of two topics which were interactions between chemical species and states of matter. Each component of Magnusson et al. (1999) model was examined by using multiple data collection tools (i.e., semi-structed interviews, classroom observations, card-sorting activity, and field notes). The data were collected from the two teachers who were teaching at 10^{th} grade. Findings revealed that both participants had multiple orientations for both topics. For instance, one of the participants had student-centered orientation about interaction between chemical species while teacher-centered orientation for states of matter. It was understood that her orientation was topic specific. In terms of knowledge of curriculum, participants were knowledgeable about the objectives, limitations, and vertical and horizontal relationships. Moreover, they did not use subject-specific instructional strategies while participants' topic-specific instructional strategies were different from each other. The teachers preferred lecturing or questioning to start the lesson. Participants used analogies, role-playing and ball-stick models to teach interaction between chemical species while preferring daily life examples to teach the states of matter. They were also aware of students' pre-requisite knowledge. However, their knowledge about students' difficulties was not quite enough. Finally, the teachers' knowledge of assessment strategies was not different for the topics. They used questioning as a formative assessment method to evaluate prior knowledge. Concerning the summative assessment, participants applied written tests including true/false, matching, multiple-choice, open-ended and fill-in-the blank type questions. The teachers generally evaluated content knowledge rather than the science process skills and nature of science understanding.

To better understand topic-specific nature of PCK, Aydin et al. (2014) revealed topic-specific nature of PCK from two experienced secondary school chemistry teachers in terms of electrochemical cells and nuclear reactions. Case study methodology was applied in this study. Data were collected through semi-structured interviews including card-sorting activity, content representation (CoRe), classroom observations and field notes. Purposeful sampling strategy was used to reach rich data. Both participant teachers seemed to have didactic orientations although they used hands-on activities, analogies, and animations during their classes. Teachers' knowledge of instructional strategies showed difference against two topics. They had teacher-centered teaching styles for electrochemical cells. In other words, teachers used lectures with the help of topic-specific structured cookbook laboratory, demonstrations, analogies, daily life examples, and video illustrations about electrochemical cells. However, they presented less teacher-centered instruction on nuclear reaction by utilizing nature of science implicitly and Science-Technology-Society-Environment (STSE). Students actively participated in classroom discussions on nuclear reactions. Teachers implicitly addressed to tentative NOS which was scientific knowledge that is a subject of change. In addition, teachers used modelling, representations, and daily life examples to make the topics more concrete on students' mind. Teachers' knowledge of the curriculum also showed differences between two topics. That is, they had more comprehensive understanding on electrochemical cells topic than nuclear reactions. To illustrate, teachers made more connections with related topics and criticized the sequence of concepts regarding the electrochemical cells. With regard to the knowledge of learner aspect of PCK, both teachers were more knowledgeable about electrochemical cell topic when it was compared to nuclear reactions topic. Finally, when it came to the knowledge of assessment, teachers did not represent topic-specific assessment strategies. However, teachers had more coherent assessment strategies about electrochemical cells than nuclear reactions. For example, they used several assessment strategies such as questioning, quiz and paper-pencil test as both formative and summative assessment throughout the electrochemical cells topic. For nuclear reactions topic, teachers did not do formative assessment. Also, teachers did not touch on students NOS understanding. Instead, they limited assessment for only science content for both topics.

In addition to studies conducted in the field of chemistry, there are also studies that revealed the PCK of pre-service teachers as well as in-service teachers. One of the studies was conducted by Aydin et al. (2010) to investigate the factors that affect pre-service teachers' decision on teaching methods in the context of separation of mixtures topic. Six pre-service teachers who were registered in teaching experience course attended this study as participants through purposeful sampling method. Although participants took the same courses, their SMK and PCK were different from each other. In addition, their motivation towards teaching were different. The data were collected via semi-structured interviews, observations, lesson plans, and participants' reflections about their own teaching. Researchers revealed that there were many factors that affect pre-service teachers' decision on instructional strategies. According to data analysis, topics, mentors, general PK, knowledge of students, teachers' their own learning styles or personalities, time, SMK, classroom management concerns, and courses that teachers previously took were the effect behind teachers' decisions. For example, although pre-service teachers prepared a lesson plan for teaching, their mentors made modifications or changed the instructional strategies that the pre-service teachers planned to use. Also, two out of six participants articulated that they were influenced by their mentor's teaching style. Furthermore, the topic was influential factor for teachers to design their lesson. For instance, one of the participants said that the laboratory activities were required to teach the separation of mixtures.

Another study explored pre-service science teachers' PCK and SMK in the context of chemical reaction. Usak, Ozden and Eilks (2011) studied with thirty pre-service teachers as participants in this study. Eight participants in the same sample were also interviewed. Results of this study show that participants' understanding of chemical reaction is not well developed. In terms of pedagogical content knowledge, most of the participants were not aware of students' learning difficulties and misconceptions.

Moreover, while four out of eight participants focused on lecturing by transmitting facts, only one teacher mentioned student-centered activities (i.e., concept mapping). As assessment strategies, teachers preferred traditional techniques such as multiple-choice questions due to entrance exam for high schools and universities.

Boz and Boz (2008) focused only one aspect of PCK and revealed prospective chemistry teachers' knowledge about instructional strategies about particulate theory. Data were collected from twenty-two teachers via vignette, semi-structed interviews and lesson plans. The results showed that teachers preferred concrete objectives, computer animations and expository teaching to introduce the topic. When teachers' lesson plans were analyzed, it was seen that they mostly preferred lecturing and questioning. Results also indicated that some of the reasons behind teachers' decisions are their knowledge of students, SMK and pedagogical knowledge. For instance, one of the participants preferred to use computer animation to overcome students' difficulties about movement of particles by showing the vibration of particles in a solid matter. Moreover, as general pedagogical knowledge, they mentioned younger students need concretized abstract concepts and visualize to understand better.

In short, the aforementioned studies indicate that PCK is specific to topic. Similar to studies on biology, it can be asserted that experienced teachers were more knowledgeable about each PCK dimension than pre-service teachers. Moreover, teachers' SMK, pedagogical knowledge, topic and experience were some of the reasons of teachers' PCK.

Researchers also examined the development of PCK regarding teaching chemistry. For instance, Schultze and Nilsson (2018) investigated how could chemistry teachers' PCK about chemical bonding be refined with the help of coteaching with two upper grade secondary school students. Vygostskian zone of proximal development and PCK were used as a theoretical framework for the study. The participants' PCK development was examined by using Magnusson et al. (1999)'s. Data were collected through classroom practices, semi-structured interviews, coreflection and coplanning sections. In coreflection and coplanning sections, coteachers and classroom teacher shared their ideas about how to plan a lesson and their evaluations about these lessons. Students were also evaluated on a web-based questionnaire after each lesson. Coevaluation and coplanning sessions as well as the interviews were transcribed and analyzed using ‘f4analysis’ software. Analysis of the current study showed that the teacher’s knowledge of students contributed the awareness of instructional strategies. Thus, it might be said that co-teachers may serve as a bridge between teachers and students. Finally, it was observed that co-teaching affected the teacher’s decision-making process in a positive manner.

Another line of development of PCK is interested in novice teachers. For example, Pitjeng-Mosabala and Rollnick (2018) explored the TSPCK of uncertified novice science teachers who attended a Professional Development Intervention (PDI) about the particulate nature of matter. TSPCK included students’ prior knowledge, curricular saliency, representations including analogies, what is difficult to teach and conceptual teaching strategies. The data were gathered from 14 teachers by TSPCK and CK test (pre-study and post-study), and CoRes (before and after teaching). Besides, video-recorded classroom observations, fieldnotes and interviews were used only for four selected teachers. The findings of the study revealed that all teachers’ CK developed as well as their TSPCK. The four teachers who were observed in classroom showed higher development than the others since their teaching practice were under investigation. Using CoRe before teaching facilitated teachers’ thinking processes. The researchers concluded that PDI and classroom teaching practice support the development of teachers’ TSPCK.

In addition to in-service teachers, the researchers also examined the PCK development of pre-service teachers. A study about pre-service teachers was conducted by Faikhamta, Coll and Roadrangka (2009). The researchers explored the pre-service chemistry teachers’ development of PCK based on chemistry method course and field experiences. Magnusson et al. (1999)’s model PCK model was used in the study following a multiple case design. The data were collected from four chemistry teachers. The purpose of the PCK-based chemistry course was to improve pre-service teachers’ PCK about chemistry. There were 16 weeks included with three-hour classes in each week. The focus of the study was more on classroom-based and school-based activities. The classroom-based activities included discussions on different topics, academic readings about NOS, constructivist-based instructional strategies. The school-based activities were related to field experience including interviews and observations of experienced teachers. Data were collected by interviews, classroom observations, a chemistry content knowledge survey, a beliefs survey, and documents. Researchers made cross-case analysis to compare four teachers. First, the pre-service teachers' educational background and beliefs to teach and learn science were gathered. Then, the participants constructed a lesson plan and applied this lesson plan for high school chemistry students. At the end of the course, teachers were asked to modify and improve their lesson plans. After they performed microteachings based on their modified lesson plans, they took feedback from their peers and instructor in addition to their own reflections. The findings of the study showed that although pre-service teachers' first lesson planning also included students' expected outcomes, instructional activities, and materials as well as assessment, there was no relationship among these components. However, their second attempt for lesson planning revealed that PCK-based chemistry method course contributed to the improvement of pre-service teachers' PCK. Participants' second lesson plans show that there were relationships among PCK components. Researchers found that role modelling and reflections affect pre-service teachers' PCK positively. In addition, the field experience seems an important factor for teachers to develop both expertise and self-confidence in their instruction.

Another line of research is about physics context. In this field, studies were interested in the comparison of reported and enacted PCK (e.g., Mazibe, Coetzee and Gaigher, 2018), interaction among PCK components (e.g., Caylak, 2017), and the development of PCK both for in-service and pre-service teachers were presented.

Studies on Physics

In South Africa, Mazibe, Coetzee and Gaigher (2018) investigated a comparison between reported and enacted PCK regarding graphs of motion. The reported PCK represent teachers finding obtained from CoRe and interviews while the enacted PCK represent teachers' PCK in their teaching. In this case study, data were collected from four physical science teachers who were teaching at 10th grade via CoRe through interviews and classroom observations. Topic-specific pedagogical content knowledge was examined as knowledge of learners' prior knowledge, curricular saliency, students' difficulties, representations, and teaching strategies. Findings from the teachers showed that their scores of the enacted PCK were lower than or similar to the reported PCK. At least one component of enacted PCK for all teachers was lower than their reported PCK. Although participant teachers reported PCK was rich, they failed to reflect their knowledge in teaching. On the other hand, few cases showed that their enacted PCK was better than reported PCK. Researchers explained these results by mentioning tacit nature of PCK. Moreover, results show that lack of content knowledge affect PCK negatively.

In the context of Turkey, Caylak (2017) investigated the interaction of PCK dimensions in terms of three topics which are work and energy, simple machines, and friction force. Data were collected from a single case through semi structured interviews, classroom observations, classroom field notes, card-sorting activities and CoRe questions. The purpose of study was to reveal PCK of a science teacher who teaches gifted students. Findings of the study showed that the teacher's class had four parts including beginning of the lesson, introduction of the new concept, elaboration of the concept and evaluation. Participant supported student-centered teaching, but classroom observation data showed that she generally utilized lecturing with topic-specific representations. She followed the objectives given in the science curriculum. In addition, the teacher utilized different activities since gifted students showed higher performance in a shorter time than regular students. These activities included upper grade level objectives and materials. Moreover, regarding knowledge of goals and objectives, the participant was knowledgeable about horizontal and vertical relationship. As an example of vertical relationship, after the teacher taught potential and kinetic energy, she questioned energy conservation. She assessed students' prior knowledge regarding simple machines. She was also aware of characteristics of gifted students and paid attention to them when she was planning and teaching the topics. Furthermore, she was knowledgeable about pre-requisite knowledge to learn work and energy, simple machines and friction force. For example, she knew that force, net force and reluctant force were prerequisite to learn work and energy. In terms of her knowledge of area of students' difficulty, the teacher was aware of the fact that students had difficulty to understand work and energy, and simple machines since they were abstract topics. She realized that students needed more concrete explanations (i.e., mathematical calculation, enriched activities) to understand better. However, the teacher did not seem knowledgeable about knowledge of students' alternative conceptions. In terms of knowledge of instructional strategies, the teacher applied different strategies for three topics. She used questioning, illustrations, demonstration, experimentation to support teaching. As her knowledge of assessment, she used both formal and informal assessment strategies. Finally, the researcher found that both planning and teaching map of participant had topic-specific characteristics in terms of interaction of PCK components.

In addition to the studies conducted with in-service teachers, a study related to pre-service teachers was conducted by Halim and Meerah (2002) in physics context. The knowledge of students' and the knowledge of topic-specific strategies of 12 pre-service teachers were examined. Participant teachers had different degrees and teaching experience. However, their teaching experience was not gained in a formal school environment. All the teachers attended a post-graduate course that lasted for a year. Data were collected by utilizing a questionnaire, and it was given to 12 teachers. Then, interviews were conducted with the selected teachers. Data were analyzed into three categories: teachers' expectations about students' answers, teachers' understanding of concepts, teachers' topic-specific strategies to remediate students' misconceptions and facilitate their teaching. The results of the study yielded different results. First, the participant teachers were inadequate in terms of their awareness about students' misconceptions. Second, there were teachers who were aware of students' misconceptions, but they did not pay attention to them. They solely relied on explicit explanations to boost their teaching and help students overcome their misconceptions. Third, there were teachers who preferred using effective teaching strategies including several representations such as analogies and experiments. In conclusion, researchers found that teachers' knowledge of students and knowledge of representations were interconnected with their subject matter knowledge. Besides, it was revealed that teaching experience facilitated trainee teachers to remediate their own misconceptions. In this way, teachers' PCK could develop over time.

Researchers also investigated the development of physics teachers' PCK. For example, Henze et al. (2018) explored nine experienced science teachers' developing PCK based on the implementation of the new curriculum. Participant teachers were working at five different schools. Their PCK was examined in four dimensions: knowledge of goals and objectives related to "Models of Solar System and the Universe" in the curriculum, knowledge of instructional strategies, knowledge of students' understanding and knowledge of assessment strategies. Data were gathered through semi-structured interviews over three years. The results of the study showed that mainly two types of PCK emerged. Type A PCK focused on model content while type B PCK focused on model content as well as model production and thinking of models. The development of Type A PCK was improved later on in terms of instructional strategies. However, knowledge of goals, objectives and knowledge of assessment did not significantly change. When the development of the PCK elements of Type A examined, it was seen that the development of teachers' knowledge of instructional strategies was related to the knowledge of assessment, knowledge of curriculum and knowledge of students. About the development Type B PCK, the knowledge of instructional strategies, the knowledge of students and the knowledge of assessment were consistent with each other. However, knowledge of goals and objective was not significantly developed. In conclusion, while Type B PCK elements consistently and dynamically developed, interaction with Type A PCK elements seems to be more static. Researchers concluded that development of PCK was influenced by the teachers' general pedagogical knowledge and beliefs as well as their subject matter knowledge.

Recently, Melo, Cañada-Cañada, González-Gómez and Jeong (2020) explored developing PCK of an experienced physic teacher in terms of the electric field through teacher training program in Columbia. The teacher PCK was identified before the program and the content were determined with the participant. Findings showed that after the training intervention program, participant’s knowledge of curriculum and instructional strategies developed.

There are also studies examining the PCK development of pre-service teachers. To illustrate, Aydeniz and Gürçay (2018) investigated the development of pre-service physics’ teachers’ PCK through CoRe construction about heat and temperature. All dimensions of Magnusson et al. (1999) framework was addressed in this study. Data were collected from 16 third year pre-service physics teachers. 18 questions constructed and answered by the participants, participants’ answers to CoRes, and participants’ reflections on the intervention were used as data. Findings showed that participants had minimum threshold SMK in terms of heat and temperature. Their scores of conceptual tests were not significantly different from each other. In terms of development of PCK, most of the participants showed progress. For instance, they became more knowledgeable about students’ misconceptions, learning difficulties as well as instructional assessment strategies. Their orientation toward teaching also developed through intervention.

In conclusion, research studies on PCK are widespread both in Turkey and abroad, and the results are generally consistent with each other. In the light of the studies mentioned above, it can be said that the experienced teachers were well-informed about students’ needs and used topic specific instructional strategies based on students’ difficulties and misconceptions. Moreover, these teachers were knowledgeable about the curriculum, and they used both formative and summative assessment strategies. Research studies on PCK show that teachers’ PCK is topic-specific as well and PCK is affected by subject matter knowledge since it is necessary for effective teaching. Moreover, pre-service teachers had limited knowledge about students’ misconceptions and difficulties. Therefore, research shows that PCK develops over time with the help of experience.

One of the pillars of this study is to elicit teachers' understanding of nature of science as syntactic knowledge of subject matter knowledge and to reveal how they reflect this understanding in their teaching. To this end, in the following section, studies on PCK for NOS were presented.

Studies on PCK for NOS

Researchers interested in development of PCK for NOS. Hanuscin, Lee and Akerson (2011) conducted a study to reveal development of PCK for NOS. Three elementary science teachers participated in this study. The teachers participated a three-year professional development program about NOS. Magnusson et al. (1999)'s model of PCK was adopted in this study. This study represented secondary analysis of researchers' previous study (see Akerson & Hanuscin, 2007). Participant teachers' teaching experiences differed from 2 to 29 years. The participant teachers were accepted as effective ones due to their strong rationale and determination of teaching NOS. Also, Hanuscin et al. (2011) believed that those teachers affected students' NOS view in a positive manner. Researchers used several data collection tools including questionnaire, interview, fieldnotes and transcripts from professional development sessions, videos, lesson plans, classroom observation fieldnotes, and teacher documents from their previous study. The results indicated that there were three ways to transmit NOS into classroom. These are using kid-friendly terms, using operational definition of NOS within inquiry, and drawing analogies about NOS by using children's literature. Another important point is development of PCK for NOS. Participants' orientation shifted from activity-based orientation, towards inquiry orientation. With regard to knowledge of curriculum, it was seen that curriculum was not appropriate to present NOS in addition to the teachers' lack of knowledge about NOS materials. Teachers claimed that they were not provided in the curriculum. With the help of a professional development program, teachers adopted NOS for their curriculum. Additionally, teachers' knowledge of instructional strategies was developed by help of professional development program, and they applied their knowledge through their lectures. For instance, they used analogies and inquiry-based activities. Also, data showed that the teachers' knowledge of assessment was not strong as knowledge of instructional strategies. That is, they were not knowledgeable about what to assess or how to assess their students. Finally, the teachers' knowledge of learners was insufficient although they proposed kid-friendly terminology for NOS. Hanuscin et al. (2011) discussed that teachers may have insufficient knowledge of assessment strategies for NOS. Therefore, lack of knowledge about assessment also inhibits teachers' knowledge of students' difficulties.

Supprakob, Faikhamta and Suwanruji (2016) conducted a study to investigate PCK for NOS of six novice chemistry teachers by adapting PCK to NOS framework (Hanuscin et al., 2011; Faikhamta, 2013). The participants' levels of experience differed between 1-5 years. All the teachers graduated from different schools. An interpretive multiple case study design was followed, and relevant data were collected through semi-structured interviews, classroom observations, fieldnotes, and documents. All interviews were audio recorded and teachers' instructions were video recorded. The researchers utilized Lederman et al. (2002)'s NOS framework and they adapted four more aspects: definition of science, scientific investigation, relationship among science, technology & society, and characteristics & work of scientists. Analysis of the data were done inductively and deductively based on Faikhamta's (2013) categorization including informed, partially informed, and naïve views. The findings of teachers' understanding of NOS were analyzed under three categories: scientific world view (i.e., definition of science, empirical evidence, scientific theory and law and tentativeness), scientific inquiry (i.e., myth of the scientific method, scientific investigation, observation and inference, creativity and imagination, and subjectivity and theory-laden) and scientific enterprise (socially and culturally embedded factors; the relationship among science, technology, and society; and characteristics of scientists). The participants show adequate understanding of some NOS aspects. Participants' views about scientific world view differed from each other. For instance, although the teachers had informed views tentativeness, they were partially informed or had naïve ideas about scientific theory and law. Regarding the definition of science empirical evidence, the teachers' understanding varied either as informed or partially informed. Second, most participants had informed views about scientific inquiry. All of the teachers had informed views in relation to observation and inference, and creativity and imagination. However, only one teacher who strongly believed that experimentation was the only way to develop scientific knowledge held naïve views about scientific investigations. Third, most participants had informed views about scientific enterprise. For example, all of the teachers were aware of the relationship among science, technology, and society. Thew were knowledgeable about difference between science and technology. However, many teachers believed that technology requires scientific knowledge. Therefore, they were labeled as partially informed. To summarize, it can be said that the teachers had adequate understanding of some NOS aspects. After their NOS understanding, the teachers' NOS definitions were also uncovered. They saw the meaning of NOS in two aspects: using scientific process to obtain scientific knowledge and the general characteristics of science. Moreover, the findings of the study showed that the teachers had poor understanding of PCK for NOS. First, teachers had different orientations about teaching NOS. For example, according to the results of interviews and questionnaires, three out of six teachers included guided inquiry orientation while other teachers had activity-driven orientation, project-based science orientation and inquiry orientation respectively. However, most of the participants did not implement NOS in their lessons. Most of their instruction did not reflect their orientation. Only one teacher presented multiple teaching strategies. Second, there was not a single teacher who articulated NOS as a central objective both in his/her planning and instruction although all the teachers were aware of the fact that NOS was included in their national standards. Third, the teachers had lack of understanding of the leaners' difficulties and prior knowledge of NOS although all teachers addressed the students' difficulties and prior knowledge in the field of chemistry. Fourth, most of the participants (five out six teachers), performed traditional teaching. Only one teacher tried to integrate multiple strategies (e.g., structured inquiry) in his/her lectures. In addition, there was not a teacher who explicitly taught NOS in their instruction. Finally, participant teachers did not aim to assess NOS neither in their lesson planning nor their instruction although they used both summative (i.e., tests, quizzes, homework, journal logs) and formative assessment (i.e., questioning, students' worksheets) techniques to evaluate students' understanding of chemistry. To conclude, the teachers had strong chemistry knowledge. They had lack of understanding of PCK for NOS although many of them had informed views of some aspects of NOS. Although their interview data revealed their adequate views of NOS, there was not any observed NOS implementation in their lessons. Supprakob et al. (2016) suggested that the reason behind teachers' deficiencies in understanding might stem from teacher preparation programs.

PCK for NOS studies were also conducted in Turkey context. Bilican, Tekkaya and Cakiroglu (2012) explored pre-service science teachers' PCK for NOS. Data were collected from three pre-service science teachers by the examination of lesson plans. Multiple case study design was applied to investigate the participants' instructional planning to teach NOS. During the previous semester before the beginning of the study, all participants were taught about NOS in a course named "Science teaching Method 1". While the study was being conducted, the participants attended "Science Teaching Method 2" course that focused on NOS and scientific literacy. Students were expected to prepare lesson plans by implementing NOS explicitly and they received feedback from their instructors. Then, they presented their lesson plans by taking the suggestions that their instructors gave into consideration. After the participants finalized their presentations, classroom discussions were held to refine students' NOS understanding. Three lesson plans of each participant were analyzed qualitatively. Analyses of the participant teachers' lesson plans showed that none of them included NOS objectives in their first lesson plans. However, they integrated NOS objectives in their third lesson plans, or both to second and third. Moreover, none of teachers implement NOS activities during their first lesson plans, although they were able to include NOS into their activities as parts of their second and third lesson plans. Finally, similar to objectives and activities, they did not evaluate NOS in their first lesson plans. In the end, except for one participant, two among the rest implemented NOS evaluation in their second and third lesson plans. In conclusion, researchers revealed that receiving feedback, classroom discussions and peer lesson plan presentations facilitated pre-service teachers' PCK for NOS understanding. In addition, since participating teachers' assessment for NOS were limited to summative assessment, it was recommended that assessment for NOS might be taught in more detail.

On the other hand, Yılmaz-Yendi (2019) explored experienced science teachers' NOS understanding about biochemical cycles in the context of education for sustainable development. Data were collected from three experienced middle school science teachers. Embedded VNOS-C questionnaire and classroom observations were used to collect data from the participants. The findings revealed that the teachers had lack of understanding of NOS. Specifically, the teachers had naïve explanations about tentative NOS, theory and law aspect, subjective NOS, and socio-cultural NOS. For instance, they believed that laws were absolute knowledge while they mentioned gravity and law of motion. The teachers also thought that scientific method required testable procedures since they believed that experimentation was needed to reach scientific knowledge. Moreover, according to participating teachers, science ought to be objective. The researchers also found that the teachers' naïve ideas affected each other. They did not implement NOS tenets in their instruction since their central goals were to transfer objectives and create environmental awareness. Researcher concluded that the participants had lack of understanding of PCK for NOS due to their orientations towards the teaching of science.

The development of PCK for NOS were also investigated in Turkey. For example, Demirdöğen et al. (2016) revealed pre-service chemistry science teachers' PCK for NOS. The participants included 30 pre-service chemistry teachers who studied at a teacher education program of a public university in Turkey. The researchers aimed at examining the development of PCK for NOS by using Magnusson et al. (1999)'s model as a framework of the study. Data were collected with several sources such as interviews, observations, 2- lesson plans (before and after NOS instruction) and reflection papers. VNOS-C (Lederman, 2002) was used to conjugate pre-interviews and post-interviews after NOS instruction. The study was presented as a part of an elective course named "Research in Chemistry Education" in the final year of the program. For this study, firstly participant teachers were given the nature of science instruction with the help of activities which were planned by the first author. There were 10 activities related to NOS instruction. It was aimed at revealing the pre-service teachers' ideas about selected component of PCK for NOS at each lesson. The instructor monitored the classroom discussions. For instance, participants were requested to explain their goals of science and chemistry education and how to support their goals with instruction. Each session ended up with presenting the scientific literacy and the importance of NOS. At the end of each classroom session, participants wrote a reflection paper. Data analyses were conducted to reveal participant teachers' NOS view and PCK for NOS by using in-depth analysis of PCK and constant-comparative method. The findings showed four major themes which will be explained here respectively. First, it was understood that the teachers need to have sufficient understanding of NOS and beliefs to intend to teach NOS. Second, participant pre-service teachers' PCK improved regarding NOS. That is, they could integrate at least some aspects of NOS into their instruction. Each participant showed different levels of integration and degree in PCK components. Third, the relationship between subject matter knowledge and PCK was revealed. Before NOS instruction, the participants had several misconceptions about NOS tenets. When VNOS-C was conducted after NOS instruction, it was seen that the pre-service teachers' NOS understanding altered positively. Even so, pre-service teachers had problems with empirical NOS, socio-cultural NOS, theory and law aspect and observation and inference aspects of NOS. The teachers implemented the tenets which they informed to their lessons. Lastly, with regard to interaction and integration of components of PCK, the teachers who had robust integration and interaction of components produced better lesson plans to implement NOS. Demirdöğen et al. (2016) revealed that participant teachers' mostly KoIS and STO were integrated into each other.

To conclude, the studies showed that the teachers had naïve ideas about NOS understanding and the reason for teachers' lack of understanding might have been due to teacher preparation programs. Therefore, professional development about NOS instruction is worthwhile for in-service and pre-service teachers to clear up misconceptions about NOS and develop PCK aspects for NOS regardless of their level of experience.

One of the scope of current study is substantive knowledge therefore, in the following section previous studies related to teachers' and students' knowledge of human body systems were represented.

2.2 Studies on Human Body Systems

In this part, teachers' knowledge of human body systems, and students' knowledge of human body systems, were respectively presented. Specifically, studies about understanding of the digestive system (e.g., Teixeria, 2000; Garcia-Barros, Martínez-Losada & Garrido, 2011; Ramadas & Nair, 1996), circulatory system (e.g., Pelaez, Boyd, Rojas, & Hoover, 2005; Sungur, Oztekin & Geban, 2001; Aydın & Balım, 2009), respiratory system (e.g., Garcia-Barros et al.,2011; Aydın & Balım, 2009) and urinary system (Prokop, Fančovičová & Tunnicliffe, 2009) were examined.

Teachers' Knowledge of Human Body System

Some studies investigated students' and teachers' misconceptions while some revealed understanding of substantive knowledge. In those studies, some of them considered the entire human body system. On the contrary, other studies focus on a specific human body system.

Pelaez et al. (2005) aimed at revealing prevalence and persistence of pre-service elementary teachers' misconceptions on blood circulation and assessing the effectiveness of learning activities on students. Participant pre-service biology teachers were students at undergraduate level in Introduction to Biology course. Data was collected from 88 students both qualitatively and quantitatively. Videotapes and interviews were utilized as data collection tools. To reveal students' understanding, first they were asked to visualize blood circulation. Secondly peer review essay was required to be written in order to organize ideas. Finally, as a third phase, a debate was organized to share ideas in a collaborative environment. The collected data showed that students had wrong ideas about blood circulation pathways, blood vessels, gas exchange, gas transportation & utilization and function of lungs. At the end of the biology course, it was seen that students had problems mostly with gas exchange, showing the highest prevalence. This study also revealed that the sources of such misconceptions emerged from deficiencies in prior knowledge, imprecise language, mental modelling.

Prokop and Fančovičová (2006) conducted a study to examine pre-service teachers' knowledge of human body who would, later on, become primary school teachers. Also, one of the purposes of their study was to reveal pre-service teachers' misconceptions about human body. The relevant data was collected from 133 freshman university students through a human biology knowledge questionnaire (HBKQ) and drawings. HBKQ included 30 open-ended questions about digestive, respiratory, circulatory, urinary, nervous, and reproductive systems, and these questions were mostly about their functions. Researchers used Reiss & Tunnicliffe (2001)'s classification to analyze drawing. The results showed that heart, lungs, and stomach were the most drawn organs respectively. However, there was no significant relationship between students' written responses and drawings. Students' written responses revealed that they lacked comprehensive understanding of digestive, respiratory and endocrine systems. On the contrary, students' drawings represented that they almost did not draw urinary, reproductive and nervous systems. Students knew that heart was vital, but they provided inadequate explanation about the reasons why it was. Moreover, students also lacked the necessary knowledge of where digestion occurs. Finally, students also had insufficient understanding of the concepts of hormones and the place of fertilization in the human body.

Patrick and Tunnicliffe (2010) explored science teachers' understanding of human body through various drawing. 71 teachers participated in this study and participants attended a workshop which was about frog and pig dissection in 2004. Before the workshop, teachers were asked several questions which included information about their gender, subjects that they taught, their reasons for attending the workshop, years of teaching experience, and whether they performed dissections in their previous classroom. Then, teachers were requested to draw the inner part of human body. The seven-point scoring method developed by Reiss and Tunnicliffe (2001) was used to analyze the data. Three scorers analyzed drawings independently and the inter-coder agreement was found to be 97%. The results of the study showed that the teachers were mostly aware of the digestive, circulatory, urinogenital and respiratory system organs. Majority of teachers drew the lungs, intestine, heart, stomach, and esophagus. Also, the researchers found that the scores of experienced teachers and teachers who performed dissection previously in their classes were higher than the others. However, according to overall results, researchers realized that the level of the teachers' scores were not very high. In other words, teachers' drawing showed similar patterns with students' drawing in the literature. Moreover, teachers were aware of the organs and which systems they belong to. However, it was found that they were insufficient to establish the connection among these organs. In conclusion, the overall knowledge of the teachers and the students were similar to each other. Patrick and Tunnicliffe (2010) suggested that teachers' subject matter knowledge should include more details. In this way, they can address the misconceptions, they can create relationships, and they can help students to construct cognitive maps. They also indicated that the teachers should also be able to create daily life connections during their lectures.

Briefly, teachers have difficulty in understanding human body systems as students.

In addition to the studies carried with teachers, there are additional studies conducted with students as well. These studies show similarities that both teachers and students had difficulty in internal human body organs and systems.

Students' Knowledge on Human Body System

There are several studies about student's knowledge of understanding of the digestive system (e.g., Teixeria, 2000; Garcia-Barros, Martínez-Losada & Garrido, 2011; Ramadas & Nair, 1996). The reported studies aimed at both pre-school age children, middle school students and high school students. For example, Teixeria (2000) conducted a study with 45 children aged between four and ten regarding their understanding of the structure and function of the digestive system. Children were randomly selected based on four groups, which are nursery group (age four), literacy group (age six), second year (age eight), and final year (age ten). Participating children were at the same private school. It was paid attention that students had no formal instruction regarding digestion concept before. Data were collected through one-on-one interviews with children. The researcher gave a chocolate bar to students and asked them to eat the chocolate and draw the body parts that chocolate passed through. After that, they were asked to tell the name and function of organs, what happens to the food they eat, and its appearance during each stage. The results were analyzed in two aspects: structure and function. First, findings related to the structure of the digestive system show that organs that children addressed were classified as mouth, pharynx-esophagus, abdomen, and anus. Four aged children preferred tummy as an abdomen while older children used scientific language and mentioned them as stomach or intestine. It shows that learning body parts takes time. All age groups use the term bottom while mentioning anus. However, the group that mentioned the anus the least is the age group of four. Also, groups age eight and age ten represented the digestive system as a tube. Moreover, 11% of children aged four and 25% of children aged six thought that an abdominal part of body is empty. Second, findings related to function of the system show that four aged children were not actually aware that ingested foods are digested and converted into tiny particles, contrary to eight and ten aged children. Moreover, although some children were aware that chewing is a way to transform foods, they had difficulty in chemical transformation of foods. Only six children (i.e., three from aged eight and three from aged ten) made a relationship between the digestive system and the circulatory system.

In conclusion, all children were aware that physical appearance of ingested food would change. Therefore, it can be said that group age of ten explained their understanding of digestion and digestive system based on biological terms while younger children's explanations based on their daily experiences and beliefs. This study supports that teachers should enrich the terms they use in the classroom and realize what students have in their minds. At this point, it is important to ask students to draw and explain their understanding. Finally, Teixeria (2000) proposed that children's understanding of transformation, especially chemical transformation, and digestive system need attention.

Garcia-Barros et al. (2011) conducted a study about students' (aged four to seven) understanding of digestive and respiratory system of the human being and other animals. They studied with 342 Spanish children who studied at same school. Researcher also aimed at recognizing changes of children ideas during three consecutive years. Data is collected with students' drawing. Findings of the study show that the older children have more complex understanding than the younger children have regarding digestion and respiration. For example, while younger children did not recognize any respiratory system organs, older ones identified the lungs. In addition, older children's drawing about digestive system were more complex than the youngers' similar to Teixeria (2000). Furthermore, students have better understanding of digestive system than respiratory system. Those students made a connection with stomach and respiration. Moreover, they did not consider the kidneys as an urinary organ. Also, children thought that feces and urine are expelled directly from the digestive system. It can be said that children had misconceptions about the digestive system. Moreover, analysis of children's understanding at the end of the three-year consecutive years shows improvement. For example, children became aware that the digestive system has two openings. Also, students became aware that intestine is one of the digestive system organs.

Ramadas and Nair (1996) studied with Indian students aged 6-13 to reveal their ideas of purpose and functions of digestive system by using system idea which includes structural/functional (static/dynamic) and purposive/non-purposive aspects, organismic or mechanistic nature of the system, and ideas of feedback and central control. Three open-ended tests and interviews were conducted to collect data. According to the school curriculum, students meet the digestive system when they are at 4th grade (at their 8 age). Participant students, who were in different schools, were asked to draw path of foods on an outline of the body. Then, structed interviews were conducted with selected students after drawing. Findings show that the idea of enclosed structured of the digestive system vary from younger children to older children. For example, many age of 6 students thought that food we eat go to entire body directly, while age of 7 students demonstrated a stomach as a bowl or irregular shape and older students were aware of organs and their shapes. Fewer students (10% of older than age 8) mentioned accessory organs. Moreover, findings show that students' socioeconomic status were an important factor to understanding nutrition. Students can be held basic concepts at their early age, but they had difficulty to incorporate with another knowledge. Students had lack of understanding chemical transformation of food although they were aware of mechanical transformation with the help of chewing. Furthermore, students did not make a connection with digestion and respiration, metabolism, growth. Therefore, researcher suggested to address importance of "system" concept to facilitate learning of human body system.

In addition to studies related to digestive system, students' knowledge of circulatory system also was examined (e.g., Fančovičová and Prokop, 2019; Sungur, Oztekin & Geban,2001). Fančovičová and Prokop (2019) investigated students' misconceptions about the human circulatory system. Data were collected from 220 students who studied grades 5-9 in Slovakia Students' misconceptions are identified by using questionnaire with open-ended questions and the drawing. Open-ended questions and drawing were about the importance of blood and breathing, draw path of blood heart and its function. Students' drawings of a heart were examined into four dimensions: heart shape, division of a heart, heart description and heart function. Then, students' drawings of the circulatory system were examined into three dimensions: the circulatory system drawing, the position of the heart and the size of the heart.

Correlational analysis was applied for data analysis. Researchers revealed that several misconceptions about the circulatory system and breathing. For instance, approximately half of the students associated breathing with oxygenation of the body. However, only 5% of students addressed the importance of oxygenation for degradation of nutrients. Many students (more than one third) were not knowledgeable about division of a heart. Furthermore, 55.9% of students had an idea relating that heart is responsible for blood purification.

Regarding circulatory system, Sungur et al. (2001) studied with eleventh grade students to reveal their misconceptions about the circulatory system and the effects of the contribution of conceptual change texts accompanied by concept mapping instruction on students' understanding. The students were interviewed to identify their misconceptions. Then, traditional instruction was applied for 23 students (control group) while instruction with the conceptual change texts accompanied by concept mapping was applied for 26 students (experimental group). Human Circulatory System Concepts Test (HCSCT) which include 16-item multiple-choice test developed by the researchers was applied to identify students' understanding of the human circulatory system. The internal consistency reliability (Cronbach's alpha) of HCSCT was 0.72. In addition, Science Process Skill Test (SPST) was applied for students to identify whether students' Science Process Skill's effect their understanding of circulatory system. Participant students were grouped as high achievers, middle (average) achievers, and low achievers based on their exam scores. Then, 10 of middle achievers' volunteers were selected and interviewed about blood, heart, and blood vessels. Moreover, the relationship between homeostasis and the circulatory system was asked to these 10 students. Results of this study shows that instruction with the conceptual change texts accompanied by concept mapping is more effective than traditional instruction to teach circulatory system better. Furthermore, students' science process skills and previous learning has important contribution on students' understanding.

Aydın and Balım (2009) carried out a study with 62 students at 6th grade to examine their misconceptions about human body systems which are the skeletal system, the circulatory system, and the respiratory system. Data were collected from three classes and while two classes were experimental groups, the rest was the control group. Lesson plans which are adapted from 7E learning cycle were applied both experimental groups. Then, technologically supported mind mapping technique was applied one experimental group and technologically supported concept mapping was applied other experimental group while the control group was taught according to the activities related to the Science and Technology Curriculum. Students' misconceptions were identified with comprehension test which includes 13 open-ended after experimental implications which lasted 4-weeks. Researchers found that students had misconceptions regarding the skeletal system, the circulatory system, and the respiratory system. For instance, students thought that oxygen-rich blood is found in the right side of the heart, or alveolus are responsible for expelling the oxygen-poor blood. Aydın and Balım (2009) concluded that conceptual change strategies will provide determination of students' misconceptions and eliminate misconceptions to improve effective learning.

There are also studies related to knowledge of all parts of human body (Ozsevgec, 2007; Aydın, 2016). Ozsevgec (2007) examined students' understanding of their internal body parts. Data collected from 112 students which were at sixth and eighth grade students in Turkey. Drawings of organs on a blank body map and writing of functions of organs were requested from students. Students' drawings were analyzed in terms of organs' presence, location, shape and function. Results show that heart was the most drawn organ. It was followed by lung, liver, stomach respectively. Also, more than half students had difficulty in representing location and shape of organs. Unlike drawings, students had difficulty to represent functions of the organs. For example, many students did not indicate the function of hearts correctly. They had also limited understanding of relationship among organs. Researcher concluded that 6th grade students had higher understanding than 8th grade since human body system topic was taught at 6th grade. Teachers' pedagogical content knowledge and students' memorization could be the reason behind this result. Researcher indicated that didactic teaching is mostly used to teach human body system. Özsevgeç (2007) also mentioned that students' terminology was controversial (i.e., using clean or dirty blood instead of oxygenated and deoxygenated blood). Teachers' terminologies, teachers pedagogical content knowledge and students' daily life experiences could be the reason for students' misunderstanding.

In the context of secondary school, Aydın (2016) aimed to reveal high school students' familiarity of organs and organ systems. Data were collected from 244 students by written responses to open-ended questions. Organs Knowledge Test which was prepared by researcher was used to collect data. Results show that heart, lungs, stomach, and kidneys were the most indicated organs among students. These organs are mostly related to students' daily life. Also, students mostly recognized the organs belonging to the digestive system. Moreover, students were aware that which system do heart, lungs, kidney, stomach and esophagus belong to. However, they confused that which system do small & large intestine, liver, pancreas and anus belong. Researcher believed that the students' view of the organs (i.e., small intestine, anus) that are a part of the digestive system as a part of the excretory system were resulted from, they are opposed by the expression of the excretory system instead of the urinary system from primary school to high school. Another important result is that students were aware of the functions of esophagus, heart, lungs, colon, and trachea while they confused the functions of liver, urinary bladder, and pancreas. Many students from 9th to 12th grade were not knowledgeable enough about functions of liver.

On difficulties that students have regarding human body systems, Tekkaya, Ozkan and Sungur (2001) investigated a total of 368 high school students, 184 were boys and 184 were girls to identify difficult topics in high school biology curriculum by consideration into gender differences. Moreover, interviews were made with 14 high school biology teachers to find out reasons behind students' difficulties. Data are analyzed with descriptive statistics. Findings show that there is significant difference between genders. Boys comprehend biology easy in contrast to girls. Moreover, Excretory System was perceived as difficult to learn by 22.6% of the students, while Circulatory System was perceived as difficult to learn by 21.2% of the students, Digestive System was perceived as difficult to learn by 20.7% of the students, Skeletal and Muscular System was perceived as difficult to learn by 20.7% of the students, Respiratory System was perceived as difficult to learn by 15.2%, among 30 topics. Teachers' and students' responses were consistent with each other. According to the teachers, students have problem with excretory system, particularly filtration done by kidney, blood pressure, and velocity of blood related to the human body systems. Moreover, students responded that lack of time, inadequate laboratory resources, and teaching style bring about learning difficulties.

On the other hand, Ahi and Balci (2017) studied children's knowledge of the respiratory system. Data were collected from a total of 60 children aged 5,7 and 10. There were 20 children from each age group. Typical case sampling was applied for phenomenology design in this research. Thinking aloud data collection was used. Before conducting interview with children, breathing exercise was made. Then, the children were given an outlined human figure and they were asked to draw the organs by considering the path of the air during the breathing process. By the way, students were interviewed by asking predetermined questions like where the breath first enters the body, how the breath is distributed throughout the body, the relationship between organs, the relationship between the respiratory system and other systems. Researchers found that as the students growing up, they stated more organs of the respiratory system. Aged 5 and aged 7 children noted that tummy is an organ and belong to the respiratory system. They also thought that intestines, heart, and stomach are the respiratory system organs. Mouth, lungs and trachea were the organs that students mostly addressed. Children were not familiar with pharynx. Moreover, students' drawings that aged 10 children represented organs better than age of 5 and 7 children. Interestingly, age of 5 children represented organs better than age of 7 children. Moreover, age of 5 children's ideas show that they thought that the digestive system and respiratory system work similarly. Age of 10 children could mention the many parts of the respiratory system. However, although 10-year-old children learned about the respiratory system at school, they did not have enough knowledge about the functioning of the respiratory system. In conclusion, researcher suggested that it is necessary to teach complex systems with different instructional strategies and identify prior knowledge about complex systems.

These studies showed that in different countries, students in different age groups had difficulty in understanding the systems. Students also had misconceptions about the digestive system, circulatory system, respiratory system, and excretory systems. For instance, students had difficulties about chemical digestion. Students were mistaken in the sense that feces and urine were expelled directly from the digestive system. Moreover, many students had misconceptions about the circulatory system and breathing.

Some studies have also explained the effect of various methods. For instance, Cansiz (2019) conducted a study to develop history of science activity to implement nature of views in the context of the circulatory system. Researcher developed an activity which last three class hours for 6th grade students. The activity was implemented at four steps which are experiencing historical material, engaging in probing questions, whole-class discussion, and creating generalization. Cansiz (2019) suggested this activity also to eliminate students' misconceptions. The circulatory system activity improved tentative NOS, subjective NOS, empirical NOS, creative and imaginative NOS. For the first step, About the Circulatory System story which is adapted based on the literature was distributed to the students. Teacher gave time students to read the story and answered their questions. Then, the students were asked to conclude the story. For the second step, the students were asked to several probing questions about the story. For instance, what could be the reason behind difference between Harvey and Galen's ideas about the circulatory system or do scientists use the same methods against problems and why.

Then, the third and fourth step demonstrated simultaneously. The teacher monitored the classroom discussion and students presents their answers to the probing questions. At the end of the discussion, the students were persuaded that there is no stepwise method to do science. Also, by addressing Galen's Blood Distribution Theory and then Harvey's Theory of Circulation, empirical NOS, subjective NOS, creative and imaginative NOS and tentative NOS were implemented. For instance, how did Harvey draw a conclusion despite not being able to observe the circulation was asked to the students to lead them creative and imaginative NOS. To conclude, About the Circulatory System activity had valuable impact to develop students' NOS understanding in the context of the circulatory system.

Sungur (2004) studied the effect of problem-based learning (PBL) on students' academic achievement in the context of excretory system in her doctoral dissertation. There were 61 tenth grade students who participated in the study. There were also two biology classes that were monitored by the same biology teacher. They were randomly selected from the classes as the experimental group and the control group. While experimental group was instructed based on problem-based learning method, control group was instructed with traditional learning method.

Human Excretory System Achievement Test and Motivated Strategies for Learning Questionnaire were applied both before and after teaching. Data were analyzed by Multivariate Analysis of Variance (MANOVA). The results of the study showed that PBL developed students' academic achievement and performance skills. Moreover, students' intrinsic goal orientation was also improved by the helps of PBL.

Prokop, Fančovičová and Tunnicliffe (2009) investigated the relationship between two types of instructions using drawings of the urinary and endocrine systems. One of the instructions, with the name of "general instruction" included more general questions (Draw what you think is inside your body), the other one, named "specific instruction" included specific questions (Draw the bones that are inside your body). 289 secondary school students (aged 10-15) participated in the study. First, the general instruction method was applied to the students, and they were asked to draw what they thought was in their body. Then, the special instruction method was applied and this time the question was "Draw the urinary system in your body". When the students finished their drawings, they were also asked to draw the endocrine system in their body. Second, urinary and endocrine systems were examined with 52 student teachers by using pretest-posttest procedure.

Results of the study showed that students aged 7 and 9 had the highest scores for each system since Human anatomy is given in the biology curriculum of that age. Moreover, the endocrine system was observed to be more difficult and abstract than the urinary system. In addition, considering the pre-test results of the pre-service teachers, it was seen that the level of the students' drawings might have been influenced by the students' prior knowledge.

The differences between the effectiveness of these two types of instructions may have emerged from the complexity of organ systems and students' prior knowledge. The researchers found that while general instruction method with drawing was appropriate for comparative studies, special instruction method with drawing was effective in revealing students' understanding in more detail. Researchers suggested that while students are taking responsibilities to sustain a healthy life, teachers should be informed about human body and guide students accordingly.

To sum up, both teachers and students had difficulty in internal human body organs and systems. They also had misconceptions regarding the digestive system, circulatory system, respiratory system and urinary system. The studies showed that different methods such as history of science activity and conceptual change texts were effective in teaching human body systems.

It can be said that the traditional teaching methods including the use of textbooks and transferring knowledge directly is not enough to remediate students' misconceptions.

In this part, studies related to teachers' PCK on different science dimensions and substantive knowledge of both teachers and students were reported. Next heading presented the methodology of the current study.

CHAPTER 3

METHODOLOGY

3.1 Research Design

In the current study, experienced science teachers' PCK regarding human body systems were revealed. PCK is a hidden construct in teachers' mind (Abell, 2008). Therefore, it requires detailed explanations to reveal teacher's PCK since knowledge and reasons behind teachers' actions in the classroom are crucial to recognizing their PCK. To meet this requirement, the qualitative methodology provides to get detailed understanding (Creswell, 2007). Denzin & Lincoln (2013) stated that "qualitative research is a situated activity that locates the observer in the world and consists of a set of interpretive, material practices that make the world visible" (p. 6). Therefore, qualitative methodology is appropriate for the current study to transform teachers' knowledge to science literature. Qualitative methodology also fits the aim of this study since the researcher is a key instrument, use multiple methods to collect data and observe participants in their natural settings (Creswell, 2007). In this study, a case study which is one of the types of qualitative methodology is selected. Creswell (2007) indicated that "case study research is a qualitative approach in which the investigator explores a real-life, contemporary bounded system (a case) or multiple bounded systems (cases) over time, through detailed, in-depth data collection involving multiple sources of information (e.g., observations, interviews, audiovisual material, and documents and reports), and reports a case description and case themes" (p.97). Merriam & Tisdell (2015) defined "a case study as an in-depth description and analysis of a bounded system" (p.37). Since two experienced science teachers were chosen as participants to examine their PCK deeply by using observations and interviews in their natural settings, they are considered a case of the current study. Therefore, this study can be considered a single case study. That is, their subject matter knowledge, including substantive and syntactic knowledge, and their pedagogical content knowledge were presented in detail.

3.1.1 General Design

In this section, sampling of the study, participants of the study, data collection tools were described in detail.

3.1.1.1 Sampling of the Study

The purpose of the current study is not to make a generalization, so a non-probabilistic strategy was used instead of probabilistic sampling (Merriam & Tisdell, 2015). Purposeful sampling, a type of a non-probabilistic strategy, was chosen to reveal experienced science teachers' PCK and SMK deeply (Merriam & Tisdell, 2015). One of the important points for purposeful sampling is deciding criteria for study (Merriam & Tisdell, 2015). The determined criteria allow researcher to identify information-rich cases (Merriam & Tisdell, 2015). In terms of reflecting the purpose of current study, the participants were selected according to certain criteria given below with their reasons were given below.

a. The first criterion was teachers' experiences since experiences is one of important factors on teachers' PCK (Chan & Yung, 2017). In addition, Abell (2008) believe that pre-service and beginning teachers do not present strong PCK. Abell (2008) indicated that science teacher education literature needs more studies on expert teachers.
b. The second criterion was that participant should be teaching at 6th graders during 2018-2019 academic year since there were classroom observa-tions during teaching human body systems, which are taught in the 6th-grade level (MoNE, 2018).

Participants' willingness to participate in the study and the location of schools in Ankara are also important. Therefore, convenience sampling, which is one of the types of purposeful sampling (Merriam & Tisdell, 2015), was used for the current study.

Two experienced science teachers were selected as a case of this study. They are working at the same private school located in Ankara. Anna graduated from middle school science education while Bethy graduated from chemistry. Some demographic information about the participants was summarized in Table 3.1.

Table 3.1 Participants' Demographic Information

Participant*	Teaching Experience	Bachelor's Degree	Faculty	Pedagogical Formation
Anna	16	Science Education	Education	Yes
Bethy	20	Chemistry	Arts & Science	Yes

*For the ethical concerns the researcher used a pseudonym Anna for Participant 1, Bethy for Participant 2.

3.1.1.2 Context of the Study

The school where the teachers are working is well-established. The physical conditions of the school are quite good and sufficient. The laboratories at the school are well-equipped. In other words, they have the laboratories capable of carrying out all the experiments given the curriculum Each classroom has computers and projectors. They do not have the smartboards at the time of study. The average number of students in classes is 25. The school consists of students generally coming from high income families.

3.1.2 Data Collection Tools

In qualitative research, interviews, observations, and documents are the ways to collect qualitative data (Merriam & Tisdell, 2015).

One of the important characteristics of qualitative research is that researcher is a primary instrument in terms of the researcher's ability to instantly respond and adapt during data collection to understand phenomenon (Merriam & Tisdell, 2015). Taking this view into account, the researcher was actively involved in the data collection and data analyzing process. Multiple data sources are necessary to reveal tacit nature of PCK (Aydın & Boz, 2012). In study, interviews, classroom observations, and teacher documents were used to get detailed information about teachers' knowledge regarding SMK and PCK (See Table 3.2.)

3.1.2.1 Interviews

Interview is one of the most common data collection tools in qualitative inquiry and best technique for case studies (Merriam & Tisdell, 2015). In addition, according to Patton (2015), interviewing is necessary to reveal people's unobservable thoughts, intentions and feelings and to make sense of what we observe. Therefore, interview is one of the important tools to capture the beliefs and ideas of teachers about their instruction and behavior in the classroom and to fill the gap that the researcher could not observe in the classroom. Semi-structured interviews were used in this study in terms of its flexibility. All interviews were audio-recorded with the permission of the participants.

Table 3.2 Data Collection Tools

Data Collection Tools	**Components of PCK and SMK**
Pre-Interview	
Human Body System Questions	Substantive Knowledge & Complex System Understanding
VNOS-C Questionnaire	Syntactic Knowledge
Content Representation (CoRe)	Orientation Toward Science Teaching Knowledge of Curriculum Knowledge of Students Knowledge of Instructional Strategies Knowledge of Assessment
Post-Interview Questions	Orientation towards science Knowledge of Curriculum Knowledge of Students Knowledge of Instructional Strategies Knowledge of Assessment

Table 3.2 (continued)

Observation	Orientation towards science Knowledge of Curriculum Knowledge of Students Knowledge of Instructional Strategies Knowledge of Assessment
Documents	
Personal Documents Visual Documents Researcher-Generated Documents	Knowledge of Assessment Knowledge of Curriculum Knowledge of Instructional Strategies Substantive Knowledge

Each type of interview was explained in detail in the following sub-titles.

3.1.2.1.1 Pre-Interviews

Three interviews which are syntactic knowledge interview including VNOS-C questionnaire, substantive knowledge interview including human body system questions, CoRe (Loughran et. al., 2004) questions conducted under the title of pre-interviews.

3.1.2.1.2 Human Body System Questions (Substantive Knowledge)

Human body as a complex system (Hmelo-Silver and Azevedo, 2006; Ben-Zvi et al., 2013), occupy an important place in both middle school science and high school biology curriculum. Understanding complex systems enable students to learn science (Hmelo-Silver & Azevedo, 2006; Tripto et al., 2013). In the middle school science, human body systems are in the 2nd unit of the 6th grade curriculum. Muscular and Skeletal System, Digestive System, Circulatory System. Respiratory System, Urinary System, Endocrine System, Nervous System occupied at 6th grade while Reproductive System is given at 7th grade. Substantive content knowledge questions were prepared by the researcher in line with the objectives given in science curriculum prepared by Ministry of National Education (2018) and science textbook approved by

Ministry of National Education in 2017. The purpose of the human body system questions is to reveal participating teachers' knowledge of digestive system, circulatory system, respiratory system, and urinary system. Overall, there were 112 questions including word association tests, drawing (i.e., concept maps, figure of respiratory system, and urinary system) to capture teachers' knowledge in depth. Extra-curricular questions were asked about homeostasis, dynamic nature of human body systems and system definition were asked to highlight teachers' understanding of human body system as complex system (see Table 3.3) (See Appendix A). Pre-interview which included human body system questions (substantive content knowledge) lasted approximately one and half hours approximately for each participant and was conducted at school where the teachers work.

Table 3.3 Examples of Human Body System Interview Questions

	Number of Questions	Data Collection Tools	Sample Questions
System Understanding	5	Pre-interview Classroom observation	How can you define a system? Can you give an example? Is HBS a system? What is it that makes HBS a system? How HBS works? What is the relationship among organ systems?
The digestive system	25	Pre-interview Classroom observation	What happens to the foods that we eat? How are foods digested? What kind of relationship is there among digestive system organs?
The circulatory system	31	Pre-interview Classroom observation	Why we need the circulatory system? What are the structures and the organs that make up the circulatory system? What is the difference between serum and plasma?

Table 3.3 (continued)

The respiratory system	20	Pre-interview Classroom observation	How can you explain the respiration? What are the structures and the organs that make up the respiratory system? What does breathing (gas exchange) mean to you?
The urinary system	18	Pre-interview Classroom observation	What is the function of the urinary system? What does urine mean to you? Can you draw a urinary system?

3.1.2.1.3 Content Representation Questions (CoRe)

Content representation is a well-known instrument developed by Loughran et al. (2004) to highlight teacher's PCK. CoRe is useful to capture teachers' PCK (Rollnick et al., 2008). Its translated version was constructed by Aydın (2012) by adapting to it chemistry. After taking permission from Aydın, Turkish version of CoRe was used as a data collection tool. In the purpose of the study, the researcher adapted the question to the human body system to reveal teachers' PCK depending on big ideas and concepts related to the objectives given in Ministry of National Education Science Curriculum (2018) (see Appendix B). Pre-interviews were conducted before the teachers teach human body systems to prevent teachers' from being preparedness. The purpose of asking pre-interview PCK questions was to reveal teachers' pedagogical content knowledge about human body systems. PCK summarizes under five main aspects: orientation toward science teaching, knowledge of curriculum, knowledge of students' understanding of science, knowledge of instructional strategies, and knowledge of assessment. These interviews spanned one and half hours approximately for each participant.

After completion of pre-interview PCK, teachers' syntactic knowledge was revealed.

3.1.2.1.4 Syntactic Knowledge

Participants' syntactic knowledge was highlighted with Views of Nature of Science Questionnaire (VNOS-C) created by Lederman, Abd-El-Khalick, Bell and Schwartz

(2002) (Appendix C). The adapted and translated version developed in Turkish by Dogan, Çakıroğlu, Çavuş, Bilican, and Arslan (2011) were used in current study (Appendix D) with permission. It consists of ten open-ended questions to reveal seven NOS aspects. These aspects explain the "Tentativeness, Creativity, Subjectivity, Empirical basis, Social/cultural embeddedness, Theories and laws, Observations and inferences" (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001, p. 15). Moreover, embedded NOS questions were asked participants. (See Table 3.4).

VNOS-C interview lasted twenty minutes approximately for each participant.

Table 3.4 NOS Questions

Number of Questions	**Data Collection Tools**	**Sample Questions**
9	Pre-Interview Classroom observation	What do you think science is and what makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g., religion, philosophy)? Do scientists use their creativity and imagination during their investigations? What is an experiment? Does the development of scientific knowledge require experiments?
3	Pre-Interview Classroom observation	Can you give any examples about experiments conducted about the human body systems? Can you give any examples about human body systems in terms of theories and laws? Do you have any information about the scientists who have contributed physiologically to the development of these systems in the past?

3.1.2.2 Classroom Observation

One of the meaningful ways of collecting data is observation (Merriam & Tisdell, 2015). Since teaching experience in real classroom context is important for PCK development (Barendsen, 2019), participating teachers were observed during their teaching the digestive system, circulatory system, respiratory system, and urinary system.

Observations were lasted for three months (October, November, December) in the fall semester of 2018-2019. Anna was observed for 21 class hours, and Bethy was observed for 24 class hours. Each lesson was audio-recorded with the permission of the teachers and the school administrations. All records were transcribed to analyze the data in detail. There were overlap in the lesson schedule of participating teach-ers. In this case, while the researcher was observing a class, she left the tape record-er to the other class to obtain data. During classroom observations, researcher took observation notes based on teachers' actions, questions, activities and interaction with students. In addition to the audio recording and field notes, researcher took photographs that participating teachers' drawing on the blackboard and slides that they presented.

Stance of observer is complete observer who is hidden from the classroom (Merri-am & Tisdell, 2015) without disturbing classroom environment. Observations were used to strengthen and confirm the findings obtained from pre-interviews. In this way, observations were used to triangulate data to increase internal validity (Merri-am & Tisdell, 2015).

3.1.2.2.1 Post-Interview

The researcher analyzed the classroom observations and pre-interviews for possible inconsistencies. Therefore, there were no inconsistencies in terms of SMK while some discrepancies were observed regarding PCK.

SMK

The researcher analyzed the classroom observation field notes and recognized that there were no inconsistencies between pre-interview and classroom observations in terms of subject matter knowledge. Therefore, post-interview did not conduct regarding about subject matter knowledge.

PCK

Post- *PCK* interviews were conducted after classroom observations were completed. The researcher analyzed the classroom observation field notes and recognized the inconsistencies between pre-interview and classroom observations for both participants. Although post-interview included some general questions (i.e., how did you feel after your teaching?), it includes unique questions for each participant based on inconsistencies between participant's pre-interviews and classroom observations. Post-interviews were conducted in the participants' natural settings (i.e., the school they work). Post-interviews were audio recorded and, all answers were transcribed by the researcher. Post-interview questions were given in Appendix E and Appendix F.

3.1.2.3 Documents

Documents are one of the data sources of qualitative research design (Merriam & Tisdell, 2015). Personal documents public records, visual documents, popular culture documents, artifacts/ physical material, researcher-generated documents are types of documents (Merriam & Tisdell, 2015). Personal documents, visual documents, and researcher-generated documents are the types of documents that are used in current study.

3.1.2.3.1 Personal Documents

Personal documents are referred as narratives that represent participant's actions, belief and experiences (Bogdan & Biklen, 2007). Personal documents are subjective as these materials are produced by the participants. In thus study, the question papers distributed by participating teachers before each unit and the quizzes they made after each unit were used as personal documents to analyze teachers' knowledge of assessment. Teachers' personal documents were used to enhance multiple sources of triangulation as well as observations and interviews for credibility of the study.

3.1.2.3.2 Visual Documents

Videos, photographs, visual materials available in natural settings where the data collected were described as visual documents (Merriam & Tisdell, 2015). In this study, researcher took pictures of teachers' drawings on the blackboard, teachers' presentations (i.e., the digestive system, the circulatory system), experimentation process (heart and kidney dissection) and models (the respiratory system model, the urinary system model).

3.1.2.3.3 Researcher-Generated Documents

Researcher-generated documents are produced by the researcher to learn more about the situation, person or event being researched (Merriam & Tisdell, 2015). In this study, researcher observed participating teachers' classroom and audio recorded their instruction to transcribe. In addition, researcher took classroom field notes. During pre-interview, participating teachers were requested to draw the digestive system, the respiratory system, the urinary system and the circulatory system model and their concept maps. In this study, teachers' drawings and concept map were used to as researcher generated documents. The researcher redrawn some drawings of teachers to make them clearer. Since all the drawings and concept maps were produced in Turkish, the researcher translated all data into English to make them understandable for people who do not know Turkish. The original data were also given in Appendix G.

The data were collected in the 2018-2019 academic year. Specifically, the data collection process started in September 2018 and was completed in June 2019.

3.2 Data Analysis

In qualitative research, data analysis and data collection happen at the same time (Merriam & Tisdell, 2015). Therefore, data analysis is an interactive and dynamic process that provides researcher to reveal trustworthy findings. In the current study, the data collection process helped the researcher organize and manage the data. The findings of the participating teachers were analyzed as their SMK and PCK. The details of analysis procedure were explained in following part.

3.2.1 Data Analysis of Subject Matter Knowledge

Shulman developed the idea of SMK based on Schwab's work (1964) which categorized subject matter knowledge into syntactic and substantive (Abell, 2007). "The substantive structure of a discipline is the organization of concepts, facts, principles, and theories, whereas syntactic structures are the rules of evidence and proof used to generate and justify knowledge claims in the discipline" (Abell, 2007, p.1107). In current study, participating teachers' knowledge of human body system and their understanding of human body systems as complex system were examined as substantive knowledge while their NOS understanding was evaluated as syntactic knowledge as Abd-El-Khalick and Boujaoude (1997) referred. Data analysis procedures of syntactic and substantive knowledge of participating teachers were explained in detail through following sub-titles, respectively.

3.2.1.1 Data Analysis of Syntactic Knowledge

In current study, participating teachers' syntactic knowledge were referred as their nature of science understanding by virtue of Abd-El-Khalick and Boujaoude (1997) and their NOS understanding revealed using VNOS-C questionnaire. Data were analyzed based on NOS aspects and descriptions (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001, p. 15). This rubric was presented in Appendix H.

3.2.1.2 Data Analysis of Substantive Knowledge

In this study, participating teachers' conceptual understanding of human body system and their understanding of human body system as complex system were presented as substantive knowledge. Specifically, data were collected for the digestive system, circulatory system, respiratory system and urinary system through pre-interview and classroom observations. The responses of participating teachers were interpreted based on the rubric prepared by researcher according to the scientific explanations of concepts related to each system (i.e., digestive, circulatory, respiratory, urinary) and complex system understanding (See Appendix L, Appendix M, Appendix N and Appendix O)

3.2.2 Data Analysis of Pedagogical Content Knowledge

In current study, participant science teachers' PCK was analyzed based on PCK model developed by Magnusson et al. (1999) in terms of on human body systems. All components of PCK and their sub-components related to human body system were used as codes for data analysis of PCK (See Table 3.5).

Table 3.5 PCK Components

Components	**Sub-components**
Orientations Toward Science Teaching	Central goals Peripheral goals
Knowledge of Curriculum	Knowledge of Goals and Objectives Knowledge of Materials
Knowledge of Students' Understanding of Science	Knowledge of Requirements of Learning Knowledge of Students' Difficulties
Knowledge of Instructional Strategies	Knowledge of Subject-Specific Strategies Knowledge of Topic-Specific Strategies *Knowledge of Activities* *Knowledge of Representations*
Knowledge of Assessment	Knowledge of Science Learning Dimension for Assessment Knowledge of Assessment Methods

3.2.2.1 Data Analysis Orientations Toward Science Teaching

Science teaching orientation is more complex and broader than described in literature (Friedrischen & Dana, 2005). Thus, in current study participating teachers' science teaching orientation was analyzed according to their central and peripheral beliefs. Friedrischen and Dana (2005) characterized central goals as dominator of teachers' thought and guide teachers how to plan lesson. Peripheral goals have less impact on teachers' decision-making process than central goals. Moreover, Magnusson et al. (1999) beliefs about goals of teaching science represent only subject matter goals. However, Friedrischen and Dana (2005) also implied affective domain and general schooling goals in addition to subject matter goals. Therefore, participating teachers' beliefs about goal of science were also categorized as subject matter goals, affective domain, and general schooling goals.

3.2.2.2 Data Analysis of Knowledge of Curriculum

Participating teachers' knowledge of curriculum examined as two sub-categories which are knowledge of goals and objectives and knowledge of specific curricular program and materials Magnusson et al., (1999). Data were obtained from interviews and classroom observations. In Turkey, all schools have to follow national board curriculum presented by Ministry of Education. Therefore, specific curricular program was not scope of this study. Codes produced based on obtained data and PCK literature. The codes used for analyzing knowledge of curriculum are presented in Table 3.6 below.

Table 3.6 The Codes for Knowledge of Curriculum

Categories	**Sub-components**
Knowledge of Goals and Objectives	HBS objectives that are prescribed by MoNE (2018) HBS restrictions that are posed by MoNE (2018) Horizontal relationships among HBS Vertical relationships related to HBS
Knowledge of Materials	Teacher's source of knowledge Materials that teacher use in classroom Teachers' purpose of using materials

3.2.2.3 Data Analysis of Knowledge of Students' Understanding of Science

Participating teachers' knowledge of students' understanding of science was analyzed into two categories namely, knowledge of requirement for learning including prerequisite knowledge to learn specific topic and knowledge of areas of student difficulty including misconceptions based on Magnusson et al. (1999). Effective teachers should be aware of students' needs (Magnusson et al., 1999). Data were gathered through CoRe interview and classroom observations. The teachers' knowledge of students' understanding of science were examined based on PCK and human body system literature. For instance, previous literature presented that student need to know cell (Sungur et al., 2001), osmosis and diffusion (Mann & Treagust, 1998; Tekkaya et al., 2001) to understand the human body systems found in literature about human body systems, sources of students' misconceptions and the way of eliminating misconceptions are reported in Table 3.7.

Concerning difficulties students have difficult about the process of digestion (Ramadas & Nair, 2007), site of absorption (Mathai & Ramadas, 2009), blood vessels, gas exchange, gas transport, and utilization, lung function, working of right and left ventricle simultaneously (Pelaez et al., 2005), breathing, gas exchange, respiration (Mann & Treagust, 1998), interaction among organs (Reiss & Tunnicliffe, 2001), filtration doing by kidney (Tekkaya et al.,2001) (see Table 3.8).

3.2.2.4 Data Analysis of Knowledge of Instructional Strategies

Participating teachers' knowledge of instructional strategies was analyzed as two categories namely, knowledge of subject-specific strategies and knowledge of topic-specific strategies based on Magnusson et al. (1999). Subject- specific strategies (i.e., conceptual change, didactic, learning cycle) reflect the teachers' orientation toward science teaching. Then, the other category which is knowledge of topic-specific strategies represented the teachers' ways to facilitate students' learning in a particular topic. Knowledge of topic-specific strategies were also categorized as knowledge of representation and activities. The knowledge of representation exemplified as illustrations, examples, models, or analogies while the knowledge of activities could be demonstrations, simulations and experiments (Magnusson et al.,1999). Teachers' knowledge of instructional strategies was examined by using of CoRe interview, classroom observations and post-interview. Some examples of activities and representations related to human body system found in literature were given in Table 3.9.

Table 3.7 Examples of Human Body System Misconceptions

Misconceptions	
Human Body System	**Example**
Circulatory System	Blood pressure is lowest in the veins since blood velocity is lowest in the veins (Sungur et al., 2001) Low blood velocity in capillaries is result from small diameter of capillaries (Yip, 1998; Sungur et al., 2001) The circulatory system is an open system (Sungur et al., 2001) “Heart beating prolongs life” (Prokop & Fančovičova, 2006, p.92)
Respiratory System	Respiration and breathing are synonymous (Seymour & Longden, 1991) “During exhalation, the lungs are compressed, and air is expelled from the air sacs.” (Yip,1998, p.469) Driver et al.,1994; Mann & Treagust, 1998).
Digestive System	The anus is the last organs where digestion takes place (Ozsevgec et al.,2012) During digestion, nutrients follow a linear pathway and go to accessory organs (i.e., liver and pancreas) (Mathai & Ramadas, 2009) Digestive system is a single open-ended system which begins with mouth and ends with stomach (Cardak, 2015) “Pancreas absorbs nutrients” (Prokop & Fančovičova, 2006, p.92) Digestive system organs are independent from each other (Cardak, 2015)
Urinary System	Lungs and skin are the part of urinary system organs (Genc,2013)
Source of Misconceptions	Everyday language (Seymour & Longden, 1991; Yip, 1998); textbooks teaching methods, terminology, teachers’ insufficient content knowledge (Yip, 1998)
Eliminate Misconception	Conceptual change approach (Cardak, 2005; Sungur et al., 2001; Tekkaya, 2003)

Table 3.8 Examples of Students' Difficulties about Human Body Systems

Difficulties		
Human Body System	**Example**	**Source**
Urinary System	Filtration doing by kidney	Tekkaya et al.,2001
Circulatory System	Blood vessels Gas exchange Gas transport and utilization Lung function Working of right and left ventricle simultaneously	Peleaz et al.,2005
Digestive System	The process of digestion Site of absorption	Ramadas & Nair, 2007 Mathai & Ramadas, 2009
Respiratory System	Breathing, gas exchange, respiration	Mann & Treagust, 1998
Complex System Understanding	Interaction among organs	Reiss & Tunnicliffe, 2001
Sources of students' difficulties	Teachers' instructional strategies Textbooks Overloaded curriculum Abstract nature of topics Time limitation Terminology Insufficient laboratory opportunities	Tekkaya et al.,2001

Table 3.9 Examples of Activities and Representations of Human Body System

Categories	**Examples**
Knowledge of Subject-Specific Strategies	5E Learning Cycle (Cardak et al., 2008; Fokides & Mastrokoukou, 2018) 7E Learning Cycle (Aydin & Balim, 2009) Discussion (Rule & Furletti, 2004) Problem Based Learning (Learning by Design) (Hmelo et al.,2000) Cooperative Learning (Ristanto et al.,2021)
Knowledge of Topic-Specific Strategies	History of Circulatory System Activity (Cansız,2019) Swedish Knife Model Activity (Özsevgeç et al., 2007) Visuals and visualization (Mathai & Ramadas, 2009) D simulation (Fokides & Mastrokoukou, 2018) Analogies (Rule & Furletti, 2004; Ozsevgec et al.,2012) Modelling (Hmelo et al.,2000) Informal Learning (Movement-Based Learning) (Monzack & Petersen, 2010).

3.2.2.5 Data Analysis of Knowledge of Assessment

Participating teachers' knowledge of knowledge of assessment was analyzed as two categories which are knowledge of dimension in of science learning to assess and knowledge of methods of assessment (Tamir, 1998; Magnusson et al.,1999). First, knowledge of dimension in of science learning to assess represented teachers' expectation related to students' learning (i.e., conceptual understanding, nature of science, science process skills) for a specific topic. Second, knowledge of methods of assessment involves the specific ways (i.e., written tests, portfolio, performance-based assessment) that teachers used for assessing students in a specific topic. In this study, formative and summative assessment were used to explain the teachers' assessment technique. Summative assessment facilitates assessing students' learning at the end of unit or end of year (Earle,2014). Summative assessment has the feature of being reported to parents or school administrations (Harlen & James, 1997). Formative assessment reveals students' understanding during a process (Earle,2014) to promote students' learning (Harlen & James, 1997). Some examples of summative assessment and formative assessment from literature were given in Table 3.10.

Table 3.10 Examples of Summative Assessment and Formative Assessment

Categories	**Examples**
Summative Assessment	Multiple choice questions Conceptual comprehension test (Aydin & Balim, 2009)
Formative Assessment	Questioning, discussion, role play, KWL grid, concept map, presentation (Earle,2014) Drawing (Ramadas & Nair, 1996; Reiss & Tunnicliffe, 2001).

3.3 Trustworthiness of the Study

The nature of qualitative study is different from quantitative study. Therefore, validity and reliability of study were addressed in different manner to support trustworthiness. Lincoln and Guba (1985) operationalized trustworthiness as credibility, transferability, dependability, and confirmability in qualitative studies instead of internal validity, external validity, reliability, and objectivity.

3.3.1 Credibility

Credibility presents the internal validity of the study (Lincoln & Guba, 1985). Credibility represents the consistency of research data with reality (Merriam & Tisdell, 2015). The nature of qualitative studies does not allow to capture "the truth"; however, there are several strategies to increase the credibility of the study (Merriam & Tisdell, 2015). Triangulation, member checks, adequate engagement, researcher's position, and peer review are the strategies that promote credibility (Merriam & Tisdell, 2015).

In the current study, first, triangulation was used to increase the credibility of data. The four types of triangulations were suggested by Denzin (1987) consisting of multiple sources of data, multiple methods, multiple theories, and multiple investigators. Therefore, data were collected through interviews, classroom observations, and documents as multiple data collection methods. Additionally, triangulation was provided by multiple data sources. Interviews and classroom observations were audio-recorded in addition to the researcher's field notes.

Second, member checks were used to support credibility. Member checks are also named as respondent validation which provides feedbacks from interviewed (Merriam & Tisdell, 2015). After data collected through pre-interviews and classroom observations, the researcher prepared post-interview questions for each participating teacher based on inconsistencies between pre-interview and classroom observations. Therefore, post-interviews facilitated the preliminary analysis.

Third, with regard to adequate engagement, the researcher was a complete observer during classroom observations and primary source of data during the interview. As a complete observer, the researcher spent at least 20 lesson hours with the participants in their natural environment (i.e., classroom). In this way, the researcher became familiar with the school context.

Fourth, the researcher's position is important for credibility. The researcher previously had the experience to conduct another PCK study and took the qualitative course (Advanced Fieldwork Methods). These experiences enhanced the researcher in terms of data collection and interpretation.

Finally, the peer review strategy was helpful for researcher to eliminate bias and inconsistency between interpretations. The researcher's advisor, who is competent in PCK studies and has several experiences, guided the researcher with her views and suggestions.

Creswell and Poth (2017) advised using at least two validation strategy. In this study, five strategies were implemented.

3.3.2 Transferability

External validity is another concerned idea that relates to generalize and transfer of the results (Merriam & Tisdell, 2015). Lincoln and Guba (1985) suggested to use the name transferability instead of external validity. As a case study, it was not aimed at generalizing the result of the current study. The use of rich and thick descriptions is one of the commonly used methods to support transferability (Merriam & Tisdell, 2015). Thick description means that the researcher explains the case in detail. Creswell and Poth (2017). In this study, the backgrounds, demographic information, and school context of the participants were described in detail. In addition, the findings of the study were supported multiple data sources including quotes of classroom observations, interviews and documents to increase transferability. Participating teachers were at the same school context, same gender and approximately the same years of experience. Therefore, only their different educational background provided variation.

3.3.3 Consistency

The nature of the qualitative study does not allow statistical data to be obtained. Human behavior is not stable. Therefore, reliability in social science is questionable (Merriam & Tisdell, 2015). Reliability represents the degree of replicability of the study. Lincoln and Guba (1985) named reliability as consistency or dependability. Triangulation, peer examination, and the position of researcher enhance the consistency of the study (Merriam & Tisdell, 2015). Each of these strategies was explained previously for credibility.

3.3.4 Ethics

First of all, the researcher informed the participating teachers about the purpose and conditions of the study. After the teachers agreed to participate in the study voluntarily, permission was obtained from METU Human Subjects Ethics Committee to conduct the study. After the ethics committee approval, permission was obtained from the Ministry of National Education. After obtaining the approval documents regarding the ethical permissions were received, the private school where the participating teachers work, and the school administration was informed. The school administration also was informed so that classroom observations could be made, and audio recordings could be made in the lessons. Participating teachers signed the consent form before the data were collected. Pseudonyms were used to protect participant's anonymity. No photos or videos of students were taken during classroom observations.

3.3.5 Assumptions of the Study

The following assumptions were taken into account in this study:

1. The Magnusson et al. (1999) model is an effective framework for revealing teachers' PCK.
2. The teachers were sincere in their answers during interviews.

3. The behaviors and actions of the teachers in the classroom were not affected by the presence of the researcher.
4. The rubric prepared by the researcher is well designed and reliable to interpret teachers' subject matter knowledge.

3.3.6 Limitations of the Study

Firstly, the number of participants is one of the limitations of this study. Although at the beginning of data collection, the CoRe interview was held with three teachers, the data collection process continued with two teachers due to the overlapping of the course schedules. For this reason, the data of the third teacher interviewed were not included in the study.

Second, there were times when the schedule of the participating teachers overlapped. In this case, while the researcher was observing in a teacher's classroom according to the flow of the subject, she left the voice recorder in the classroom where she could not be found. Then, by listening to the lesson recorded, she had the opportunity to listen to the questions asked by the teacher in the class and the examples she gave. Even though the researcher could not be present in the classroom during the lecture, she also took pictures of the figures drawn by the other teacher at the end of the lesson because the participating teachers were in the same school.

Third, data collected in Turkish. Then, all transcribed data and classroom observation records were translated into English. This translation may cause terminology problems. The researcher took consideration into her advisor’s suggestion to eliminate the limitation.

Finally, the researcher could not observe the classroom activities related to the health of the human body system. Since the health of the human body, the system was taught during spring term as different topics in the national science curriculum.

CHAPTER 4

FINDINGS

This report organized into two main parts. First part presents science teachers' Pedagogical Content Knowledge (PCK) of Human Body System (HBS) and second part presents Subject Matter Knowledge (SMK) of Human Body Systems. Under the PCK of HBS Orientation towards Science, Knowledge of Curriculum, Knowledge of Students' Understanding of Science, Knowledge of Instructional Strategies, and Knowledge of Assessment are reported. In the second part, participants' SMK examined as substantive and syntactic knowledge (Nature of Science). The teachers' substantive knowledge of Human Body System is evaluated for the four human body systems which are The Digestive System, The Circulatory System, The Respiratory System and The Urinary System. Then, their NOS understanding as syntactic knowledge is examined by considering Tentative NOS, Theory & Law, Empirical NOS, Inferential NOS, Imaginative and Creative NOS, Socio-Cultural NOS, Subjectivity. First of all, teachers' background is explained.

4.1 CASE 1: Anna's Pedagogical Content Knowledge and Subject Matter Knowledge Regarding Human Body System

4.1.1 Anna's Background

Anna is a female teacher, and she has 16 years of experience in teaching Science in middle school. She graduated from middle science teaching program at one of the public universities in Ankara. She began her teaching career at a private school, and she continues working at the same school. The school consists of students coming from high-level bureaucrat families usually with high income. The physical conditions of the school are quite good and sufficient. Each classroom has computers and projectors. They do not have the smartboards at the time of study. The teacher claimed that she did not participate in seminars or workshops about human body systems except for her graduate education. She has a high level of self-efficacy for teaching human body systems.

4.1.2 Anna's Pedagogical Content Knowledge of Human Body System

4.1.2.1 Anna's Orientation Towards Science

In this section, Anna's orientation towards science is presented by reflecting on her beliefs about the goals of teaching science. Anna's orientation towards science was evaluated through interview questions and classroom observations. The data were examined according to central goals and peripheral goals which were proposed by Friedrichsen and Dana (2005) to address teachers' beliefs about the goals of teaching science.

4.1.2.1.1 Anna's Beliefs about Goals of Science Teaching

Anna's beliefs about goals of science teaching were examined by asking her about the meaning of science teaching, the goals of science teaching and the roles of teachers and students according to her point of view. Anna's beliefs about goals of science teaching are summarized in Table 4.1 according to her interview data.

Anna's responses show that her central goal is a schooling goal since she mentioned mostly preparing students for daily life and educate students to use the knowledge that they learn in school in their daily lives. Furthermore, she mentioned that they [as teachers] teach objectives that are already given in the science curriculum. Thus, her peripheral goal is a subject matter goal.

Table 4.1 Anna's Orientation Towards Science Teaching

Question	Response (Reported-PCK)	Types of Goals
The purposes of science teaching	Prepare students to life and to the problems that emerge from daily life	Schooling Goal
	Help students gain analytical thinking skills in social life	Schooling Goal
	Educate students who can apply the knowledge they have learned to their daily life	Schooling Goal
	Prepare students for life using scientific methods, which are free from superstitions	Schooling Goal
	Teach curriculum objectives	Subject Matter Goal
	Increase students' curiosity and attention	Affective Goal
The role of teacher in science teaching	Be a guide	Schooling Goal
Role of students	Take responsibility of their learning	Schooling Goal
Purpose of teaching Human Body Systems	Evaluate the signals coming from the body	Schooling Goal
	Prepare students for high school entrance exam [which is taken at the upper classes]	Schooling Goal
	Enlighten students' professional orientations	Schooling Goal

First Anna was asked her belief about teaching science with the help of following questions.

> Researcher: What does teaching science mean to you? What, in your view, are the purposes of teaching science?
>
> Anna: [I teach science because] Science prepares students to life [pause] and to the problems that emerge from daily life. [pause] It [science] helps students gain analytical thinking skills in social life… I mean that student who is

studying science wants to examine every concept by dividing them into small parts (or chapters) …. s/he wants to examine each concept by drawing its frame. [By this way] students do not get confused and they [students] know what they want. They also direct themselves towards their goals…Actually, the overarching aim [of science teaching] is to educate individuals who can apply the knowledge they have learned to their daily life...That is why the main purpose [of science education] is to prepare students for life using scientific methods, which are free from superstitions. Our biggest goal is to bring up a student who can solve the everyday problems using scientific methods… Although they [students] will never experience liquid pressure in their life directly, they can explain many daily life encounters by referring back to liquid and gas pressure, such as ears barotrauma when diving into the sea or feeling the pressure when they are on an airplane. Also…Scientific literacy… Of course, we have to teach the objectives of the science curriculum. In this teaching process, our [as teachers] main purpose is to direct the students towards where and how they will use the useful information transferred during the classes.

As a follow up question, she was requested to explain analytical thinking skills that she referred.

Researcher: You mentioned analytical thinking skills before. Which skills or knowledge do you expect your students to gain by teaching science?

Anna: Science is interrelated with mathematics, engineering, and many other technological topics. Besides, in all these [mathematics, engineering, and many technical] subjects, students' manual skills should be developed. Our [as teachers] goal is to raise students who can integrate what they [students] have learned in class into their [students'] daily lives. For instance, it may be a higher-level example but, it would be nice as well as important if students learn the resistance of a conductor and then realize that resistance increases or decreases when sound level of a mobile phone is turned on or off.

Then, since Anna mentioned scientific literacy to explain her purpose of science teaching, she was requested to explain what scientific literacy means to her.

> Anna: It [scientific literacy] means that students should avoid fortune-telling and should not accept everything they [students] hear without questioning them. They need to ask questions, inquire. They [students] should believe in science. That is our [as teachers] aim.

Anna's answer demonstrates that her purpose of teaching science is preparing students for life. Her main goal is to educate the students in a way that they can solve the problems they face in daily life in a scientific manner. She also mentioned scientific literacy. According to her, it is important to raise students who believe in science. She emphasized mostly the relationship between science and students' daily life. Additionally, she expected her students to gain analytical thinking skills. Thus, it can be said that her central orientations are based mostly on schooling goals. Then, her peripheral goal is subject matter goal since she also mentioned she has to teach curriculum objectives.

What is more, Anna was asked about the role of teacher and student in science teaching. Anna defined the teachers' role in teaching science as a guide while students are active in their learning process.

> Anna: The system in which the teacher is teaching in front of the board with chalk in her hand and the students listening passively is not valid anymore…It is over. It [direct teaching] was used in our generation, and that is why we [our generation] suffered from this teaching style. Now, the teacher is the guide. There used to be encyclopedias in our homes, but now there's Google, so accessing information is quite easy, but it is important to teach students how to use this information or knowledge. I feel myself as a guide, a master... In a sense, I show my students how to dice a potato, but they cook the dish with a potato, not me. Every time I tell my students that it is their responsibility to learn how to use a knife to peel or chop the potato. I think

> the teacher's role should be that of a “guide” … The student will be the person in the kitchen who cooks the food and eats it later on.

It can be seen that, according to her, the teacher should teach students how to use the knowledge. In other words, she argues that students should be responsible for their own learning during the science education by saying that *students would be the people in the kitchen who cook and eat the food.*

Classroom observation data also reveal that Anna transmitted the information about the topic directly to the students with the help of questioning and discussion in the classroom. As she mentioned, she guided her students with the questions she asked.

During interview, Anna also was asked to explain reason why she teaches human body system. Anna suggested that how vital organs work at the basic level should be taught to this age group [middle school level]. She thought that science helps students to develop their manual skills and affect students’ career choice. For example, she said that experiments such as heart and brain dissections may be the reason for students to become surgeons. Moreover, she also addressed that because the human body systems are mostly related to students’ life, it can be taught, without much difficulty. Thus, she had schooling goals.

> Anna: what we teach about human body systems are completely related to students’ own body and their own life. So, no matter what people’s occupations are, no matter who they [people] are, it [human body system] is something that everyone can face with in their everyday life, not only in the case of diseases but also to be familiar with our own body... Students must know circulation and respiration because they include the vital organs. They are the very first things checked during the first aid. Is a patient breathing, or is his/her heart beating? Thus, students should know how these vital organs work at the basic level. Since it is very related to our life, how vital organs work should be taught to this age group [middle level students]. For example, students will not say “my kidney hurts” when their left chests hurt. They [students] will know the source of the problem [in students’ body]. Basically,

> that is enough for students to know the related hospital department to their [students'] health problem. [Assume that] Students will do a brain dissection, or a kidney dissection. Talking about the details of these processes [organ dissections] can enlighten their career choice. Maybe some students will become surgeons. When students know how organs work, we [as teachers] may affect their [students] professional orientations. I have many students who once said that "I will never touch [organs]" and they want to be surgeons later on. It is nice to see how I am affecting students' ideas over the years. For example, when I talk about DNA or tube baby, I say "either you will have a student or you will have a partner, thus you need to know this [DNA topic] because these [DNA topic] are necessary in daily life". Human body systems are the most trouble-free topics because every topic I have described above is a part of their [students] body.

It is crucial to address the classroom observations. According to classroom field notes, it can be seen that her central goal represents both schooling goal and subject matter goal since she focused on transmitting the content knowledge, which is human body systems (i.e., digestive, circulatory, urinary, and respiratory system). In other words, she dwelt on objectives given in the science curriculum while she was teaching the human body systems. Her teaching of human body systems is based on lecturing, questioning, and discussions related to scientific facts. Moreover, Anna used daily life examples, topic-specific representations, extra-curricular explanations to make her instruction more meaningful. Moreover, she cares increasing students' curiosity and attention. In short, she focused mostly on transmitting the scientific information about the human body systems. Thus, it can be said that her central goals are the schooling goals and subject matter goals. Moreover, her peripheral goal is affective goal.

In the next sub-title, Anna's knowledge of curriculum was described.

4.1.2.2 Anna's Knowledge of Curriculum

Anna's knowledge of curriculum was analyzed by pre-interview questions, classroom field notes, and post-interview questions. First, Anna's knowledge of goals and objectives of human body systems is presented, and then, there was a shift towards her knowledge of materials.

4.1.2.2.1 Anna's Knowledge of Goals and Objectives about Human Body Systems

Anna correctly indicated that the human body systems have been moved from 7th grade to 6th grade and are placed in the 2nd unit in the recent science curriculum [MoNE, 2018]. She is also aware of the fact that the place of all human body systems at the previous science curriculum the human body systems (MoNE, 2013; p.21-30).

First, the place of digestive, circulatory, respiratory, and urinary system in the science curriculum was asked to Anna.

> Researcher: Specifically, do you know the places of digestive, circulatory, respiratory, and urinary system in the science curriculum?
>
> Anna: All of the human body systems are in the 6th grade curriculum. In the previous science curriculum [MoNE,2013], while the skeletal and muscular system, the circulatory system and the respiratory system were in the 6th grade; the digestive system, urinary system and nervous system were in the 7th grade. We [teachers] will teach human body systems to 6th graders this year for the first time with this changing curriculum (from 2013 to 2018 science curriculum) ... …Mmm…But, here, there is a handicap. I mean the human body systems are complex topics. There are a lot of details [in human body systems], and the students tend to memorize these details. Therefore, understanding each human body system and realizing the differences between each organ [in the human body systems] can cause problems for students because they [students] will encounter so many human body systems

(i.e., digestive, circulatory, respiratory) at this age level [6th grade]. We [teachers] are going to experience it [teaching human body system at 6th grade] now and see what will happen. The Ministry of Education have made the science curriculum [MoNE, 2018] in a very simplistic manner thus, maybe, we [teachers] will only mention the heart, the veins, and the blood in the circulatory system. So, it [human body systems] may not be too difficult for the students, but we [teachers] need to experience and see.

Researcher: You mentioned about possible problems associated with the recent curriculum. What kinds of problems do you expect to face during the teaching of human body systems?

Anna: Mmm… There are too many details, and they may be discouraging, frightening for the students. We [teachers] will teach it [human body systems] in the 2nd unit. As it is the beginning of the semester, I am afraid that the students can develop negative attitudes toward science course. On the other hand, as this topic [human body systems] is directly associated with students [their own body], it [human body systems] can actually create curiosity and receive students' attention, which will the positive aspect of teaching them for us.

Her explanations revealed Anna's understanding of the place of human body systems in science curriculum. Although Anna commented on the simplicity of the curriculum by saying; "*[The Ministry of Education] have made the science curriculum [MoNE, 2018] very simplistic"*, she also stated that there were a lot of details about the human body systems. She seems confused about this.

Then, the order of the digestive/circulatory/respiratory/ urinary systems in the curriculum was asked to Anna to uncover her knowledge of the science curriculum in more detail. Anna was not knowledgeable in what order the digestive/circulatory/respiratory/ urinary systems are presented in the science curriculum [MoNE, 2018]. However, she believed that the order of the systems should be circulatory/respiratory/urinary/digestive system in the current science curriculum. Thus, her idea about the order of the systems is partially consistent with the curriculum. Her responses show that her emphasis is mostly on the circulatory system, that is, the circulatory system should be taught first according to her.

> Researcher: Do you know the order of the digestive/circulatory/respiratory/ urinary systems in the curriculum?
>
> Anna: I need to check the curriculum for this question because I do not remember the order…But for me, firstly the circulatory system and then the respiratory system should be taught and then, the other systems [i.e., digestive system, urinary system] should follow this order…For instance, without knowing the circulation, students do not understand the oxygenation of the blood in the kidneys since I mention the arteries and veins while teaching urinary system… For example, it is necessary to mention the blood circulation in order to explain hormones. The nervous system may be independent [of other human body systems] thus, you do not need to explain anything. However, in the digestive system, when we say, *nutrients enter bloodstream*, it is necessary to mention blood again…I think the order should be like this [circulatory/ respiratory/ urinary/ digestive system]..

She horizontally associated circulatory system with urinary, endocrine and digestive system. Then, Anna's responses to following question represented her understanding of vertical curriculum. First, Anna correctly stated that there is a solar system unit [1st unit] before the human body systems unit [2nd unit]. Since the teacher is already teaching the solar system which is the 1st unit according to the science curriculum, this data does not give any definite inference about whether she is really knowledgeable in this case.

> Researcher: What are the units before and after the human body systems?
>
> Anna: Before that [human body systems], there is 'the solar system unit' ...it [the solar system] starts with eclipses [lunar eclipses and solar eclipses], and followed by a chemistry unit, a unit about matter will be taught, if I remember correctly. Mmm… I am not so sure. Then, the human body systems come...

The human body systems are divided into two parts [in the science curriculum, which is MoNE,2018].

Researcher: Do you think this order [solar system/human body systems/matter] is appropriate?

Anna: The science curriculum has changed 4 times (2005, 2008, 2013& 2018) since I started teaching. So, this is the 4th program, and I feel like only the 2005 curriculum had logical reasoning behind it. Other than that, among the four curricula I experienced up to now, there is not a sensible sequence, or a purpose of three others. Mmm…. There is a science curriculum which has been taught for years. I assume that They [curriculum authorities] said; "STEM is the new trend now, let's add STEM into it [science curriculum]", instead of asking; "What is the deficiency in the science curriculum? What should be done?"...So, it [the science curriculum] does not make sense…

Anna's responses to the previous question shows that Anna complained about reasons behind changing science curriculum. The topics in the human body systems are explained in the first and second semesters. First academic term starts at September and last 18 weeks. At the beginning of the first term as a 2nd unit in a-24 class hours, muscular and skeletal system, digestive system, circulatory system, respiratory system, and urinary system are taught. When first semester finished, after a 2 -week break, the second term starts. In the middle of the second term as a 6th unit, integumentary system / exocrine system, sense organs, and the health of human body systems are given in 18 class hours. Interview data shows that Anna made two different comments on this case. Her first opinion supports that it is not appropriate to divide the human body systems into two semesters. If the reason behind this division is so much content knowledge related to human body systems, the topic should be taught in the 7th grade without any division. The second view about the teaching of the human body systems is that it may cause students who do not like biology or have difficulties to understand it to have a negative attitude towards the science course at the beginning of the semester since there are so much content knowledge related to human body systems. Therefore, according to her, the distribution of the human body systems in the current curriculum is inappropriate.

During pre-interview, Anna's knowledge of vertical curriculum was also revealed with following question. She stated that science curriculum is spiral in its nature, but new curricula [MoNE, 2018] affected this spiral manner negatively. She supported the fact that the previous science curriculum [MoNE, 2013] was more logical than the new science curriculum [MoNE, 2018] in terms of human body systems. However, she mentioned that there is a cell topic [at the 7th grade] related to human body systems and foods topic [at the 4th grade] related to the digestive systems (see 4.1.2.3.1 Anna's Knowledge of Requirements of Learning Human Body Systems)

> Researcher: Are the human body systems, specifically the digestive/ circulatory/ respiratory and urinary system, associated with other units or grade levels in science curriculum?
>
> Anna: No. They [The human body systems, specifically the digestive/ circulatory/ respiratory and urinary system] are not associated with other units or grade levels in science curriculum] ... As I said before, in the previous curriculum [MoNE, 2013], the place of human body systems was appropriate. When it [MoNE, 2013] was applied in the 6th grade, the students learned the circulatory system first and then respiratory system. Then, in the 7th grade, they [students] learned the digestive system, the urinary system, and the nervous system, which are more detailed [than circulatory system and respiratory system]. However, this year, they [students] are going to learn them [digestive, urinary, nervous, circulatory, and respiratory system] at 6th grade, and learn reproduction system at 7th grade according to the current science curriculum [MoNE, 2018]. However, the 6th graders who are becoming adolescents need to learn the reproductive system earlier. I think that biology, physics, and chemistry should be equally distributed in the science course due to the spiral nature of the curriculum. However, new

science curriculum [MoNE, 2018] does not represent these spiral relationships between the grade levels.

At this point, it is necessary to mention that in the post-interview, Anna stated that it is not logical to teach human body system both in the 1st and the 2nd academic term as offered by the science curriculum. Thus, she proposed that during the next academic year (2019-2020), the health of each system can be taught at the end of each related system in her school.

Anna was asked the following question in order to reveal her knowledge of the objectives given in the curriculum about the human body systems. Firstly, she did not remember the prescribed objectives that are intended to be followed about the human body systems and which concepts and skills that students should develop in the science curriculum. However, when her own point of view was asked according to her experiences, she stated that students should know the organs that make up that system, and know how they [organs] work.

> Researcher: What are the most important objectives and concepts about the human body systems in the science curriculum according to your experiences?
>
> Anna: I think the students should know the organs that make up that particular system, and they should know how they [organs] work….For instance, considering the circulatory system specifically, the students should know how a heart works, how a muscle relaxes [and contracts], why our heart has four chambers, and they should be able to realize that blood in our body which has less and more oxygen circulates separately... [Students should understand] why some animals are hot blooded and why some [animals] are cold blooded.

Anna believed that the teaching of human body systems helps students to comprehend the part-to-whole relationship, and once more she emphasized the relationship between human body systems and students' daily life.

Researcher: You said that students should know what are the organs that make up the digestive, circulatory, respiratory, and urinary system, how are their structures and how they work together. What do you expect your students to do with all this information?

Anna: Actually, the students cannot use these knowledge [organs, functions of organs and structure of organs] directly in his / her daily life, but they learn how do organs work together. If an organ is damaged or does not work, students learn which system will suffer, respectively. That is, students can learn the part-whole relationship with the help of human body systems. The four-chamber structure of the heart may not be used in students' daily life, but what would be damaged if one of the chambers is not working is learned. That is, it [learning human body systems] can help students to identify and solve problems in their body… Unless a problem occurs, for example, if someone does not have angiography and does not have bypass around the students, they are not very interested in the structure of the heart. If a student knows the location of the heart and kidney, it would be enough. That is, someone who has never heard the term nephrologist have no idea where s/he should go to when his kidneys are harmed, but if s/he has heard of the term nephrology, then s/he can have the idea mentioned above.

Although the objectives suggested by the teacher coincide with those in the science curriculum [MoNE, 2018], there are deficiencies. For instance, her reported-PCK shows that she did not specifically mention physical & chemical digestion, functions and structures of blood, blood transfusion and blood donation. However, classroom observation field notes show that she addressed all of the objectives given in the science curriculum [MoNE, 2018] during her teaching. Her knowledge of goal and objectives are given in Table 4.2.

Table 4.2 Anna's Knowledge of Goals and Objectives

Human Body Systems	**Interview (Reported-PCK)**	**Classroom Observation (Enacted-PCK)**
Digestive System	Know the organs that make up that system Know how organs work	Explain the structures and organs of the digestive system by using models. Infer the nutrients must be digested physically (mechanical) and chemically in order to enter bloodstream. Explain the functions of the digestive organs.
Circulatory System	Know the organs that make up that system Know how organs work Know how a heart works, how a muscle relaxes and contracts Know why heart has four chambers	Explain the structure and organs of the circulatory system by using a model. Examine the systemic and pulmonary circulati on on the scheme and explain their functions. Define the structure and functions of blood. State to the transfusion of blood between blood groups. Evaluate the importance of blood donation for society.
Respiratory System	Know the organs that make up that system Know how organs work	Explain the structure and organs of the respiratory system by using models.

Table 4.2. (continued)

Urinary System	Know the organs that make up that system Know how organs work	Explain the functions of the urinary system organs. Explain the structure and organs of the urinary system by using models.

Table 4.3 Anna’s Knowledge of Restrictions Posed by Curriculum

Human Body Systems	Interview (Reported-PCK)	Classroom Observation Enacted-PCK
Digestive System	The structures of the enzymes Chemical structure of the organs	The chemical digestion equations Structure of enzymes, their mechanism of action Structures of liver and pancreas
Circulatory System	-	Structures of arteries, veins, and capillaries Structures of blood cells The transportation of gases with hemoglobin Molecular basis of blood groups
Respiratory System	-	The gas exchange mechanism and the transportation of respiratory gases through blood
Urinary System	-	Structures of the large intestine, skin and lung

In addition to the objectives of the human body systems, the limitations and the misconceptions about the human body systems were also asked to Anna. Anna correctly stated that science curriculum [MoNE, 2018] does not mention any misconceptions. About limitations, Anna was aware that the structures of the enzymes or the chemical structure of the organs are not mentioned in the science curriculum.

> Researcher: Does the curriculum include the limitations and the misconceptions about the human body systems?
>
> Anna: Misconceptions have never been included in any curriculum I have ever met. It [misconceptions] is all important, but there is no attempt in the curriculum to overcome these misconceptions…If we talk about level of the class, they do not know chemical structure of the enzymes.

Anna seems aware that the structures of the enzymes or the chemical structure of the organs are not mentioned in the science curriculum. However, her enacted-PCK shows that while she paid attention limitations and did not address the structures of the enzymes, the chemical structure of the organs [the digestive system], she mentioned the name of enzymes [the digestive system], the names of four chambers of the heart and Rh incompatibility [the circulatory system], lymphatic circulation [the circulatory system], parts of kidney [the urinary system] in the classroom although these are given as restrictions in science curriculum (MoNE, 2018). (See Table 4.3)

To summarize, Anna seems knowledgeable enough about the place of the human body systems. She referred vertical and horizontal relationships. In the pre-interview, she did not remember the order of the digestive, circulatory, respiratory, and urinary system in the curriculum. However, she taught these topics according to the order given in the science curriculum. Anna was able to state most of the objectives given in the curriculum, but she covered all objectives and regarding the human body systems during her teaching. She was aware of the fact that science curriculum does not cover any misconceptions considering the human body systems.

Anna's knowledge of materials is explained in next sub-title.

4.1.2.2.2 Anna's Knowledge of Materials

In this sub-title, Anna's knowledge of the materials is covered and summarized in Table 4.4.

Table 4.4 Anna's Knowledge of the Materials

Materials	**Interview (Reported-PCK)**	**Classroom Observation (Enacted-PCK)**
Lesson plans	Mentioned	Observed
Visual materials - Lecture slides - Simulations - Drawings - Models	Mentioned	Observed
Lecture notes	Mentioned	Observed
Human Body System Booklet	Not mentioned	Observed
Additional books from different publishers	Mentioned	Observed
Science textbook	Mentioned	Observed

Anna stated that she has many sources such as visuals, her books from her university years, lesson plans, additional books from different publishers to have different points of views towards the topics.

> Researcher: Which sources do you use while teaching human body systems?
>
> Anna: I check the textbook when I think; "huh…let me see if there is any missing detail related to the topic". I use the textbook as an additional resource to give students homework. We [Anna and her colleagues] write our lesson plans so detailed that I do not need to look at the textbook. I have a file which includes my lecture notes that I organize from different sources and lesson plans. In these lesson plans, what should I do step by step is

written? These [lecture notes] are my own reviews from a variety of sources... I sometimes use visual materials.

Similarly, Anna used her lesson plans in classroom observations. Besides, as visuals she used lecture slides, additional videos [i.e., about physical & chemical digestions, how heart works etc.] and drawings. As an example of her drawings, the structure of the kidney on the blackboard are shown in Figure 4.1 below. Additionally, although she did not mention it through pre-interview, she also used Human Body System Booklet which is prepared by her and her colleagues.

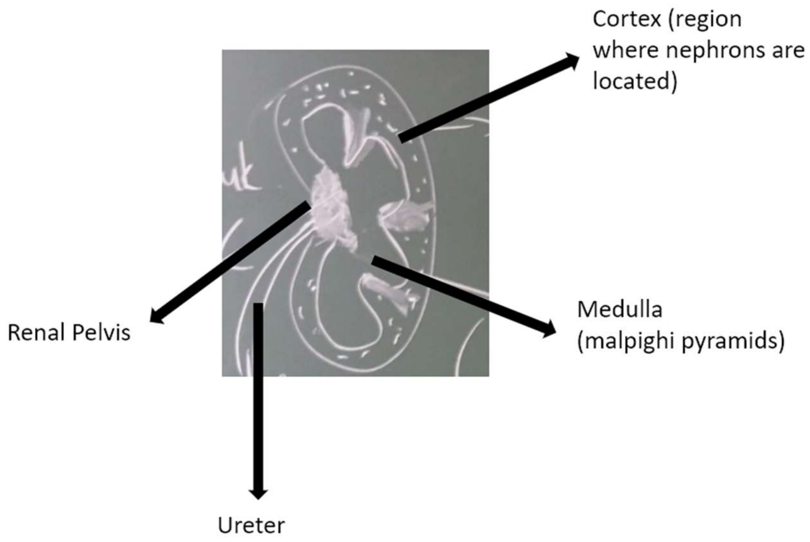

Figure 4.1 Anna’s Drawing of Structure of Kidney

In summary, Anna was aware of the place of human body systems in the science curriculum. She addressed objectives and some restrictions posed by curriculum related to the human body systems in the curriculum. She did vertical curriculum connections by mentioning the cell topic related to the human body systems in 7th grade and foods topic related to the digestive systems at 4th grade. Besides, she mentioned horizontal relationships about human body systems. She also said that spiral curriculum is affected negatively in the new science curriculum [MoNE, 2018]. To talk about her knowledge of the materials, she designed her teaching according to her own resources such as her lesson plans and the lecture notes instead of using the textbook. Additionally, she mainly used slides during her teaching to make it easier for students to follow up.

In the next section Anna's knowledge of students' understanding of science is revealed.

4.1.2.3 Anna's Knowledge of Students' Understanding of Science

In this section, Anna's knowledge of requirements for learning human body systems and knowledge of students' difficulties regarding the human body systems were presented to examine her knowledge of students' understanding of science.

4.1.2.3.1 Anna's Knowledge of Requirements of Learning Human Body Systems

Anna's knowledge of requirements for learning the human body systems was reported in this section and summarized in the Table 4.5.

Table 4.5 Anna's Knowledge of Requirements for Learning the HBS

Interview (Reported-PCK)	**Classroom Observation (Enacted-PCK)**
Cell-tissue-organ-system-organism relationship	Cell-tissue-organ-system-organism relationship
-	Classification of nutrients
The meaning of digestion/circulation/excretion	The meaning of digestion/circulation/excretion

In her opinion cell-tissue-organ-system-organism relationship should be given for students to teach human body systems better. Anna seems worried about new curricula [MoNE, 2018] because current 6^{th} grade students will learn human body systems without knowing cell-tissue-organ-system-organism relationship. Moreover, she stated that current 6^{th} grade students, at the time of study (2018-2019 Fall Term), learned blood circulation in our body conceptually at 4th grade. Although she remembered that excretion and digestion were given in the 4th grade, the excretion and digestion of nutrients in our body are among the 5th grade subjects in the previous science curriculum [MoNE, 2013]. Students learned the organs and what does digestion and excretion mean conceptually when they were at 5th grade. In addition, Anna supported that classification of nutrients is prior knowledge for understanding of the digestive system.

First, Anna was asked about what the students' prior knowledge before should be they start learning the digestive/circulatory/respiratory/ urinary systems as follows:

> Anna: In the 4th grade, students conceptually learn what digestion is and what excretion is… Students did not learn the topics [i.e., digestion, excretion, circulation] as a system, but they learn them [i.e., digestion, excretion, circulation] conceptually… For example, students learnt that the food we eat is broken down into smaller pieces and enter into the bloodstream; blood circulates in our body, it [blood] carries the necessary matters as prior knowledge. However, students do not need to know what substance blood carries. When students are in higher classes [middle school] they already know digestion and excretion conceptually. We [as teachers] give these concepts [digestion, excretion] in more detail and teach human body systems in the middle school. For example, in the previous curriculum [MoNE, 2013], during the 6th grade, we [as teachers] started with the cells first, then we taught the cell-tissue-organ-system-organism relationship, and later on we started teaching human body systems. Now, for the first time, we [as teachers] will explain the human body systems without giving this [cell-tissue-organ-system-organism] relationship. I do not know how it [teaching the human body systems without giving cell-tissue-organ-system-organism relationship] will happen. In other words, we have given this [cell-tissue-organ-system-organism] relationship in each curriculum, and then we have explained the human body systems. Maybe we can give these [cell-tissue-organ-system-organism] concepts with an extra activity independent of the

curriculum, but it is also difficult because the concept of cell seems to have been moved to the 7th grade. So, there is no logic [in the curriculum].

In the classroom observation, she mentioned her concern and addressed to cell-tissue-organ-system-organism relationship as a response to a student's question during her lecture about the respiratory system.

Student: We learned that we have a lot of chambers in our body…

Anna: Yes, these are cells.

Student: Does alveoli include these cells?

Anna: The cells are the building blocks of everything. Unfortunately, you did not learn the this [cell] knowledge due to the new curriculum [MoNE,2018], you will learn about the cell topic next year [7th grade]. Next year will be too late for this [learning cell] …You have to understand the logic behind how human body systems are formed. You should also know that your body is made up of cells. These cells work together to do the same function and form tissues, these tissues work together to do similar functions and form organs. For example, there are blood tissues, muscle tissues, nerve tissues in the heart. All these [blood, muscle, nerve] tissues work together to form the heart. The heart, blood and vessels work together to form the circulatory system. The circulatory system, the respiratory system and the digestive system work together to form the organism. So of course, there are cells in the structure of the alveolus.

Student: You said that systems and the tissues make up the organism... Single-celled organisms are not organisms, they are single-celled living things. So, how can they [single-celled organisms] survive?

Anna: Because a single cell is capable of doing everything an organism can do alone.

Moreover, her enacted-PCK shows that Anna started the digestive system by explaining the classification of nutrients as a prior knowledge to her teaching although she did not mention about classification of nutrients in the pre-interview. When the teacher asked the students what they already know about the classification of nutrients, the students stated that they only learnt this knowledge [classification of nutrients] from the poster hanging on the billboard in the school cafeteria. After Anna explained the classification of nutrients as prior knowledge, she did the "My Sandwich" activity (see Anna's Knowledge of Topic Specific Strategies) to make sure that students were learning about the concept in a better way.

In the post-interview, while she was being questioned about why she explained the classification of nutrients, which is included in the 4th grade science curriculum, before teaching the digestive system, she stated that *they should know the classification of nutrients as preliminary information for digestive system*.

Also, in the lesson plan about the circulatory system, systemic circulation and pulmonary circulation are explained before vessels and their properties. However, Anna changed the order and taught vessels and their properties before systemic and pulmonary circulation while she was teaching the related subject. In the post-interview, when the teacher was asked about the reason for this [change the order of systemic and pulmonary circulation and vessels and their properties], she stated that the vessels should be explained first in order for students to better understand the circulatory system.

Anna's knowledge of the difficulties that students have regarding the human body systems was reported in next section.

4.1.2.3.2 Anna's Knowledge of Students' Difficulties

Anna's knowledge of the difficulties and misconceptions that students have regarding with respect to the human body were reported (see Table 4.6).

Anna thinks that student have difficulty to understand respiratory system when compared to other human body systems. She stated that due to the lack of prior knowledge, students have difficulty to understand gas exchange in the alveoli [respiratory system], mechanism of breathing [respiratory system] chemical digestion [digestive system], and breaking molecules into building blocks [digestive system].

Table 4.6 Anna's Knowledge of Students' Difficulties

Human Body System	Students' difficulties (Reported-PCK)	Students' misconceptions (Reported-PCK)
Digestive System	Chemical digestion Breaking molecules into building blocks Building blocks of molecules passing through a cell membrane	Digestion only happens in the stomach
Circulatory System	-	There are dirty blood and clean blood
Respiratory System	Mechanism of breathing Gas exchange in the alveoli	Cellular respiration and breathing are similar
Urinary System	-	-

First, Anna was asked about what were the concepts that the students have difficulty to understand about the digestive / circulatory/ urinary and respiration systems as following:

> Anna: Students' difficulties…Hmmm…They [students] do not understand the breathing mechanism due to lack of prior knowledge. In other words, since students do not know the relationship that pressure of the gases depends on the volume, they are having difficulties to understand the mechanism of breathing…When the diaphragm muscle is contracted, the volume expands and because of that, the pressure decreases and it is, then, equalized to the

external pressure. Since students do not know this [volume-pressure] relationship, it [mechanism of breathing] is seen as a chain of events that students have to memorize. If it [mechanism of breathing] was asked in the exam, they [students] could write it [mechanism of breathing] all, but they would not be able to explain. For example, we [Anna and her colleagues] conducted the experiment where we stretched the balloon around the bottom of plastic bottle then, the students observed what happened when the balloon was pulled and pushed. [In this experiment, the balloon around the bottle represents the diaphragm and the balloon inside the plastic bottle the lung]. I said that "Look, I have expanded the volume, the pressure has decreased, and the air filled up to equalize external pressure." The students nodded and they said "Yes", but they [students] did not fully understand the process due to the lack of previous knowledge.

Researcher: So, can we say that one of the reasons why students have difficulty to understand is the insufficient prior knowledge?

Anna: Yes, so students do not have enough prior knowledge to understand human body systems. Mmm…What is that students do not understand in the circulatory system?... Circulatory system is generally understood. Gas exchange in the alveoli [respiratory system] is not understood since the student does not know the concepts such as binding hemoglobin to oxygen and binding hemoglobin to carbon dioxide, diffusion that happens from an area of high concentration to an area of low concentration. The least understandable topic is the respiratory system [among digestive/respiratory/urinary and circulatory system]. Besides that, students cannot learn chemical digestion very well [digestive system] because they do not know the enzymes. Additionally, the concept that how molecules are broken into the building blocks is not quite understood because students do not know the logic of chemical reaction. I mean the students do not make sense of how carbohydrate is converted to glucose, how can glucose pass through the cell membrane while carbohydrates cannot. They [students] can solve the problems by memorizing this process [how molecules break into building blocks, passing through a cell membrane], but they [students] do not have a nuisance about it. [i.e., how the glucose molecules that is sent small intestine pass through a cell]…There is no integrity between human body systems. The student's understanding about the glucose molecule, which passes through the cell and which is subsequently used in the respiratory reaction, develops many years later when students become high school students.

During the classroom observations, since Anna stated that students have difficulty to understand the mechanism of breathing due to lack of prior knowledge, which was the volume-pressure relationship, she demonstrated the volume-pressure relationship by using her hands. Classroom observation excerpt is given as follows:

> Anna: Mechanism of breathing is related with the volume-pressure relationship. Diaphragm is a dome shaped muscle [Also she shows dome shape with her hands]. When the volume increases, the pressure decreases. The only thing that you should know is how does air enter and leave the body. It continues until the pressure of lungs is equaled to the external pressure.

Just as she said, as there was no preliminary learning, the students had to memorize the human body systems. Thus, during her teaching, she showed a respiratory system model given in Figure 4.3 (see Anna's Knowledge of Instructional Strategies) during her instruction to demonstrate volume-pressure relationship.

Moreover, according to the classroom field notes, Anna explained the diffusion by an example from the daily life, by simply making the gas exchange in the alveoli more meaningful during her instruction.

> Anna: Gases have these characteristics that they tend to move from an area of high concentration to an area of low concentration. We call it diffusion which is in Latin. This [diffusion] is a general physical feature. You can also

understand this [diffusion] with this example: If I spray a deodorant which is in gaseous state here, your friend at the back will sense this smell since all the gases tend to go that way [move from an area of high concentration to an area of low concentration]. There is so little concentration there [at the back of class]. So, what substance is more in the capillary, carbon dioxide or oxygen?

Student: Carbon dioxide

Anna: So, where does the carbon dioxide want to move?

Student: To alveoli

Anna: Then, carbon dioxide moves to the alveoli. Where oxygen concentration is high? Oxygen concentration is high in alveoli. Where will the oxygen want to move? Oxygen will want to move to the capillary vessel. Oxygen will move to the capillaries and blood will return to the heart as oxygen-rich blood. This process happens every time when we breathe. Gases move from an area of high concentration to an area of low concentration and this is called diffusion. In this [diffusion] way, carbon dioxide passes through the alveoli and the oxygen in the alveoli passes through the blood.

During pre-interview, in addition to students' difficulties, Anna's knowledge about students' misconceptions regarding digestive/respiratory/urinary and circulatory system was revealed**.** Anna asserted that students' misconceptions emerge during class discussions, quizzes, and assessments at the end of the chapters. She stated that she does not do any specific activity to eliminate misconceptions because of the limited time, and more responsibility put on her shoulders by the school administration. However, she said that they emphasize misconceptions during their instruction or give classroom notes by writing these notes with bold font and big letters. Anna mentioned that one of these misconceptions in respiration system is that students think that cellular respiration and breathing are synonyms.

Researcher: Are there any misconceptions about the digestive/circulatory/respiratory and urinary system?

Anna: In the classroom, if students say that "digestion only happens in the stomach" at the beginning of the digestive system topic, I ask this; "Well…why do we have the intestines or our mouth then?". I am trying to explain that digestion takes place not only in the stomach, but also in other organs [mouth, intestines, pharynx, esophagus]. However, this [digestion only happens in the stomach] is not a bigger problem than the students' understanding of cellular respiration-gas exchange and dirty blood-clean blood phenomenon… For example, the major misconception about the respiration is breathing versus respiration. Cellular respiration and breathing are always confused, and this distinction is never emphasized in any book and curriculum. It [difference between cellular respiration and breathing] is unquestioned. If the teacher has no special interest and knowledge about this topic [respiratory system], s/he may only mention respiration and neglect the other. However, the students must be taught that they [cellular respiration and breathing] are different, one [cellular respiration] is a reaction to produce energy and the other [breathing] is a gas exchange for this reaction [cellular respiration] to occur. This [difference between cellular respiration and breathing] is an important misconception. Other than that, there are not many misconceptions about circulation. They [misconceptions] are mostly about breathing. The biggest misconception about digestion is that "digestion happens in the stomach". However, the intestines, the mouth, the tongue, and the enzymes also have functions in digestion process.

Researcher: Well, how do you identify the misconceptions when they occur?

Anna: We [Anna and her colleagues] detect the misconceptions mainly from the students' answers during my teaching. However, the most efficient way to capture a misconception is that we have quizzes at the end of each chapter.

Researcher: You have already mentioned the misconceptions and gave specific examples about it. So, do these misconceptions affect your teaching and the decisions you make in the class? If such misconceptions affect your teaching, do you mention them while preparing the lesson plan with the possible examples?

Anna: Yes [misconceptions affect my teaching]. For example, if we [Anna and her colleagues] are going to distribute some lecture notes about respiration to students, we [Anna and her colleagues] are suing bold fonts and big letters, for example, "Breathing is the exchange of gases. Cellular respiration is different." Even if we [Anna and her colleagues] do not carry out an activity related to misconceptions specifically, it [misconceptions] is always mentioned and emphasized during teaching. We emphasize dirty blood-clean blood and respiration for example. I do not let them [students] say dirty-clean blood [instead of oxygen rich-oxygen poor blood]**.** I say that "When you say respiration, you should understand cellular respiration. Energy... Let us talk about mitochondria because what is the *power plant* of cell? It [power plant of cell] is mitochondria. Then, mitochondria do the cellular respiration. Who does the gas exchange for respiration?" In my classes, I always stress out that our lungs are doing gas exchange.

Researcher: Well, you said that you do not do any activities to overcome with the misconceptions. Why don't you prefer any activities? Is it enough to just eliminate the misconceptions? Do students internalize the accurate knowledge?

Anna: We [Anna and her colleagues] do not have time for that [to do extra activity to overcome with misconceptions]. These [misconceptions] can be thought as the parts which cannot be emphasized during the classes. Yes, students have difficulty to understand these misconceptions [i.e., thinking that cellular respiration and breathing are the same, describing blood as dirty or clean instead of oxygen rich or oxygen poor blood, thinking that digestion

> only happens in the stomach] generally, but I do not encounter a huge problem. If we [Anna and her colleagues] encounter the same misconception more often, there will be an activity, but it [misconceptions] does not happen frequently. Can students internalize [accurate knowledge]? I do not know. Teaching and background of teaching [such as preparation of lessons, quizzes, exams, projects] are always done in a hurry. I cannot catch up with the occurrences of misconceptions. I have 3 different classes, I teach 3 different topics at the same time, there are 100 students… There are responsibilities that the school administration requires from us… Some things are missing, and this [our school] is one of the most meticulous institutions, among others. I cannot go back to misconceptions although students do not internalize because there is program that should be completed in June. If I had only two classes, then there would be no misconceptions or incomplete learning occurrences, but that is not the case.

In classroom observation, for instance, Anna emphasized that *Breathing is the exchange of gases. Cellular respiration is different* just as she mentioned this during the interview. However, she used only direct instruction to eliminate this confusion. Although she supports student-centered instruction, she did not use the conceptual change approach. Anna began her lesson by saying; *There are systems in our body such as the digestive system and circulatory system. Is there an energy system?* Then, she continued her lesson with the following statement: *To be a system, it must be composed of organs.* Since her current 6^{th} grade students do not know the cell topic, she explained this subject by using the questioning method. During her teaching, she highlighted mitochondria to explain the cellular respiration as she mentioned in the interview. Thus, in the post-interview, when the reason why she mentioned the mitochondria was asked, Anna stated that it was important to prevent students from having misconceptions about cellular respiration and breathing. She indicated that the students could have difficulty in understanding mitochondria very well, but she emphasized that cellular respiration did not occur in the lungs.

To summarize, Anna thought that students should know the cell-tissue-organ-system-organism relationship, the meaning of digestion/circulation/excretion conceptually, the classification of nutrients as prior knowledge before learning about the human body systems. Although in the interview she stated that it is possible for her to do extra activity to give cell-tissue-organ-system-organism relationship, she did not practice it during her teaching. She only mentioned these concepts briefly. She was aware of the difficulties that students have and focus on these concepts such as gas exchange in the alveoli, while teaching. In addition, she was aware of students' misconceptions such as the differences between breathing and cellular respiration. However, the limited time did not allow her to do extra activities to promote the students' understanding of these concepts. Indeed, explanation is not enough to make conceptual change for students to eliminate their misconceptions.

Next, Anna's Knowledge of Instructional Strategies is represented.

4.1.2.4 Anna's Knowledge of Instructional Strategies

Anna's knowledge of instructional strategies was uncovered through pre-interview, post-interview, and classroom observation field notes. In this section, her knowledge of instructional strategies was reported under two sub-headings which are "*Knowledge of Subject-Specific Strategies*" and "*Knowledge of Topic-Specific Strategies*."

4.1.2.4.1 Anna's Knowledge of Subject-Specific Strategies

In this sub-title, Anna's knowledge of instructional strategies was presented. It was summarized in Table 4.7.

Anna indicated that she uses demonstration, experimentation, field trip, questioning, and modelling techniques to increase students' curiosity and to capture their attention. She mentioned that she learned these instructional strategies during her graduate education and in-service seminars.

Table 4.7 Anna's Knowledge of Instructional Strategies

Dimension	**Interview (Reported-PCK)**	**Classroom Observation (Enacted-PCK)**
Instructional Strategies	5E&7E Learning Cycle Questioning Experimentation* Modelling* Demonstration* Field trip*	5E&7E Learning Cycle Questioning Experimentation* Modelling* Demonstration* Drawing*
Purpose of using the strategies	Capture students' attention Increase students' learning to the highest level Increase students' curiosity Monitor students' learning	
Source of using the strategies	Her graduate education In-service seminars	

***Present topic-specific strategies**

First, instructional methods that Anna used in classroom was questioned.

> Researcher: Which instructional techniques do you use to teach science in general?
>
> Anna: Constructivist education is the basic step. I use any technique that is compatible with the topic while designing the lesson. Demonstration is used, experiments are conducted, observation is done, field trip is also utilized. For example, a trip to Eymir Lake was organized last year for the classification of living things for the 5th grade students. Every opportunity like this [plan to field trip] is considered by the teachers in our school. I think we [Anna and her colleagues] have a very rich archive on instructional strategies which are use used…. We sometimes use visual materials. We discovered a method which name is *Bagless School* and for the first time, we have applied it to the 6th graders for the current unit [solar system and eclipses]. We will not teach

anything. We have prepared worksheets for this [solar system and eclipses] and offered various resources to our students.

Researcher: Can you explain the specific methods that you use the most, with the reasons?

Anna: For example, we use the experimentation method mostly. We [Anna and her colleagues] are also configuring the experiment, I mean the students follow some steps that causes experiments to have problems in them. In other words, there is a problem at the beginning of the experiment, there are dependent-independent variables, experiment process, observations, and conclusions after the observations. After the observations, students discuss the conclusions with their group members or on their own. Then, we [Anna and her students] evaluate the experiment together. In other words, if it is not a demonstration experiment, it is necessary to go to the laboratory after these stages [problem situation, experiment, observation, conclusion] are completed in the classroom. Demonstration is one of the methods I use more often. I do not remember the names of the methods, but you should remind me. The other method we use is the modelling. For example, human body systems cannot be explained without showing a model. I mean the organs and their shape can be shown using models. I also do some organ dissections. On the other hand, apart from human body systems, when we teach our students the speed problems, I take them out to the garden in order to make them race and observe who completes the road within the shortest time. This activity is probably an experiment...

Researcher: You said that you use demonstration as an instructional method and you do outside activities with students. Why do you choose these instructional strategies?

Anna: Someone who speaks all the time without a break drowse me. The students will also sleep if we do so…But, if I give them something, I mean if they touch and look at something during the teaching process, there will be no opportunity for students to lose their interest and sleep. The students are 12-13 years of age, and they are teenagers, thus they lose their attention much more easily. So, using different methods attract students' attention. So, I think the students have the content learned with pleasure and fun [when I use different instructional methods].

Researcher: I mean you use them [instructional methods] to attract students' attention?

Anna: Certainly, if you surprise the students, they await you [as teacher] impatiently. They [students] think that "I wonder what teacher will do now, what will happen now" etc... They [students] always want an action in the class because they grow up with statements like "What is coming up next?". We [teachers] lose the students' attention when we [teachers] utilize direct teaching method.

Researcher: How did you learn about different instructional strategies?

Anna: I learned instructional methods at the university. The university I graduated is a very successful one. We had already learned what everyone heard for the first time. For example, when the Constructivism came out, we had already learned to use it [constructivism] through 5E, 7E instructional methods. It has been 16 years since I graduated. However, apart from that, I have attended to approximately 50 in-service seminars after I came to this school. So, we [teachers] are constantly renewing. In order to observe different fields than science education, the school gives opportunities to us to have trainings such as critical thinking training and psychological analysis training. For example, the new trends are modeling and coding…We have program specialist and assessment and evaluation specialist [in our school] ... They [program specialist and assessment and evaluation specialist] are researching constantly as a Research and Development [R&D] team and they inform us of new instructional strategies. So, our school is developing and changing constantly.

Additionally, as she mentioned above her school that she is teaching at currently has Research and Development Department. Thus, she mentioned that the lesson plans were prepared in the form of a group work and in this group, besides the other science teachers, there are measurement and evaluation specialists and program development specialists. The lesson plans were prepared in line with the constructivist education base according to a 6-stage model, which is based on the 5E and 7E teaching models. This 6-stage model consists of problem situation, engagement, exploration, explanation & discussion, application, and evaluation.

> Anna: We work as a group at school. There are four science teachers who give only science classes. Then, there are our branch teachers [physic, chemistry, biology teachers], but even if they teach science classes, we are responsible as four science teachers in the preparatory stage [of lectures]. We have one measurement-assessment specialist and one program development specialist. Our measurement specialist usually helps with the preparation of questions. However, we write a plan with the program development specialist for how we can teach topics by taking the objectives [in the curriculum] into consideration. For every objective in the curriculum, from entering the classroom to exiting the classroom, until that objective is achieved, we brainstorm about what we do, which activities are better understood, and then write a plan. These plans are prepared based on the 5E and 7E models in constructivist education. Our plans include 6 stages, which are problem situation, engagement, exploration, explanation & discussion, application, and evaluation. We are doing these steps for each lesson plan, namely for every objective. First, we start with the problem situation until the evaluation of each objective is processed by activities one by one.

In classroom observations, it was observed that she mostly preferred questioning, demonstration, and modelling similar to her pre-interview responses. For instance, Anna benefited from some power point presentations including questions (i.e., what are the roles of the digestive system? what are the structures and organs that make up the respiratory system?) and answers. She taught circulatory system through these questions and answers. It can be said that Anna used questioning method mostly. She used questioning at the beginning of the instruction to elicit students' prior knowledge, in the middle of the instruction to monitor students' learning. Some examples are shown in Table 4.8. Finally, she used questioning at the end of each topic to create chances for students to utilize their knowledge in given authentic situations.

Table 4.8 Examples of Question in Classroom

Name of Topic	**At the Beginning of The Instruction**	**At the Middle of The Instruction**
Digestive System	Is there any system known as energy system in our body? How does energy obtain?	Does physical digestion occur in the stomach?
Circulatory System	What does circulatory system mean?	How ventricle and atrium work?
Respiratory System	What does respiration mean to you?	How gas exchange occurs in alveoli?
Urinary System	What are the structures and organs that come to mind when you think of the urinary system?	Have you ever heard of dialysis center?

In conclusion when Anna's teaching of human body systems [digestive, circulatory, respiratory, urinary] was observed, it could be seen that she mostly preferred direct teaching method and questioning to monitor her courses. Although she supported student-center education and her lesson plans are based on 5E and 7E learning cycles, it can be seen that lecturing dominated her lectures.

Next, Anna's Knowledge of Topic-Specific Strategies is represented.

4.1.2.4.2 Anna's Knowledge of Topic-Specific Strategies

In this section Anna's knowledge of topic-specific strategies was presented under two sub-titles, which are knowledge of representations and knowledge of activities about the human body systems.

4.1.2.4.2.1 Anna's Knowledge of Activities

Anna's knowledge of activities about the human body systems [digestive, circulatory, respiratory, and urinary system] was presented in Table 4.9.

First, the instructional strategies that Anna used while teaching human body systems, specifically digestive/respiratory/circulatory and urinary system, were questioned.

> Anna: We have a technique for all human body systems. We have questions about each system [i.e., digestion, urinary, circulatory, respiratory]. There are about 7-8 questions we have prepared by considering "What the students should know when this topic [digestion, urinary, circulatory, respiratory] is completed". We [Anna and her colleagues] give these questions to the students before teaching each system [digestion, urinary, circulatory, respiratory system]. We give students some time to solve the questions at home as a homework… (continued in next page)

Table 4.9 Anna's Knowledge of Activities

Interview (Reported-PCK)	Classroom Observations (Enacted-PCK)	Related Topic	Purpose
Demonstrations	Demonstrations		Make students' learning permanent
Heart	*Heart*	The parts of heart	
Kidney	*Kidney*	The parts of kidney	
Lung	-		
Activities	Activities		
Card Game Activity	*Card Game Activity*	Pulmonary and Systemic Circulation	Explain students that circulation is a cycle
	"My Sandwich" Activity	Digestion of Nutrients	Conclude digestion of nutrients
Learning Station Activity	-	Human Body Systems	Reinforce human body systems
-	Eating a Biscuit	Digestion Pathway of Nutrients	Warm up students to instruction
-	Fill in the Blanks of Body Shape	The Digestive System	Evaluate students' prior knowledge

Anna (continued): Then, students answer these questions [related questions about each system] using their textbooks and other sources that they have and bring them [answers & questions] to the classroom. What do the students do? Students read each system [digestion, urinary, circulatory, respiratory] [from their book or lecture notes] once (or first), they read the questions and answer them. They are prepared to learn something about the topic, and then we [Anna and her students] solve these questions one by one in the classroom. We do the same process for each question. That is, for each question, I follow the process that include "What should be the answer? It [answer] must be this, what was your answer?” They [students] control each other’s answers and exchange their books [to check]. When the topic is finished, we have learning stations about each system. I mean, there are different tables in our science laboratory. On these tables, there are different sources such as transparency papers, models, additional source books, posters related with to each system on the tables, respectively. I divide students into four groups. Students come to each table with group members respectively… There was an overhead projector before, we used it [overhead projector] by this way. Each group travels to each station and examine each one by one. In this way [learning station activity], the students have a chance to examine the visual materials by talking among themselves [with group members]. What else… We do kidney and heart dissections, and if we can find the lung with its trachea, we can examine the lung. In addition to these, I have a game about the circulatory system for systemic circulation and pulmonary circulation. This game is played with the cards. Finally, we make a quiz that consists of 3-5 questions at the end of the unit. After completing this process, I explain some points that students do not understand, and then, we finish talking about the topic. Most probably, we will apply the same process this year again because this method [giving preparation questions before teaching] works very well. If students come to the class with no preparation, they [students] only listen to me and forget all the information that I explain until the next lesson. Activities like writing, reading, or underlining the important parts will be better for students. This year, we [Anna and her colleagues] will probably teach human body systems in this way [giving preparation questions before teaching].

Researcher: How do you decide whether activities that are planned with your colleagues are effective?

Anna: I understand the effectiveness of the activities thanks to the feedback from the class. For example, one of my colleagues says, "I did this [an activity] in the classroom, but the student did not understand", but another teacher says "No, my class understood that very well." Sometimes, an activity may not work for a whole year, students do not understand the process. However, another year, the same activity works very well for the students of the same level. It depends on students.

Researcher: Do your methods [laboratory activity, learning station, questioning…] reflect your objectives?

Anna: Thanks to these methods [laboratory activity, learning station, questioning…], students do not only passively listen but also see and feel. I also include other sensory organs. Thus, students become active in the classroom. They [students] research, write, do, walk around instead of just sitting. So, I think that the activities are quite correlated with the lesson objectives.

Then, Anna was asked about whether she is doing any specific activities to deal with students' difficulties or not. Anna mentioned a card game about systemic and pulmonary circulation.

Researcher: Are there any specific activities that you do in the classroom while dealing with students' difficulty in understanding the human body systems [digestive/ respiratory/circulatory and urinary system]?

Anna: For example, when teaching systemic and pulmonary circulation, I am doing an activity to show that the beginning and the end of circulation cannot be drawn precisely. Although circulation is divided into systemic and pulmonary circulation, circulation is in the form of a loop. However, to clarify this, I write each station on the cards, like left ventricle, left atrium… After that, I order the systemic and pulmonary circulation on the figure. Then, I mix all the papers with the names on them. I request a student to sort all the circulation. For example, I say that start with the right atrium and sort all the circulation... Then, I ask another student to evaluate whether the order is correct or not and ask him/her to correct it [order of circulation] if it is wrong.

> I do this [sorting circulation] several times without naming it as systemic and pulmonary circulation. Then, I want students to separate the systemic and pulmonary circulation after the correct sorting is done. In this [doing card game] way, students do not have any problems in my written exams and realize that circulation is a cycle. However, I do not know if they forget it two years later…

In the classroom, she did this game and students understood systemic and pulmonary circulation better. In this game, first, Anna distributed a paper to 10 students randomly. She told different words to each student to write on these sheets. These words were Aorta, left ventricle, right atrium, right ventricle, pulmonary arteries, lungs, left atrium, pulmonary veins, whole body, pulmonary artery, superior vena-inferior vena cava. She told the students who wrote these words to come to the board with their papers. The students lined up in front of the board with the sheets in their hands facing the class. Then, she chose one of the seated students and said, "Would you explain the circulation starting from the aorta?". Then, she evaluated whether the student was doing it correctly and the circulation was completed. Anna played this game with the students throughout the lesson, starting with different words at each round. Then, she finalized the game by saying that *the systemic and pulmonary circulation in our body is not like a train station. This circulation is a cycle. There is no starting point and finish line. We refer to this cycle as systemic and pulmonary circulation to separate them according to their purpose.*

Her enacted-PCK also revealed that Anna demonstrated the heart and kidney dissection in the laboratory similar to her reported-PCK. Although she monitored this activity by demonstration, each student touched heart and kidney and examined them. Since she could not find the lung with its trachea, the lung dissection was not done as an activity.

In the post-interview, the teacher stated that there were more activities and more emphasis on the circulatory system; thus, it was understood better than the other systems. She stated that card game activity received very good feedback from the students.

Anna's objectives and her classroom practices are in the same line, and they reflect each other. As she said in the interview, students were active by asking questions when the activities were being done. During the classroom observations, when the teacher said, "we will do heart dissection", students got very excited. Also, during the card game about systemic and pulmonary circulation, as students were very active, they understood the term "circulation" better.

During the pre-interview, she said that they used to do learning stations activity to reinforce human body systems, but Anna did not do the learning stations activity. The reason why learning stations activity was not done this year was asked Anna during the post-interview. She stated that the learning stations activity does not work very well in general and there were also time limitations.

Moreover, in the classroom observation, when she started teaching the digestive system, Anna distributed a biscuit for each student. First, she wanted students to close their eyes and start eating a biscuit at the same time and requested; *Try to feel through which parts of your body the biscuit passes while you are eating it.* Then, she asked several other students, *What did you feel? Which parts of the body did the food go through?* There was a discussion part and then she began to teach digestive system by asking *What is the purpose of the digestive system?* In addition, she also included an activity at the end of the digestive system part. After Anna explained the classification of nutrients, she did "My Sandwich" activity. In this activity, students brought a sandwich they prepared beforehand to the class, and the classification of the nutrients table, which was distributed by teacher in advance, was filled by each student according to the ingredients in the sandwich. This activity helped Anna to conclude digestion of the nutrients subject. In addition, she asked the students to write the organs of the digestive system on a blank body shape to evaluate if they know the names and locations of the structures and organs that constitute the digestive system.

In addition, in the post-interview, the teacher explained what happened during this process since the organ transplantation topic was not observed.

> Anna: The mother of one our students work in the tissue typing laboratory and has a project she has conducted. This student went to the laboratory and made an interview about the organ transplantation process, then, told us how to do organ transplants. S/he also interviewed the doctor who does the transplantation. We wanted our students to talk about it to create awareness about organ transplantation.

Next, Anna's knowledge of the representations is explained.

4.1.2.4.2.2 Anna's Knowledge of Representations

Anna's knowledge of the representations and the specific examples were presented in Table 4.10.

First, Anna was asked about if she use any figures, simulations, metaphors, or drawings while teaching digestive/circulatory/respiratory and urinary system.

Anna: There are very detailed heart drawings on Google. However, I definitely teach my students how to draw a heart and I say that "You will need to draw a heart in any case". [Anna is drawing a heart which is given in Figure 4.2]. It [heart drawing] seems very complicated at first. I comfort my students by saying; "If you see the final version [of heart], you may be confused. You must follow me while I am drawing". I also ask some leading questions like "Where are the atriums? Where are the ventricles?" … For the gas exchange in the alveoli in the respiratory system… [Anna is drawing gas exchange in the alveoli]. It is a simple drawing. I draw these figures even these figures are in the books. Students do not understand the digestion of fats, so I draw a figure representing that the bile has broken them [fats] into smaller droplets. Then, the enzyme gets involved, and the smaller droplets of lipid transform into fatty acids and glycerol. So, students realize the physical digestion of fats. I give details by saying "Look, we cut fats into small pieces, we cut like knives do."

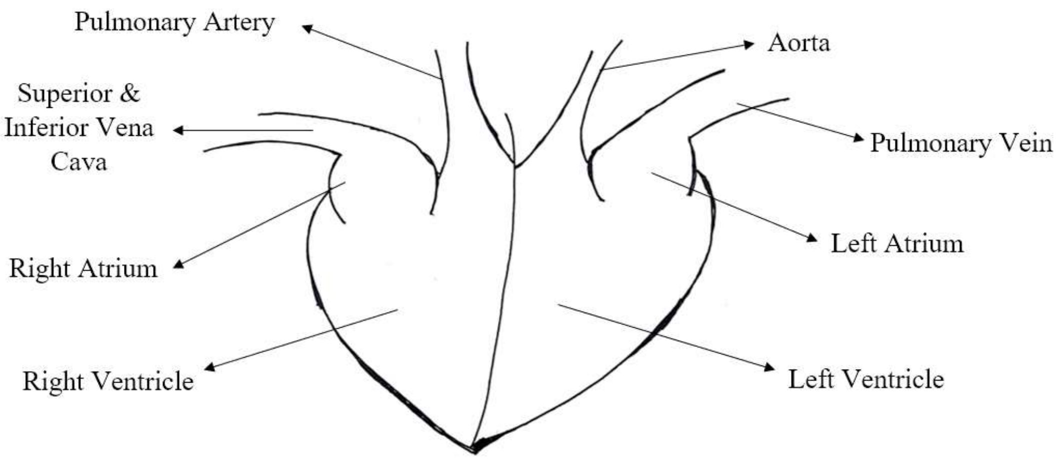

Figure 4.2 Drawing of a Heart

Classroom observation notes revealed that Anna used same drawing about gas exchange in the alveoli, drawing representation about digestion of fats and heart both pre-interview and classroom.

Moreover, during the classroom observations, to illustrate that the lipid molecules are physically digested with the help of bile, Anna first hold an A4 paper as an example to the lipid molecules. Then, she cut the paper into small pieces. Then, she gave the following explanation: "*The lipid molecules are broken into small pieces, but the structure has not changed chemically. bile helps physical digestion of fats while lipase enzyme helps chemical digestion of fats"* [in the digestive system].

Besides, her explanation as an example of specific representations while teaching the villus [in the digestive system] was like the following:

Table 4.10 Anna's Knowledge of Representations

Name of Representations	**Examples from Classroom Observation Implementations (Enacted-PCK)**
Illustrations	
Visuals	
Photos	Digestive system organs photos
Simulations	Physical and chemical digestion simulation
	Heart pumping mechanism simulation
	Systemic and pulmonary circulation simulation
Modelling	Respiratory system model
	Kidney model
Drawing	Digestion of fats
	Heart
	Gas exchange process in the alveoli
	Parts of kidneys
Daily Life Examples	Chemical digestion
	taste of sugar while taking a slice of bread
	The role of the skin in excretion
	sweating while doing sports
	Physical digestion of fats

Table 4.10 (continued)

Comparisons or Metaphors	Visualization of metaphor of rhythmic
	Contraction and relaxation of the heart
	Muscle by using hands and squeezing towel
	Explanation of one-way blood flow through heart with WC drain metaphor
	Explanation of pharynx with traffic policeman on the intersection (cross-roads) point
	Explaining the result of wrong blood transfusion by precipitation if buttermilk is not shaken
	Comparison of lungs with bunches of grapes
	Comparison of working principle of urinary system with strainer
	Comparison of formation of urine with muddy water filtration

> [First, she showed an A4 sheet and] If you try to place this sheet somewhere, you need an area that as big as at least the size of the sheet. However, if the space is too narrow, can you fold the paper and fit it [A4 paper into narrow area]? Here, there are villus which are recessed, finger-shaped, cell-thick structures on the inner wall of the small intestine, to expand the surface area, to create more surface in a small area."

Even though she did not mention it in the interview Anna also used the drawing given in Figure 4.1 to explain structure of kidneys [in the urinary system].

In addition to drawing, Anna also used daily life examples during her instruction. For example, she stated, "*We said that chemical digestion starts in the mouth. Take a piece of bread in your mouth, wait and soak, your saliva will get the taste of sugar. This is an indication that the chemical digestion of carbohydrates begins in the mouth"* when she was teaching the digestion of carbohydrates [in the digestive system].

Additionally, Anna used metaphors while teaching. For example, while she was explaining simplex (one-way) operations of valves, she used the comparison of *a water closet drain.* In her example, Anna compared the water closet drain with the valves in terms of one-way operations [in the circulatory system]. In addition to that, she said; "*If we do not shake the buttermilk, precipitation occurs"* while she was explaining the blood transfusion [in the circulatory system]. Moreover, Anna correlated pharynx with intersections (cross-roads) and traffic police officers. A traffic policeman manages cars on the cross-roads and while allowing some cars to go, he leads the others towards other ways. Like a traffic policeman, the pharynx allows inhaled air to enter the nasal cavity, and it also leads the ingested food towards the esophagus [in the digestive system]. Furthermore, she also compared lungs to bunches of grapes [in the respiratory system].

Figure 4.3 Respiratory System Model

Apart from the metaphors, Anna also used models to incorporate more visuals into classroom. For example, she used the respiratory system model given in the Figure 4.3 to show what is happening in the diaphragm and the lungs during the gas exchange [in the respiratory system]. Moreover, Anna used models such as kidney (see Figure 4.4) to explain the parts of the kidney [in the urinary system]. Even though she did not mention it in the interview, she used simulations to show physical & chemical digestion, systemic & pulmonary circulation in the classroom and pumping mechanism of the heart.

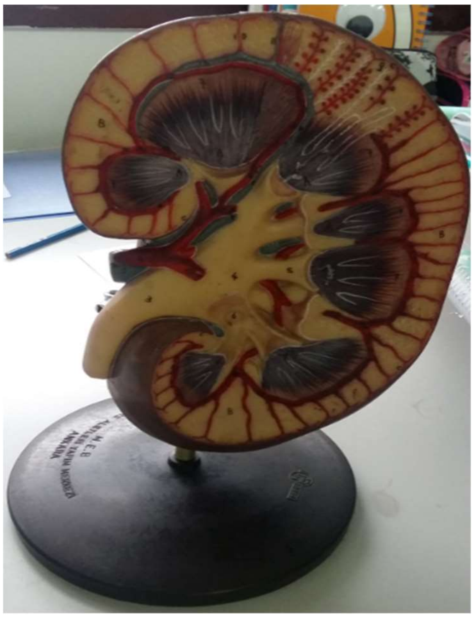

Figure 4.4 Parts of Kidney

To sum up, in line with Anna's reported-PCK and enacted-PCK pointed out that direct instruction dominated her teaching human body systems although Anna supported constructivist education. In other words, despite of the fact that she used different methods such as questioning, demonstrations and representations such as daily life examples, visuals, and comparisons, her teaching was closer to teacher-centered model. She did a card game activity, and organ dissection to enrich her instruction. In the light of these information, Anna seems knowledgeable enough about the existing instructional strategies.

Anna's knowledge of assessment strategies was reported in next section.

4.1.2.5 Anna's Knowledge of Assessment Strategies

Anna's knowledge of assessment was examined through pre-interview, classroom field notes and post interview. The collected data in this section is divided in two sub-titles namely, Knowledge of Science Learning Dimension to Assess and Knowledge of Assessment Methods.

4.1.2.5.1 Anna's Knowledge of Science Learning Dimension for Assessment

Anna mostly focused on students' conceptual understanding based on objectives given in curriculum. In addition to this, she paid attention to evaluate students' performance in classroom.

> Researcher: What exactly do you want to evaluate while assessing students' understandings of human body systems [digestive, circulatory, respiratory, urinary system]?
>
> Anna: Well, if you really want to know what the curriculum limits me to ... [I want to assess] the structure of the organs very basically, the tasks of the organs, how do organs work ... However, when I prepare my questions, I always put a graphic, for example, a graphic about breathing… [Assume that] I say what a student might be doing if the graph shows the oxygen level in the blood or I'm showing the value of the heartbeat…The main goal is to interpret the graph and use the knowledge about structure of the organ and then make the necessary interpretations…Also, I have in-class performance evaluations with the criteria rubrics about what I expect my students to do.
>
> Researcher: What are your performance evaluation criteria?
>
> Anna: The criteria that I evaluate my students are being able to explain the previous knowledge about the topic or concept, being able to produce a better solution to the topic or the problem, being able to transfer information, being able to utilize science terminology. I observe students according to these criteria. I observe students' responses and evaluate their ability to transfer the knowledge that they learn during the classes while they are answering the thought-provoking questions that we ask at the end of each unit. I mean, I give their performance grade according to students' classroom performance based on these criteria. Also, there are tests, quizzes, written exams, and this [performance tasks].

Anna's explanations show that she asses the objectives that are given in the curriculum as conceptual understanding. Moreover, it can be seen that she pays attention to evaluate interpreting graphs. She also indicated that she evaluates students' understanding according to students' reactions in the classroom. In

accordance with the classroom observation field notes, the performance grade criteria that Anna mentioned during the interview were on the classroom wall. At the end of the first unit [the unit before human body systems], the teacher showed students' grade and reminded them [students] of these criteria.
Classroom observation data revealed that Anna did quizzes at the end of each human body system [digestive, circulatory, respiratory, and urinary] as an example of evaluating conceptual understanding. For example, she asked name of digestive system organs by using models, organs in which physical and chemical digestion take place, organs in which digestive enzyme secreted, and functions of liver and pancreas regarding digestive system to evaluate students' understandings about digestive system. Moreover, she asked name of blood cells, functions of vessels, parts of heart by using models, the systemic and pulmonary circulation on the scheme and their functions, the blood transfusion between blood groups to evaluate students' understandings about circulatory system. Furthermore, she asked the structure and organs of the respiratory system by using models, events that occur during the process of inhalation and exhalation, organs that gas exchange that it where takes place evaluate students' understandings about respiratory system. Finally, she asked the structure and organs of the urinary system by using models, the structure and organs of the urinary system, the structure and organs that help the urinary system to evaluate students' understandings about urinary system (see Table 4.12).

Then, at the end of the human body system, as a purpose of discussion she distributed a one page of question list and requested to the students to interpret of the graphs or figures. These questions are thought-provoking questions which was something Anna stated during the interview. Regarding circulatory System, students were asked about the relationship between the development level of the fish, frog, reptile, bird, and mammals and their heart structures by giving the figure of the heart shapes of them. Regarding respiratory System, students were asked about plotting the oxygen demand- types of living organisms, respiration rate- types of living organisms, hemoglobin level- types of living organisms' graphs for living things given in a question using the information given about metabolism rates of living things and the definition of metabolism in the question. Finally, about urinary system, students were asked about showing the time- dependent change of the amount of vitamin C in the blood of a person who takes a large amount of vitamin C with a graphic using an explanation and example about kidney threshold value.

According to above data, it can be clearly seen that firstly, students learned knowledge level questions, and then, they learned how to use this knowledge and interpret the questions given. Anna did not give a score for these thought- provoking questions.

Table 4.11 Anna's Knowledge of Dimension of Science Learning

Knowledge of Dimension of Science Learning to Assess	**Interview (Reported-PCK)**	**Classroom Observation (Enacted-PCK)**
Conceptual understanding	Mentioned	Observed
Science process skills	Not mentioned	Not observed
NOS Understanding	Not mentioned	Not observed

To conclude, she focused mostly on students' conceptual understanding by evaluating her students according to the course objectives and she also evaluate their performance in classroom. (See Table 4.11)

Table 4.12 Quiz Questions for Each System

Human Body system	**Digestive System**	**Circulatory System**	**Respiratory System**	**Urinary System**
Questions	Name of digestive system organs by using models Organs in which physical and chemical digestion take place Organs in which digestive enzyme secreted Functions of liver and pancreas	Name of blood cells Functions of vessels Parts of heart by using models The systemic and pulmonary circulation on the scheme and their functions The blood transfusion between blood groups	The structure and organs of the respiratory system by using models Events that occur during the process of inhalation and exhalation Organs that gas exchange that it where takes place	The structure and organs of the urinary system by using models The structure and organs that help the urinary system

4.1.2.5.2 Anna's Knowledge of Assessment Methods

In this title, Anna's knowledge of assessment methods is presented and summarized in the Table 4.13.

Table 4.13 Anna's Knowledge of Assessment Methods

	Interview (Reported-PCK)	**Classroom Observation (Enacted-PCK)**
How to assess?	Thought-provoking questions Multiple choice questions Quizzes Formal exam Performance evaluations	Short-answer questions (Fill in the blank) Thought-provoking questions Multiple choice questions Quizzes (short-answer questions, matching activities, and true-false questions) Formal exam Performance evaluations
When to assess?	Formative Summative	Formative Summative

Anna evaluated her students by multiple-choice exams, quizzes, written exams, and performance evaluations. The students are given exams at the end of each topic [digestive, urinary, respiratory, circulatory system] and unit [human body systems] and written exam at the middle of the semester as a way of summative assessment.

First, she was asked about how she assesses her students' understanding. Anna's answer revealed that she used traditional assessment techniques including multiple choice exams, quizzes, written exams, and performance evaluations. She used the results of her evaluations to understand whether the topic was learned or not.

Researcher: We already mentioned the students' difficulty, your instructional strategies etc. Which assessment techniques do you use to assess your students' understanding?

Anna: I use the questioning method for evaluation. What else…you remind me, I do not remember the methods. I prepare multiple-choice questions and formal written exams at the end of each unit.

Researcher: So, you tend to evaluate your students quite often. Why do you prefer to use these methods? Do you think evaluating students quite often is effective?

Anna: I think it [evaluating students constantly] works because I receive feedback from their parents in a positive way. The students feel alert, and they feel like they need to study continuously. For example, recently, one of the parents has said, "You never allow students waste their time. They [students] have examinations both at the end of the topic and at the end of the unit… Then [there is] a written exam… So, students never postpone studying and they are always ready" ... This parent thanked us with these sentences.

Researcher: How do you use these results? What do these results mean to you?

Anna: For example, quizzes that are done at the end of each topic show me whether the topic is understood or not. We do not do the written exams in multiple choice format because we always confront the students with the thought-provoking questions. Thus, written exams consist of short-answer questions that include interpretations of the presented data. The students are ready for the exam because they have previous quizzes for 2-3 times until they are given the written exam.

Her enacted-PCK revealed that Anna prefers short-answer questions, matching activities, and true-false questions as formative assessment in whole process. Anna did quizzes at the end of each human body system [digestive, circulatory, respiratory, and urinary]. These quizzes included multiple-choice questions, short-answer questions, matching activities, and true-false questions which can serve as example of traditional assessment tools. In addition to this, Anna also asked 20 multiple-choice questions at the end of the human body systems unit as a summative assessment tool.

Anna argued that she was good at writing questions due to her graduate education and publishing experiences (writing a book). Moreover, she also had some experiences in writing performance assignments.

> Researcher: Then, how good are you in exam preparation?
>
> Anna: I am quite assertive about preparing questions. I mean I am good at writing stories and questions related to these stories… I also claim that I lead my colleagues while preparing the questions. I feel qualified about this process [writing questions].
>
> Researcher: Why do you think that you are good at writing questions? What enables you to write effective questions?
>
> Anna: When the science curriculum [MoNE, 2005] changed, we wrote a 6^{th} Grade book as a team. This book was not published by the Ministry of National Education, but… it was the second or third year of my career, I was new in teaching and this experience [writing a book] developed me. We [as a team] researched a lot of resources and methods, so it [writing a book] improved me. …Also, we never constructed short answer questions in our education faculty Knowledge level questions or short-answer questions do not satisfy me. So, I am writing the questions like this [writing stories and related questions]. As I said before, there are too many performance tasks. I wrote all the performance tasks for 6^{th},7^{th}, 8^{th} grades and prepared the rubrics with limitations. I had no problems in that regard...

Furthermore, in the post-interview, Anna explained that it is forbidden for the students to take the exam paper home. However, parents also want to see students' mistakes in exams. For this reason, Anna suggested the application of the "control sheet" technique. This technique has been applied since 2005. The control sheet includes the objectives that the students are not able to do in the exam and a study on these objectives. The control sheet consists of questions based on the same objectives of the exams. In this way, the students know what they cannot do and prepare themselves for the next evaluation.

To sum up, Anna seems knowledgeable enough about the assessment strategies. She focused on the objectives given in the curriculum [MoNE, 2018] when she assessed her students. She used both traditional methods such as multiple-choice questions, and alternative assessment methods such as performance assessment while she was evaluating her students.

Anna’s subject matter knowledge of human body systems was presented in the following title.

4.1.3 Anna’s Subject Matter Knowledge of Human Body Systems

Anna’s subject matter knowledge is examined as syntactic knowledge and substantive knowledge. First, her substantive knowledge is highlighted.

4.1.3.1 Anna’s Substantive Knowledge of Human Body Systems

Anna’s substantive knowledge of human body systems is evaluated with respect to four systems which are digestive system, circulatory system, respiratory system, and urinary system followed by her understanding of Human Body System as a complex system.

4.1.3.1.1 Anna's Knowledge of Digestive System

Anna's knowledge regarding the digestive system is highlighted with interview questions including concept maps, drawings, word association tests, and classroom observations. First, interview data is presented. Then, classroom observation findings are covered. Her interview data analyses, and classroom observation findings are shown in Table 4.14.

Anna's knowledge regarding the digestive system during interview is examined into four subtitles which are *Understanding the Digestive System and Its Components, The Adaptation of the Digestive System, The Health of the Digestive System and The Relationship Between the Digestive System and Other Human Body Systems* to elaborate her responses better.

Table 4.14 Anna's Knowledge of Digestive System

Categories	**Anna's Knowledge of the Digestive System**
Digestion	− The process of breaking down of the large molecules [into smaller molecules], both physically and chemically, so that they can easily pass through the cell membrane. − Physical and chemical digestion
The Role of the Digestive System	− To break the foods, we eat, down into their building blocks so that they can pass through the cell membrane easily.
The Digestive System Organs	− Mouth − Esophagus − Pharynx (*classroom observation only*) − Stomach − Small Intestine − Large Intestine − Anus
The Accessory Organs	− Gallbladder − Pancreas − Liver − Salivary Glands

Table 4.14 (continued)

The Adaptation of the Digestive System *(interview only)*	− Being cecum is dysfunctional − Number of teeth
The Health of The Digestive System	*Disorders* − Acid-reflux − Gastritis − Ulcer − Colon cancer *Conditions for healthy digestive system* − Staying away from spicy, sugary, salty, fatty foods − Avoiding from extreme hot or cold foods − Chewing food well − Eating healthy − Having adequate and balanced nutrition − Doing sports

4.1.3.1.1.1 Understanding the Digestive System and Its Components

In this subtitle, Anna's understanding of digestion and the digestive system is examined in terms of functions of the digestion, types of the digestion, the digestion process of nutrients, the functions of the digestive system and the organs and structures that make up the digestive system.

Overall, Anna's answers show that she was aware of what is the general function of digestion. As she mentioned, digestion brakes large molecules down into their building blocks which can pass through the cell membrane. She mentioned *foods we eat are broken down into smaller pieces and then, they enter bloodstream*, *they [small molecules can easily pass through the cell membrane [via digestive system]*, and *undigested foods are eliminated through anus.* In addition, she mentioned absorption during her teaching. Thus, it can be said that Anna was aware of four stages of food processing which are ingestion, digestion, absorption, and elimination

(Simon et al.,2018). She determined mouth, esophagus, stomach, intestines (small and large) regarding the organs that make digestive system. However, she did not mention pharynx. Moreover, she made a relationship between a digestive system and a factory in terms of working principle.

First, she was asked to share her opinions on what happens to the foods that we eat. Anna responded that *the foods we eat are broken down into smaller pieces and then, they enter bloodstream.* Then, follow-up questions were asked as follows.

> Researcher: So, how can you define digestion?
>
> Anna: Digestion is the process of breaking down of the large molecules [into smaller molecules], both physically and chemically, so that they can easily pass through the cell membrane.
>
> Researcher: How are foods digested?
>
> Anna: First, large molecules are physically broken into small molecules. These small molecules, then by the help of enzymes, able to enter bloodstream… able to pass cell membrane.

As a follow up question, Anna was asked about the types of digestion. She explained that while physical digestion is like cutting something with a knife or scissors, there is a chemical change occurs in chemical digestion, and nutrients are broken down into their building blocks. After she explained the types of digestion, she was asked about the function of the digestive system and her response is given as follows:

> We need the digestive system because the molecules are too large to get through the cell membrane. For the molecules to pass through the cell membrane, they [large molecules] must be digested. The digestive system is to break the foods, we eat, down into their building blocks so that they can pass through the cell membrane easily.

Then, to better understand and elaborate her response, Anna was asked to write 12 words about digestion, and digestive system. First, followed by the role of the digestive system Anna listed words regarding digestion only (See Table 4.15), and added that '[my list] of digestive system will not be different from that of [digestion]… Mmm…digestive system…*System, Organ, Interrelation, Common function, Stomach, Mouth, Pharynx, Esophagus, Enzyme, Small Intestine, Duodenum, Anus. The term that digestive system refers a system, the term that digestive is a concept.*

Briefly, as presented in the Table 4.15, her response to WAT were grouped under four categories: the categories included *organ* (i.e., mouth, esophagus, stomach) *structure* (i.e., villus), *molecule* (i.e., amino acids, carbohydrates*),* and *process* (i.e., chemical digestion).

Table 4.15 Anna's Concepts of Digestion as Shown in WAT

Groups of concepts	**Corresponding Concepts**
Organ	Mouth Esophagus Stomach Intestines (small and large) Teeth
Structure	Villus
Molecule	Building blocks Amino acids Carbohydrates Enzyme
Process	Chemical Digestion Physical Digestion

After Anna listed words related to digestion and digestive system, she was asked to explain the digestive system in humans by drawing in attempt to get more information regarding her understanding of the digestive system organs and digestion process. Her drawing is given Figure 4.5 below.

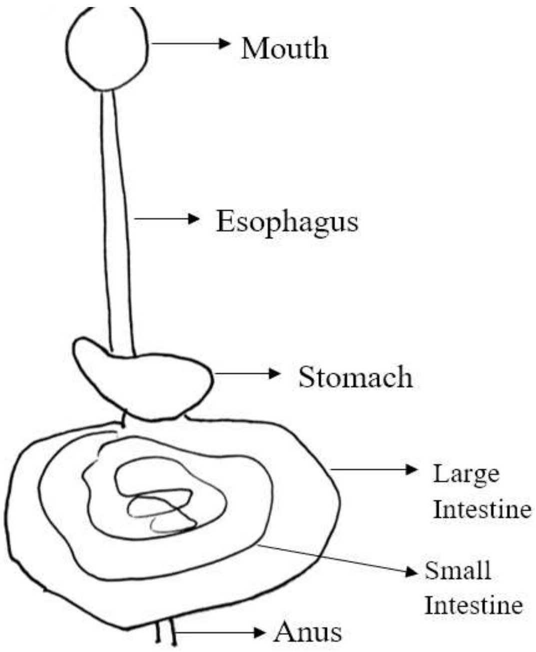

Figure 4.5 Drawing of Digestive System

As seen above her drawing did not include pharynx, gallbladder, liver, salivary glands and pancreas similar to her WAT previously asked. To reveal her understanding about organs in detail, following question was asked to Anna.

> Researcher: What kind of relationship is there among these organs [digestive system organs]?
>
> Anna: Each [organ] completes the task of the previous one and helps to complete to the next step. Something… like a factory… [Assume that] the production line is moving its product; another machine comes into place and adds something else to the same product and the belt completes again to the next step…They [production line and machines] work together. I mean...like production lines and machines in the factory, they [organs] support each other.

It can be said that Anna used a factory as an analogy for the digestive system. She explained the working principle of the production line like the digestion in the context of current study. As a follow up question to the organs and structures which constitutes the digestive system, their functions were asked Anna and her response is given as follows:

> *The mouth* consists of teeth, tongue, and salivary glands. Teeth, tongue, and salivary glands mainly support the physical digestion of all nutrients. Primarily, they [teeth, tongue] physically break large parts into small molecules. The ptyalin substance [which is an enzyme] found in saliva is also the first substance that initiates the chemical digestion of carbohydrates. *The esophagus* provides only the connection. There is not any physical and chemical digestion in there [the esophagus]. At the same time, the physical digestion of nutrients that enter the stomach continues with the churning process, chemical digestion of proteins starts in the stomach. The foods that are digested here [in the stomach] move into the small intestine where the chemical digestion of fats begins and completes. After then, the digestion of proteins and carbohydrates is completed in the small intestine, the nutrients enter bloodstream.

In the previous question, Anna mentioned physical and chemical digestion of the nutrients. She also continues her explanation about digestion of carbohydrates, proteins and fats in detail as given below.

> Researcher: How are carbohydrates digested?
>
> Anna: The digestion of carbohydrates starts with the ptyalin enzyme in the mouth. Physical digestion of carbohydrates, fats, and proteins begins in the mouth, while only chemical digestion of carbohydrates begins in the mouth. Carbohydrates are never digested in the stomach because the acidic environment in the stomach is not suitable for enzymes to work. Then, carbohydrates get through the duodenum and the small intestine and their chemical digestion continues there. Finally, in the last division of the small intestine, carbohydrates are transformed into glucose.

Researcher: What about proteins and fats?

Anna: The physical digestion of proteins begins in the mouth. Then, the first interaction between enzymes and proteins starts in the stomach, and after the digestion [of proteins] is partially completed, they[proteins] passes through the small intestine. After the chemical digestion of proteins is completed in the small intestine, they [digested proteins, which are amino acids now] get through the blood from the last division of the small intestine. The digestion of fats is different [than the digestion of proteins and carbohydrates]. Fats are not digested until they reach to the duodenum. Large lipid molecules are physically broken into tiny lipid molecules with the help of bile in the duodenum. Then, ...mmm..., they [small lipid molecules] are converted into glycerol and fatty acids with the help of enzymes. All these actions occur in the duodenum. The building blocks of foods enter bloodstream through the small intestine while glucose and amino acids enter bloodstream directly with the help of villi. On the other hand, the building blocks of the fats pass into circulation through the lymphatic system. There is such a difference among them.

It can be clearly seen that Anna seems aware of digestion of different types of nutrients. She addressed physical and chemical digestion and the role of enzyme through digestion. Thus, she was asked the meaning of enzyme. She explained that *enzymes are substances that help nutrients break into pieces during digestion, but they[enzymes] are not affected by the reaction in any way. For instance, lipase enzyme helps the digestion of fats.*

So far, she did not include pharynx, and liver, pancreas and gallbladder regarding her drawing and her wordlist, although Anna explained salivary gland while she was explaining the role of mouth through digestion process. In addition to her wordlist, she represented anus while she was drawing the digestive system. Then, Anna was requested to draw a concept map regarding the digestive system. As the drawing presented in Figure 4.6 shows, Anna mentioned concepts such as mouth, esophagus, stomach, small & large intestine, anus. While she was explaining anus, she said *"undigested foods eliminated through anus*." Even though she established some relationships to represent where the chemical digestion of food begins and completes, she did not create a link between the organs. Again, she did not include pharynx and accessory digestive organs when creating her concept map.

Up to now, she mentioned only salivary glands as accessory organs while she was constructing her concept map, wordlist, and drawing. Thus, she was asked about accessory organs that help the digestive system to reveal her understanding in detail.

> Anna: Pancreas, liver, and gallbladder. The pancreas…Hmmm… sends the necessary enzymes to the small intestine. Proteins, fats, and carbohydrates… I am not sure about the digestion of fats, but it [pancreas] sends the enzymes required for the digestion of proteins and carbohydrates. Gallbladder produces bile. In fact, gallbladder carries stored bile [to small intestine] because the liver produces bile. The liver also has digestive roles such as adjusting blood sugar levels. To be short, they [accessory digestive organs] also support the digestive system with the substances they produce such as the bile or the enzymes. Indeed, they [accessory digestive organs] really help the digestive system to perform [digestive system's] its role.

In short, under her understanding of digestive system and its components, Anna mentioned mouth, esophagus, stomach, small and large intestines, and anus. Also, she talked about the role of teeth, tongue, and saliva as supporters during digestion. As shown in the rubric given in Appendix L, she correctly listed pancreas, liver, and gallbladder under the category of accessory digestive organs while omitting salivary gland. However, she mentioned the role of salivary gland while she was explaining the role of mouth.

Another important finding is that Anna attempted to make a relationship between digestive and respiratory system by saying that *the oxygen taken by the help of the respiratory system turns into energy by breaking glucose into pieces until carbon* *dioxide in the mitochondria in the cells* when she was asked about the way that the foods we eat converted to energy. Overall response to interview questions revealed that although she correctly stated that the function of the digestive system is food processing that breaks large molecules down into their building blocks that can pass through the cell membrane easily, she did not mention that the digestive system supplies ATP to the body (Simon et al.,2018) until she was asked about the relationship between energy and digestion.

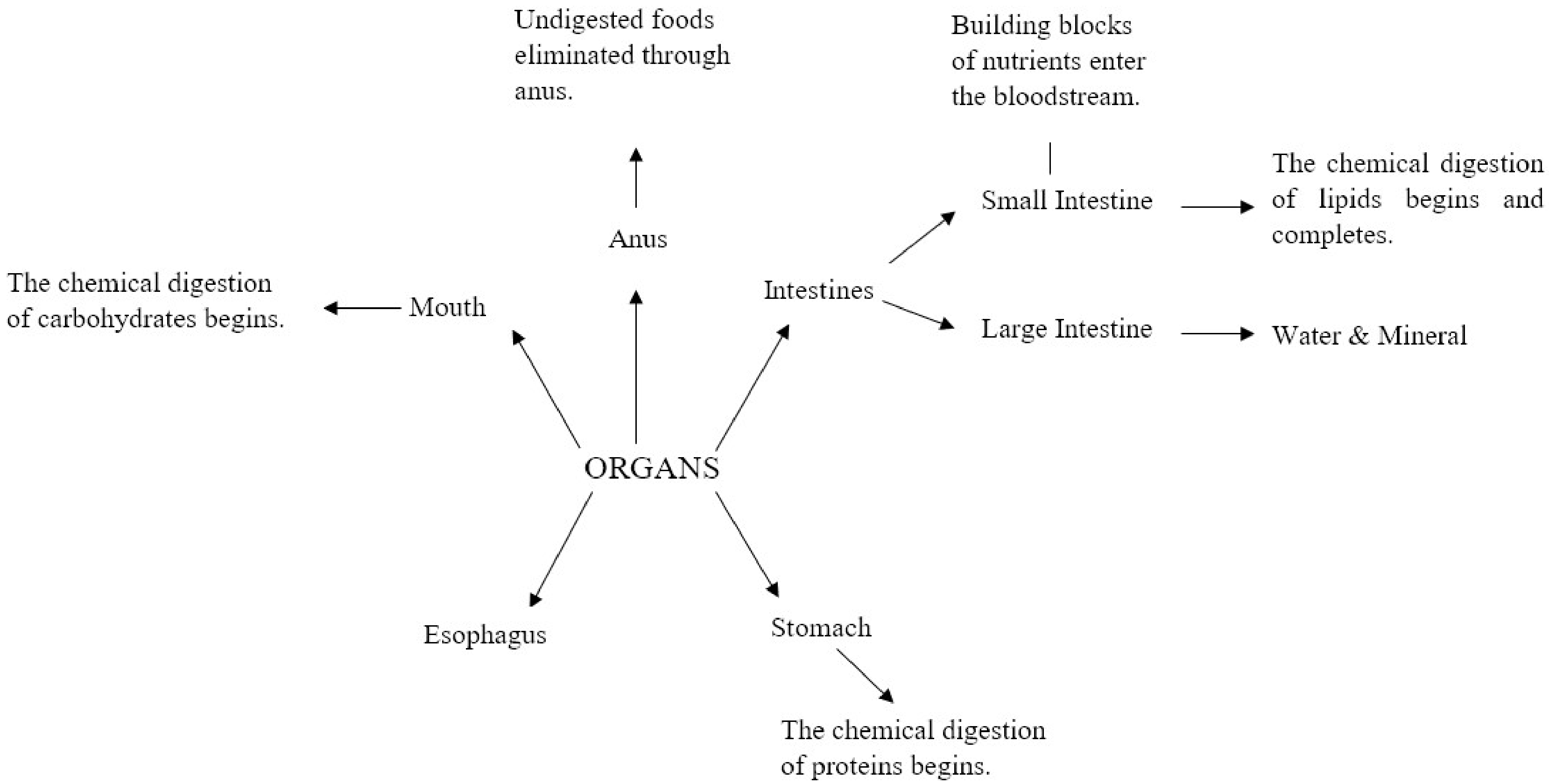

Figure 4.6 Drawing of Concept Map of Digestive System

4.1.3.1.1.2 The Adaptation of the Digestive System

Afterwards, Anna was asked to explain the adaptations that occur in the digestive system. She mentioned that cecum is dysfunctional and dental adaptations, but not in much detail.

> Anna: Well… the cecum is dysfunctional (vestigial organ) now. I do not know if it has been proven, but earlier, cellulose could be digested in our body... However, then, I do not remember where I read it, but it is said that the cecum lost its function... Therefore, our body has now adapted itself to it [cecum not being used] What else... Teeth… As far as I am concerned, we do not have 32 teeth…. I do not know anything else.

In the following section, the questions that are related with the health of the digestive system were asked to Anna**.**

4.1.3.1.1.3 The Health of the Digestive System

In this sub-title Anna's knowledge of the health of the digestive system is presented. Anna was asked about the digestive system disorders, the relationship among disorders, and our responsibilities to keep the digestive system healthy. She mentioned that acid-reflux disorder, ulcer, gastritis, colon cancer are the digestive system diseases. Like she said, ulcer is caused by a bacterium. However, she did not give the name of this bacterium, which is *Helicobacter pylori*. Her response is given as follows:

> Acid-reflux disorder, ulcer, gastritis, colon cancer are digestive system disorders. All of these [acid-reflux disorder, ulcer, gastritis, colon cancer] actually result from acid in the stomach. In fact, I should say that many of them [acid-reflux disorder, ulcer, gastritis, colon cancer] result from acid in the stomach…a bacteria causes ulcers… however, others [acid-reflux disorder, gastritis, colon cancer] are associated with the damaged tissue in the

> acidic environment of the stomach. We should eat healthy, have adequate and balanced nutrition, do sports, and stay away from excessive spicy, sugary, salty, greasy foods and avoid from extreme hot or cold foods to keep the digestive system healthy.

In short, overall interview findings regarding Anna's knowledge of the digestive system shows that Anna seems aware of the organs while omitting pharynx that constitute the digestive system. Furthermore, she knows the general function of digestive system and how the foods are digested. That is, she correctly stated that the digestion of carbohydrates, fats, and proteins. Moreover, she addressed dental and intestine adaptations. Then, she is aware of the digestive system disorders.

Later on, classroom observation data were presented and compare with the interview finding.

Classroom Observations Findings

During her teaching Anna addressed why do living organisms need food, how our body use large molecules (i.e., carbohydrates, proteins, and fats), purpose of digestion, function of digestive system, types of digestion (physical and chemical digestion), role of enzyme during chemical digestion, organs that make up digestive system, organs that help digestive system similar to interview. For example, regarding energy and food, it was noted in the classroom observations that Anna explained that all living things need energy to live, grow and repair wound, and this provided from foods and her sample excerpt is given as follows:

> Foods are large molecules thus they break down into small molecules throughout digestion process which starts from teeth to small intestine. Large molecules are able to enter the bloodstream in the small intestine finally, and they go all over our body to be raw materials to provide the energy that the body needs.

In the classroom observations, similar to interview, it was noted that she was teaching physical and chemical digestion of foods in the class as follows:

> Physical digestion of foods occurs in the mouth with the help tongue and teeth. It is physical digestion that the nutrients we take in our mouth are moistened and lubricated cut into small pieces such as cut with a knife. There is a chemical change in chemical digestion. These large molecules such as carbohydrates, proteins, and fats break down into smaller pieces, and enzymes are definitely involved in chemical digestion process.

Moreover, she explained enzyme in the class similar to interview as follows:

> There are special enzymes for the chemical digestion of carbohydrates, proteins, and fats to separate these large molecules into building blocks. Enzymes react and are chemicals that are not affected by this reaction at all.

Contrary to her interview, during her teaching she taught pharynx and its role. According to classroom observation data her sample excerpt is given as follows:

> Pharynx is an intersection point. The pharynx has a very important task, which ensures that the food you take moves to the esophagus and the breath you take moves to the lungs. There is no problem if the air you take to moves to your stomach, you will have gas in your stomach or bloating. If you talk while you are eating, you will start coughing because the pharynx cannot do its function, and something pass into your lungs. However, this can be lethal if anything liquid or solid, other than gas, moves into the lungs. That is why the task of the pharynx is very important. We will also see the function of pharynx in the respiratory system.

General Summary of Anna's Finding about The Digestive System

General summary of Anna's understanding of digestive system shows that she referred all concepts related to the digestive system at middle school level. Her knowledge seems compatible with the curriculum. She is aware of digestion process, purpose of the digestion, the digestive system organs and relationship between these organs, the relationship between energy and digestion, the health of the digestive system. Thus, Anna seems knowledgeable in terms of the digestive system.

In response to Anna's explanation about relationship between the digestive system and circulatory system, her knowledge regarding circulatory system is reported by asking related questions. Next section represents her knowledge of circulatory system and the relationship among other human body systems.

4.1.3.1.2 Anna's Knowledge Regarding the Circulatory System

In this part, Anna's knowledge regarding the circulatory system is resulted and presented. The data related to Anna's knowledge of the circulatory system is collected through pre-interview questions including concept maps, drawings, and word association tests, and classroom observations.

Her interview data analyses, and classroom observation findings are summarized in the Table 4.16.

Anna's knowledge regarding the circulatory system during pre-interview is examined into two titles which are *Understanding of The Circulatory System and Its Organs*, *The Health of The Circulatory System*.

4.1.3.1.2.1 Understanding of the Circulatory System

In this subtitle, Anna was asked about her understanding of circulatory system and types of the circulation.

Anna's responses show that she only mentioned the transportation role of the circulatory system. She defined the circulatory system as a transportation system in the body. She seems aware of the difference between pulmonary and systemic circulation.

Table 4.16 Anna's Knowledge of Circulatory System

Categories	**Anna's Knowledge of the Circulatory System**
Circulation	– Pulmonary Circulation & Systemic Circulation
The Role of the Circulatory System	
Interview only	– provides cells with nutrients and oxygen – removes waste products
Classroom observation only	– carry molecules that is formed at the end of the digestion – carry oxygen which is inhaled with the help of the respiratory system – carry hormones from secretory glands to the target organs – provide water balance of the body – protect the body temperature
Both	– carry metabolic wastes of the cells to the urinary system – carry carbon dioxide formed in the cells to the respiratory organs
The Circulatory System Components	– Blood Blood cells *White blood cells* *Red blood cells* *Platelets* Plasma – Vessels Arteries Veins Capillaries – Heart

Table 4.16 (continued)

The Health of the Circulatory System	*Disorders*
Interview only	– Systolic and Diastolic pressure – Atherosclerosis – Heart failure – Blockage of vessel
Classroom Observation	Hypothermia
Both	Varicose Hemophilia
	Conditions for healthy circulatory system – Eating healthy – Doing sports – Staying away from excessively salty or fatty foods – Avoiding smoking and alcohol

Anna's definitions of blood cells matched with their scientific definitions. Anna was aware of the organs and structures that make up the circulatory system. She pointed out blood cells which are white blood cells, red blood cells and platelets. Moreover, she correctly stated that using the terms that dirty and clean blood is wrong and explained the correct usage of these terms. Furthermore, she explained blood groups, blood transfusion, Rh factor, and erythroblastosis middle school level. Additionally, she was aware that the blood donation is crucial for social solidarity. She stated that Turkish Red Crescent Society (Kızılay) is an institution that receives blood donation.

First, what does the circulatory system mean to her the function of the circulatory system in the body were asked Anna to reveal her understanding about the function of the circulatory system.

> Anna: I can define the circulatory system as the system that delivers substances in the body. [The circulatory system] provides cells with nutrients and oxygen, and it removes waste products. We need the circulatory system because we are made up of trillions of cells, and it is impossible to carry oxygen and nutrients to all these cells. Therefore, the body needs a transportation system and the circulatory system do this transportation.

After Anna defined the circulatory system and explained the reason why we need the circulatory system, she was asked to write 12 words about circulatory system. As presented in Table 4.17 below, these words were grouped under six categories. The categories included *organ* (i.e., heart), *tissue* (i.e., vessels, blood), *cell* (i.e., white blood cells, red blood cells), *molecule* (i.e., oxygen), *types of circulation* (i.e., systemic and pulmonary circulation), and c*irculatory system diseases* (i.e., varicose, hemophilia).

As a follow up question to the words she listed, the relationship between these words was asked. She explained the relationship as follows:

> Actually, these [heart, vessels, blood, white blood cells, red blood cells, platelets, veins] are the organs, and the structures that make up the circulatory system. Hemophilia, which I remember when I teach platelets, means that blood does not clot normally. Systemic and pulmonary circulation explain

blood flowing in the body. Blood carries oxygen. Varicose can cause discomfort.

Table 4.17 Anna's Concepts Associated with Circulatory System

Groups of concepts	**Concepts**
Organ	Heart
Tissue	Vessels Blood Veins
Cell	White blood cell Red blood cells Platelets
Molecule	Oxygen
Types of Circulation	Systemic Circulation Pulmonary Circulation
Circulatory System Disease	Varicose Hemophilia

Afterwards, since Anna mentioned systemic and pulmonary circulation while she was constructing her wordlist, she was asked about the following question below.

Researcher: You have already mentioned the systemic and pulmonary circulation while you were constructing your wordlist above. Is there any difference between them? If yes, how?

Anna: Systemic and pulmonary circulation have a different purpose. While systemic blood circulation carries nutrients and oxygen to the body, pulmonary circulation provides that deoxygenated blood become more oxygen-rich in the lungs.

Thereafter, she was requested to draw systemic and pulmonary circulation. However, instead of drawing she prefer to show this circulation by using flow chart as stated in in the Figure 4.8. Her drawing reveal that she drew a flow chart as if pulmonary and systemic circulation were independent of each other. In the next part, the circulatory system organs and structures are presented.

After she listed the words related to the circulatory system, one more time, the structures and the organs that make up the circulatory system were asked to Anna. She stated that *the heart, blood, and vessels* make up the circulatory system. Then, she was asked to draw the human circulatory system to reveal her understanding about the circulatory system in detail. She explained her drawing as follows:

> There is a heart. The blood is moving through the body from the right side of the heart. Then, the blood moves to the lungs and back to the heart. It became a complicated drawing. I do not draw like this (see Figure 4.7) in the classroom.

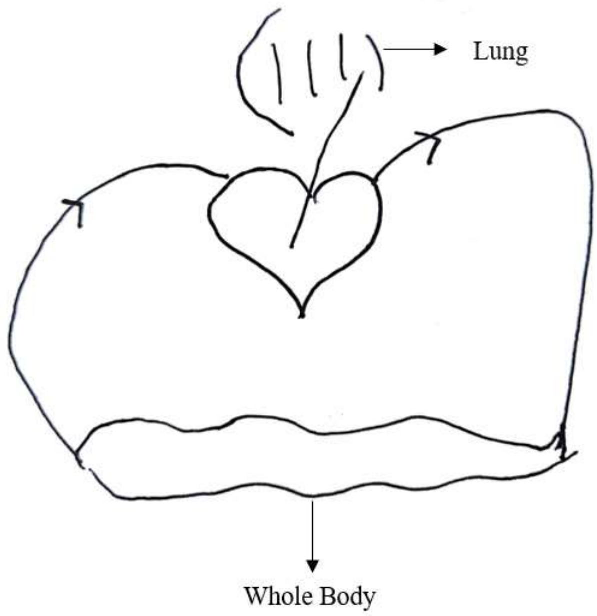

Figure 4.7 Drawing of Circulatory System

As seen in Figure 4.7, Anna's drawing shows that she did not represent vessels. However, she correctly indicated the relationship between lungs and heart. In the following step, the relationship between the organs that make up the circulatory system was asked to Anna. She stated that *all of those [the heart, blood, and vessels] help each other. That is, the heart is pumping, the blood is carrying, the vessels are transporting. All of those complete each other and they have the same purpose and the same function.*

Pulmonary Circulation

Right Ventricle → Pulmonary Artery → Lung → Pulmonary Vein → Left Atrium

Systemic Circulation

Left Ventricle → Aorta → Whole Body → Superior & Inferior Vena Cava → Right Atrium

Figure 4.8 Pulmonary and Systemic Circulation Drawing

Afterwards, the functions of the structures and the organs that make up the circulatory system were asked Anna to reveal her understanding of the heart, blood, and vessels in detail. Her response is given below:

> Blood is composed of cells that are specialized in carrying oxygen, nutrients, and waste products. Red blood cells carry oxygen and nutrients that are in the blood plasma. The function of the heart is pumping blood to the body. The pressure, which is the result of pumping of the heart is quite necessary for blood to be carried throughout the body. The vessels carry the blood that the heart pumps. The vessels are specialized as arteries, veins, and capillaries according to their functions. The arteries have thick walls, which are resistant to the pressure of blood flow. The arteries carry blood which is oxygen-rich throughout the body. The veins are thinner [than arteries] because there is low pressure. The veins also return deoxygenated blood to the heart. The capillaries are very thin vessels that are made up of a single cell, specialized for the exchange of food and oxygen. While the arterial capillaries release oxygen and food into the cell, the vein capillaries take the carbon dioxide and waste materials back to the heart.

As she already mentioned the pressure she was asked about the meanings of the pulse and the tension. *She explained that the number of times that the heart beats in a minute is called the pulse. Tension (Blood pressure) is called the pressure that the blood creates on the vessel walls as it flows through the vein.*

Above data shows that Anna seems aware of how vessels are specialized in terms their structures and functions. However, she did not mention the difference between arteries and pulmonary artery or veins and pulmonary vein. Then, since Anna have just mentioned the heart, she was requested to draw a heart (see Figure 4.7).

As seen in the Figure 4.7, she represented the heart in not detail but her drawing was beyond the middle science curriculum. She also drew the same drawing while she was teaching the heart in the classroom (see Anna's KoIS). Then, it was requested for Anna to draw a concept map (see Figure 4.9) related to the circulatory system.

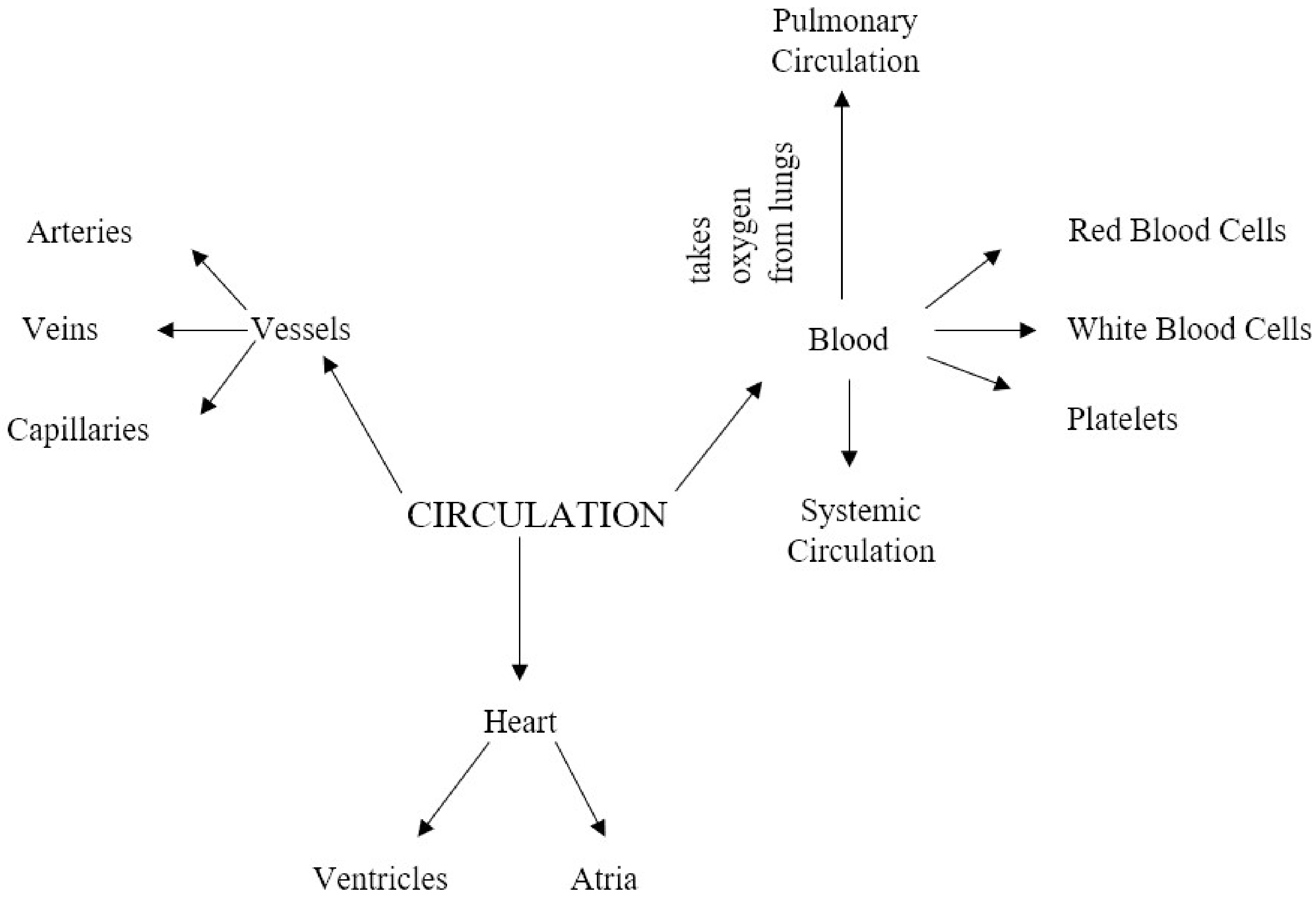

Figure 4.9 Circulatory System Concept Map

Anna's circulatory system concept map shows that she included only circulatory system organs in her concept map. Moreover, her map did not show the relationship between the organs and the structures because she did not write any linking words while she was creating the map.

Anna mentioned the blood during her concept map and her wordlist while she was explaining the organs and structures that make up the circulatory system. Thus, once more, to get detail information about her knowledge regarding blood, she was requested to explain the structure and the function of blood. She was aware that blood consists of plasma, red and white blood cells, and platelets. Moreover, she correctly explained that blood plasma is composed mostly of water while it includes nutrients, vitamins, minerals. Nonetheless, she did not mention that blood plasma also includes ions and dissolved gases.

> Researcher: You have already addressed that blood is composed of cells that are specialized in carrying oxygen, nutrients, and waste products. Can you explain the structure and the function of blood?
>
> Anna: The function of blood in the body is to transport oxygen and nutrients to the cells and take waste materials back. The blood is composed of three blood cells and blood plasma. The function of red blood cells is transporting hemoglobin, which gives blood its red color. The hemoglobin binds oxygen, thus transporting oxygen to the cells. That is, the primary function of a red blood cell is to carry oxygen and carbon dioxide. The white blood cells are the protector and the fighter—the white blood cells battle against bacteria and viruses by producing chemicals against their poison or engulfing them. Thus, the white blood cells form the body's defense mechanism and the immune system. The platelets stop bleeding out of the vessels and blood clotting. A major part of blood plasma is made up of water, but it also [blood plasma] includes nutrients, vitamins, minerals.

As a follow up question to her explanation regarding blood plasma, she was asked about serum and plasma. Anna said that *there was a difference between serum and plasma, but I do not remember it right now.*

As she mentioned in students' misconceptions related to HBS, she once more addressed the concepts that called "dirty blood and clean blood" in Turkish frequently used in everyday context. She responded that *the words that make me angry most are dirty blood and clean blood. Generally, books present deoxygenated blood as dirty blood and oxygen-rich blood as clean blood. I know the misconception, but I try to avoid using dirty blood and clean blood as much as possible.*

The blood groups were asked to Anna to get detail information about the blood. She seems aware that the blood groups are determined according to the proteins that the blood possess. Moreover, she explained that if the anti-B antibodies of the type A recipient bind to the transfused a person who has type B it causes them to block the vessel. She responded that:

> Anna: There are two different proteins in the structure of blood, which are protein A and protein B. According to the different amounts of these proteins, the blood groups are formed. If there are protein A and anti-B antibody that means that a person has a blood group A, if there is protein B and anti-A antibody, that means that a person has a blood group B. If protein A and protein B are together and there is no antibody, that means you have blood group AB. If there are no proteins and if there are only antibodies A and B, this is called blood group 0 (zero). The group of the blood is solely based on the proteins present in that blood….When protein A is combined with anti-A antibody, it forms a clot in the vein. Thus, if a person with blood group A is transfused the blood group B, these two [protein A and anti- A antibody] come together to block the vein and cause the death of that person.

Then, in order to find out how much Anna knows about blood transfusion, following questions were asked to her:

> Researcher: How does the blood transfusion occur?
>
> Anna: Each blood group can only donate blood to the same blood group. However, the students see some concepts such as the universal donor group and the universal recipient in books. So, I explain this situation for students like this "I assume that there is a war and one of the soldiers has a severe bleeding, and I point out that there is a possibility that the soldier may die whether you transfuse the blood or not. In this case, I say that the doctor takes this risk and transfuses blood group 0, which is known as the universal donor group, to the soldier. However, under normal circumstances, only the ones with the same blood group can give blood to each other."

Like she explained above, she was aware of the fact that correct matching of the donors and recipients' blood types are important during the process of blood transfusion. Then, the Rh factor is asked to Anna during the interview, she explained that Rh is a protein which was found in a monkey, which was called Rhesus Macacus.

> Researcher: What about Rh factor?
>
> Anna: The students have enjoyed it whenever I told this story. The Rh factor is a protein which was found in a monkey named Rhesus Macacus for the first time. Scientists used the first two letters of Rhesus Macacus. If your blood has this protein, you are Rh-positive. If your blood lacks the protein, you are Rh-negative. There is no advantage of having a Rh protein. I mean, if your blood has the protein, it does not mean that you live long, or you are genius. It [Rh] is a protein that should be considered only in blood transfusion. So, if a person who is Rh-negative gets Rh-positive blood, his/her body resists against the Rh factor because Rh is perceived as a foreign substance. Also, I am not really sure, but the body can create a precipitation.

> Thus, while people with Rh-positive blood may be infused Rh-negative blood, people with Rh-negative blood cannot be infused Rh-positive blood.

Moreover, when erythroblastosis fetalis (Rh incompatibility) asked to explain Anna correctly stated that erythroblastosis fetalis occurs when Rh-negative mother has a Rh-positive baby.

> Erythroblastosis fetalis … If a Rh-negative mother has a Rh-positive baby, a specific amount of blood of the baby can pass into the mother's body through the placenta. Then, something is formed in the mother's body, which affects the baby [negatively]. Moreover, I know that the blood needs to change as soon as the baby is born.

Anna was asked about the blood donation and its importance for society, personal responsibilities regarding blood donation. She mentioned that blood donation is necessary for cooperation as given below:

> Solidarity… Something bad that happened to you, may happen to me tomorrow… Blood donation is very essential for cooperation…Turkish Red Crescent Society collects blood donation. I do not know if there is an official institution other than the Turkish Red Crescent Society. Hospitals may have blood banks, but they are not as common as the Turkish Red Crescent Society. They receive blood from Turkish Red Crescent as far as I know. However, if your relative who is a bleeding a lot in a hospital and if s/he is going to have surgery, you can also donate blood to that particular hospital…. As a teacher, I emphasize the importance of blood donation to students because solidarity is quite necessary.

Then, Anna was asked about the adaptations that occur in the circulatory system. She stated that the most significant adaptation that is related to the circulatory system is the increase of the red blood cells in the places that have a low oxygen level.

Additionally, Anna was questioned about the health of the circulatory system in the next part.

4.1.3.1.2.2 The Health of the Circulatory System

Anna was asked about the circulatory system diseases, our responsibilities to keep our circulatory system healthy. She mentioned lower and higher tension, heart failure, atherosclerosis, blockage of vessel are circulatory system diseases, and these are related with each other. Her responses are given below:

> Eating healthy, doing sports, staying away from excessive salty or fatty foods, avoid smoking and alcohol. These would help. There is a cardiology department of hospitals responsible for circulatory system diseases... The well-known diseases are lower and higher tension, heart failure, atherosclerosis, blockage of vessel…. These diseases are caused by the heart not working properly.

In short, according to interview data, Anna seems aware of the organs that constitute the circulatory system. However, she did not remember the difference between blood plasma and serum. She knows the general function of circulatory system and types of circulation. That is, she correctly stated that the pulmonary and systemic circulation have different purpose. Then, she is aware of the circulatory system disorders.

Afterwards, classroom observation data were presented and compare with the pre-interview finding.

Classroom Observations Findings

During her teaching, she explained function of circulatory system, the organs that constitute the circulatory system and their functions, systemic and pulmonary circulation, oxygenated and deoxygenated blood, diseases which are related to circulatory system such as varicose, hypothermia.

For example, during classroom observation she started the lesson by asking *What does the circulatory system mean? What is the purpose of circulatory system?* After Anna asked these questions to students, they said that the purpose of circulatory system is transporting nutrients to organs. Then, Anna asked that *whether the only purpose of the circulatory system is to transport nutrients to organs or not? to the students in the classroom* After that, she listed the purposes of the circulatory system on the blackboard (Table 4.18)

It can be said that during the classroom observations Anna established a relationship among human body systems which are respiratory system and urinary system by listing the functions of the circulatory system.

Table 4.18 The Roles of Circulatory System

Circulatory system;
carries molecules that is formed at the end of the digestion.
carries oxygen which is inhaled with the help of the respiratory system.
carries metabolic wastes of the cells to the urinary system.
carries carbon dioxide formed in the cells to the respiratory organs.
carries hormones from secretory glands to the target organs.
provides water balance of the body.
protects the body temperature.

Moreover, during the classroom observation, while Anna was presenting the heart dissection, she explained structure of heart even though she did not mention it in the interview. Her sample transcript from classroom notes is given below:

> The heart muscle works involuntarily, and our own heart is the same size as our fist. The heart is located slightly inclined to the left between the two lungs. The heart has four chambers. There is one-way flow in the valves in the heart. The muscles to the left of the heart are thicker than the muscles to the right since the blood is pumped from the left of the heart to the whole body. The contraction and relaxation of the heart at different times creates a heartbeat.

In addition, to indicate pulmonary and systemic circulation are not separate from each other Anna made a card game (Also see Anna's KoIS) even though Anna's representations about pulmonary and systemic circulation are linear and seems independent during interview drawing (see Figure 4.8). Her sample transcript from classroom notes is given as follows:

> Circulation is not a train station [Pulmonary and systemic circulation are not sequential events. Circulation continues in a loop simultaneously.] Circulation is a cycle. We divide the circulation into systemic and pulmonary to indicate their purposes.

Moreover, during her teaching she explained serum and plasma although she did not remember the difference between serum and plasma in the interview. Her sample transcript from classroom notes is given as follows:

> Blood is composed of two parts which are blood plasma (up to 5% volume) and blood serum (up to 95% volume). Blood plasma consists of white blood cells, red blood cells and platelets while blood serum consists of water, vitamin and mineral.

Furthermore, she warned her students in the classroom when they used the miscomprehended terms (dirty and clean blood). Then, in the classroom she explained:

> What does dirty mean? Is the blood muddy? Dirty blood does not make sense. What is meant to be described with dirty blood is actually deoxygenated blood.

In the classroom observation similar to her interview, she indicated blood transfusion by this explanation as follows:

> If a blood with protein A comes together with a precipitator A, they may interact and it may cause obstruction in the vein, eventually, causing the person to die.

Also, she explained erythroblastosis fetalis in the classroom like she mentioned in the interview as following:

> When the mother is Rh-negative, there is no problem if the baby is Rh-negative. If the mother is Rh-negative and the baby is Rh-positive, the baby may be poisoned because of the mother's blood, so medical intervention will be required. Even if there is no problem in the first child of the expectant mother, the second child may have blood incompatibility.

In the classroom, Anna indicated hemophilia is a disorder where blood does not clot normally similar to interview.

Summary of Anna's Finding about The Circulatory System

In brief, her knowledge of the circulatory system seems beyond the curriculum. She is aware of types of circulation, purpose of the circulatory system, the circulatory system organs and relationship between these organs, the health of the circulatory system and the relationship between the circulatory system and other human body systems. She does not seem aware of the adaptation process of the circulatory system in detail. Thus, Anna seems knowledgeable in terms of the circulatory system.

Anna emphasized all human body systems are absolutely connected to the circulatory system. She exemplified the urinary, endocrine and the respiratory system regarding the relationship between the circulatory system and other human body systems. Her explanation about the carbon dioxide and oxygen being transported through blood shows the relationship with the respiratory system. Therefore, next section represented both Anna's knowledge of respiratory system and relationship among systems with additional questions.

4.1.3.1.3 Anna's Knowledge Regarding the Respiratory System

Anna's knowledge regarding the respiratory system is presented below with interview questions including concept maps, drawings, word association tests, and classroom observations. Interview data and classroom observation findings are covered, respectively and summarized in the Table 4.19.

Anna's knowledge regarding the respiratory system during interview is examined into three titles which are Understanding of the Respiratory System, and Its Components, The Health of The Respiratory System.

4.1.3.1.3.1 Understanding of the Respiratory System and Its Components

In this subtitle, Anna's knowledge regarding respiration, gas exchange, and the respiratory system was asked. Anna's answers show that she was aware of what is the general function of the respiratory system**.** She knows that respiratory system consists of a nose, a trachea, lungs, and bronchus, bronchioles, and alveoli. Moreover, she mentioned role of pharynx and larynx in the respiratory system when it was asked. In addition, she indicated that using "respiratory system" as a term is confusing since using the term "breathing system" is more appropriate for her. When we asked why we need the respiratory system, she emphasized that the role of the respiratory system is taking the oxygen that the body needs and then, giving out carbon dioxide as a waste. The respiratory system provides our body with the oxygen it requires to produce energy.

At the beginning, Anna was asked about the meaning of breathing and the respiration to reveal whether she has misconception or not. First, she defined respiration as a gas exchange. When the meaning of the breathing was asked above, she realized that she gave the wrong answer to the previous question. Thus, Anna's answers show that she was aware of what were the actual meaning of respiration and breathing. As she indicated, while respiration is producing energy from nutrients in mitochondria, breathing (gas exchange) is the intake of oxygen into the body from the environment and releasing carbon dioxide to outside.

Table 4.19 Anna's Knowledge of the Respiratory System

Respiration	− A process that obtaining energy by combining oxygen and nutrients in mitochondria
Breathing	− A process that is inhaling oxygen and releasing carbon dioxide to outside
The Role of the Respiratory System	− To take the oxygen that the body needs and giving out carbon dioxide as a waste
The Respiratory System Components	− Nose − Trachea − Larynx − Pharynx − Lungs − Bronchus − Bronchioles − Alveoli
The Health of The Respiratory System	*Disorders* − COPD − Bronchitis − Lung cancer − Pneumonia *Conditions for healthy respiratory system* − Do exercise − Eat healthy − Live without stress − Support our immune system − Avoid smoking

Researcher: How can you explain the respiration?

Anna: Respiration means inhaling oxygen into the body and releasing carbon dioxide to outside.

Researcher: What does breathing (gas exchange) mean to you?

> Anna: Breathing… In Turkish, breathing and respiration…. Mmm… Sorry. I should fix the previous question. Respiration means that obtaining energy by combining oxygen and nutrients in mitochondria. Breathing is inhaling oxygen and releasing carbon dioxide to outside.

> Anna: Actually, the respiratory system… If the term that "The Breathing System" was used, students would never be confused. However, the term "The Respiratory System" was preferred. The respiratory system consists of a nose, a trachea, lungs, and bronchus, bronchioles, and alveoli that make up lungs.

Then, what kind of changes happen to our body during breathing was asked to Anna in order to uncover her understanding of the breathing process. She stated the aforementioned process as the reason behind the relationship between atmosphere and lungs. That is, air pressure is higher in atmosphere than it is in lungs. Her explanation is given as follows:

> Hmm…Maybe we cannot feel the contraction and relaxation of the diaphragm, but upon inhalation, the diaphragm muscles contract. Thus, the volume of the lungs expands. As the volume of the lungs expands, the air moves inside. [when we exhale] The diaphragm expands and relaxes. When the diaphragm expands, the volume [of the lungs] decreases. When the lungs become smaller, air moves out to equalize the pressure.

After Anna explained respiratory system and listed organs that make up the respiratory system, she was asked to write 12 words about respiratory system, and she listed the words given in the Table 4.20 below.

Table 4.20 Anna's Concepts Associated with Respiratory System

Groups of concepts	Corresponding Concepts
Organ	Lungs Trachea Diaphragm Nasal Cavity
Structure	Alveolus Bronchus Bronchioles
Tissue	Blood
Molecule	Oxygen Carbon dioxide
Process	Pulmonary Circulation Gas exchange

As presented in the Table 4.20, the words that Anna provided were grouped in five categories. These categories included *organ* (i.e., lungs, trachea), *structure* (i.e., alveolus, bronchus)*, tissue* (i.e., blood)*, molecule* (i.e., oxygen, carbon dioxide)*,* and *process* (i.e., pulmonary circulation, gas exchange). When the relationship among her wordlist, she explained that as follows:

> These organs [lungs, trachea, diaphragm, nasal cavity] make up the respiratory system. These [CO_2 and O_2] are the gases that are exchanged. The diaphragm, which is an accessory organ that helps the respiratory system, is active in the working process of the respiratory system. Blood is oxygenated with the help of pulmonary circulation, and carbon dioxide is moved out with the help of the respiratory system. All of these are actually based on gas exchange.

Later on, Anna was asked about the which organs that the respiratory system has, she explained that *respiratory system consists of a nose, a trachea, lungs, and bronchus, bronchioles, and alveoli*. Anna was requested to draw the respiratory system.

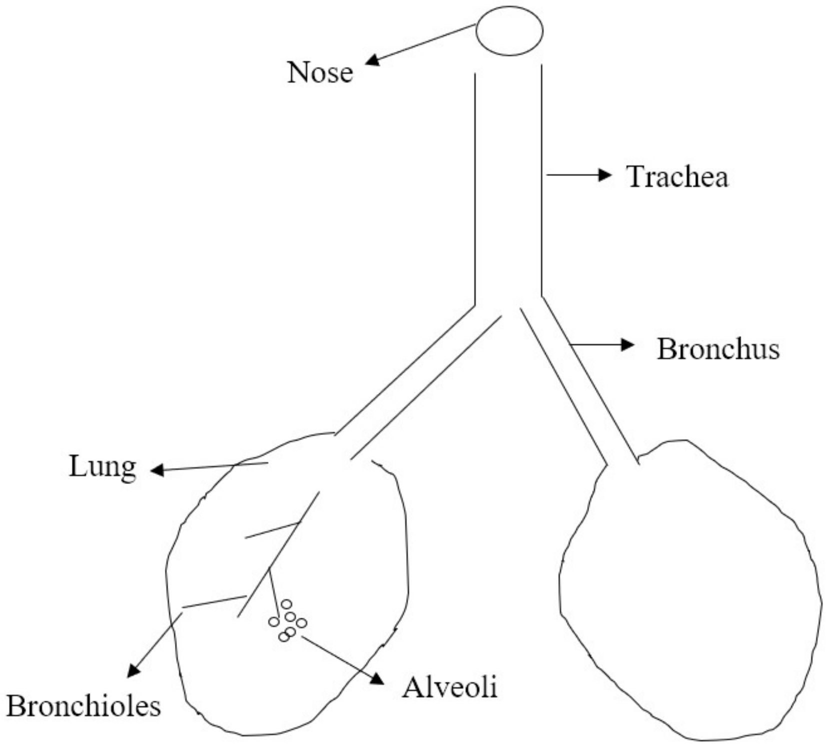

Figure 4.10 Drawing of Respiratory System

As seen above, her drawing did not include a larynx, a pharynx as respiratory system organs similar to her explanation above which is *the respiratory system consists of a nose, a trachea, lungs, and bronchus, bronchioles, and alveoli*. Afterwards, the relationship between these organs was asked Anna. She stated that *all of them [structures and organs] simplify and complete each other's tasks*. To reveal her understanding in detail the functions of the structures and the organs that make up the respiratory system were asked to Anna. She mentioned the nose hairs and the mucus, and she correctly stated that they are filtering and warming the air, which is why they are called as 'the nasal cavity'. Then she correctly defined the structure and the function of the trachea in the respiratory system. The trachea has a cartilage structure, and it continues filtering the air. Just as Anna said, the trachea is divided into two bronchi. Moreover, she explained that there are the alveoli at the end of the bronchioles. She indicated that the alveoli ensure the exchange of O_2 and CO_2.

The nose has a mucus layer and nose hair. These [nose hair and the mucus layer] together help to filter and warm the air inhaled. The trachea has the same structure, which includes the mucus layer and hair to continue filtering. The air taken from the nose passes through the trachea and then the bronchi. The trachea has a tough cartilage tissue, and it is made up of moist and hair. The trachea is responsible for filtering and warming up the air. If there is the air that the nose still cannot filter, the trachea is making the air warmer before it [the air] moves towards the lungs. Then, the air goes the alveoli, which are the air sacs at the end of the bronchioles, and it inflates the alveoli. The alveoli have very thin structures. Alveoli, which has high carbon dioxide, gives the air out with the help of the diaphragm, and ensures that the carbon dioxide moves out. The diaphragm is a muscle that is located in the abdomen. The diaphragm helps us breathe by changing the volume of the lungs with the help of contraction and relaxation movements.

Since Anna did not address the pharynx and larynx her drawing (see Figure 4.10) and her wordlist (see Table 4.20), it is decided to ask these organs. She defined pharynx as a junction point. Then, she mentioned that the larynx has vocal cords to produce sounds. Moreover, she indicated that diaphragm is a muscle, and it changes the volume of lungs and helps us when we are breathing.

Researcher: Can you define pharynx and larynx?

Anna: Pharynx serves as a junction between the esophagus and the trachea. Pharynx closes the trachea while eating, and closes the esophagus while breathing, thereby it [pharynx] ensures that nutrients and air go to the right organs. There are vocal cords at the end of the larynx. When we exhale, those vocal folds vibrate to produce sounds.

After Anna explained the organs and the structures that make up the respiratory system, the adaptations that occur in the respiratory system was asked to her. She does not know any adaptations that is related with the respiratory system.

4.1.3.1.3.2 The Health of the Respiratory System

In this title, her understanding of the respiratory system health was checked. Anna was asked about our responsibilities to keep the respiratory system healthy, respiratory system diseases, the relationship between the respiratory system diseases. She correctly stated that Chronic Obstructive Pulmonary Disease (COPD), lung cancer, bronchitis infection and the pneumonia are respiratory system diseases.

> Anna: Smoke…smoke…smoke… [We should not smoke]. We should do sports, eat healthy, and live without stress…Chronic Obstructive Pulmonary Disease (COPD), lung cancer are the respiratory system diseases… Of course, there is a relationship between these diseases. For example, bronchitis infection and the pneumonia are caused by lungs which are not being used appropriated and healthily…It [the respiratory system diseases] is entirely caused by the deterioration of the structure of the lungs.

Later on, Anna's classroom observation notes were represented in the next part.

Classroom Observation Findings

In the classroom, Anna taught function of the respiratory system, the reason for oxygen demands of cells, the organs and the structures that make up the respiratory system (i.e., nose, lungs, larynx) and their function, breathing process similar to her interview responses.

For instance, at the beginning of teaching the respiratory system, she started her lesson by asking *What does the respiratory system mean? Why does our body need oxygen? Does your body have any energy system?* Then, she explained the role of the respiratory system to students, she mentioned the difference between respiration and breathing in the classroom similar to her interview responses. Her explanation from classroom notes is given as follows:

> Respiration is different. Breathing is the exchange of gas. Cells provide their energy needs from the food they receive and oxygen in the blood. Cells do aerobic respiration.

She did not extra activity to do conceptual change regarding the difference between respiration and breathing, she indicated the relationship between the atmosphere and the lungs in terms of the pressure while she was explaining gas exchange just like she did during the interview. In the classroom she explained as:

> Gas exchange occurs when the gases move from where they are more concentrated to where they are less concentrated. We call it diffusion. Breathing is all about the relationship between pressure and volume. This continues until external pressure and lung pressure are equalized.

Anna's explanations both during her lesson and during the interview show that she is aware of purpose of the respiratory system at middle school level. Her sample excerpts in the classroom observation as follows:

> To be a system, it must be composed of organs. Although the respiratory system is the same word as respiration, it is actually the gas exchange system where the oxygen needed by our body is taken and carbon dioxide is given. What we call respiration is a reaction that takes place in the cell and this is carried out by an organism in mitochondria of the cell. We need the respiratory system in order to get the oxygen that mitochondria need into the body.

Moreover, in the classroom she explained the diaphragm by using volume-pressure relationship as follows:

> Mechanism of breathing is related with volume-pressure relationship. Diaphragm is a dome shaped muscle [Also, she shows the shape of diaphragm with her hands]. When the volume increases, the pressure decreases. The only thing that you should know is how does air enter and leave in the body. It continues until pressure of lungs equals to external pressure.

Finally, it was noted that in the classroom observations, similar to her explanations during the interview she explained the relationship between the circulatory system and the respiratory system by saying *"the oxygen in the air moves into the blood and the carbon dioxide in the blood is expelled to the air with the help of the lungs."*

Summary of Anna's Finding about The Respiratory System

In brief, her knowledge seems compatible with the curriculum. She is aware of respiration, breathing, purpose of the respiratory system, the respiratory system organs and relationship between these organs, the health of the respiratory system and the relationship between the respiratory system and other human body systems. She does not seem aware of the adaptation of the respiratory system. Anna mostly seems knowledgeable in terms of the respiratory system.

In the next section, Anna' knowledge of the urinary system and its relationship with other human body systems is reported.

4.1.3.1.4 Anna's Knowledge of the Urinary System

Anna's knowledge of the urinary system is highlighted with interview questions including concept maps, drawings, word association tests, and classroom observations. Interview data and classroom observation findings are described consecutively and summarized in the Table 4.21.

Anna's knowledge of the urinary system during interview is examined into three subtitles which are *Understanding the Urinary System and Its Components, The Adaptation of the Urinary System the Health of the Urinary System* to grasp her responses better.

Table 4.21 Anna's Knowledge of the Urinary System

Categories	**Anna's Knowledge of the Urinary System**
Excretion	− The disposal of the wastes resulting from the metabolism of the protein
The Role of the Urinary System	− Remove nitrogen-containing compounds, which are toxic, from the body
The Urinary System Components	− Kidneys − Ureter − Urethra − Urinary bladder
The Health of The Urinary System	*Disorders* − Nephritis − Kidney inflammation − Kidney failure − Kidney stones − Cystitis *Conditions for healthy urinary system* − Drink plenty of water − Avoid alcohol and smoking − Not to keep the urine in our body for a long time − Avoid spicy foods

4.1.3.1.4.1 Understanding the Urinary System and Its Components

In this sub-title, Anna's knowledge of definition of the excretion, urine formation and the role of the urinary system is shown. Anna explained excretion as the removal of metabolism waste from the body. She only mentioned the removal of nitrogen-containing compounds as the function of the urinary system. She addressed the role of kidney, ureter, bladder, and the urethra. Anna seems to be aware of what urine includes, and urine formation.

First, she was asked to provide her understanding for the term "excretion". She correctly explained that the excretion is a process that includes the disposal of metabolism of protein, and the urinary system provides this disposal process.

> Excretion is the disposal of the wastes resulting from the metabolism of the protein, and the whole system that does all of this is called the urinary system. Urinary system is quite essential to ensure the removal of ammonia, which is a nitrogenous compound and formed as a result of the metabolism of the substances with protein in cells. Ammonia is converted into urea and uric acid in the liver, then it passes to the kidneys through the blood. After the kidneys drains it, it [ammonia] gets removed from the body.

Then, Anna was asked about the function of the urinary system in detail to get more information about how much she knows. Once more, she addressed that *the role of the urinary system is to remove nitrogen-containing compounds, which are toxic, from the body.* She did not explain regulating pH and blood pressure etc.

Afterwards, Anna was asked to write 12 words about the urinary system, and she listed the words given in the Table 4.22 below. As presented in the table, these words were grouped in four different categories: These categories included *organ* (i.e., kidney, liver)*, structure* (i.e., urethra, ureter)*, molecule* (i.e., protein, urine)*,* and *tissue* (i.e., vein, artery).

As a follow up question, the relationship between the aforementioned words was asked to her. Bethy explained the relationship among the words by explaining urine formation as follows:

> Ammonia, which is formed as a result of the metabolism of protein, is converted to urea and uric acid in the liver. The blood with high-uric acid concentration is transported to kidney with the help of the renal artery. After the draining process in the kidney, it [blood] is, then, transported to the bladder through the urethra. After it is drained again in the kidney, the blood which is filtered returns to the body through the vein. Then, the urine in the bladder is excreted through the ureter.

Since Anna addressed two different terms which are “urine” and “waste”, she was asked to get more detailed information.

Table 4.22 Anna's Concepts Associated with Urinary System

Groups of concepts	**Corresponding Concepts**
Organ	Kidney Liver Bladder
Structure	Urethra Ureter
Tissue	Vein Artery
Molecule	Protein Urine Urea Uric Acid Ammonia

Researcher: What does urine means to you? What about the waste?

Anna: The urine contains plenty of water and urea. Mmm… Additionally, it [the urine] may contain vitamin B and C. However, the urine that is excreted from a healthy human being never contains protein, glucose, or blood. The substances that can no longer be benefited by the human body are called waste.

Moreover, she explained the meaning of “waste” as a substance that is unnecessary for the human body. Then, Anna was requested to draw concept map of urinary system to see how much she associates related concepts and events.

As seen in Figure 4.11, her concept map includes the structures and the organs that make up the urinary system. She only shown the relationship between blood and kidney in her map.

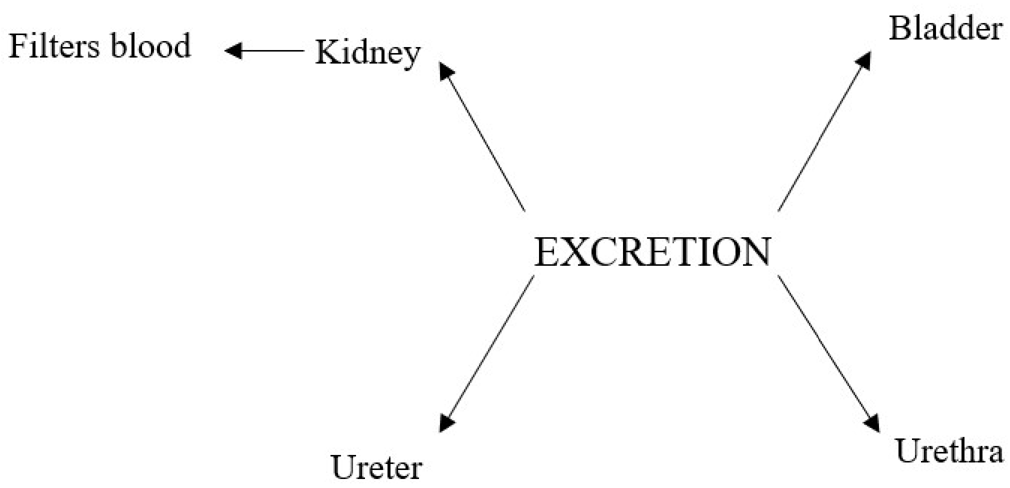

Figure 4.11 Anna's Concept Map of Urinary System

After Anna draw a concept map, once more she was asked about the structures and the organs that make up the urinary system. Anna correctly stated that the urinary system consists of kidneys, urethra, bladder, and ureter. When the relationship between the urinary system organs was asked Anna, she indicated that *each organ that make up the urinary system helps each other to complete their full functions*.

Then, Anna was requested to draw the urinary system.

As seen in the Figure 4.12, Anna represented kidneys, ureters, bladder, and the urethra likewise her wordlist above (see Table 4.22). Since she has already mentioned kidney, she was requested to draw a kidney. Her kidney figure can be seen in the Figure 4.13. Moreover, she also explained her drawing as following:

> That is…. There is an inverted pyramid in the structure of the kidneys… These are called Malpighi pyramids. This is the renal pelvis; this is the cortex. The blood which has high urea concentration is transported with the renal artery and it is filtered by the nephrons, which are located in the cortex. The filtered blood passes through the pyramids and comes to the renal pelvis. That is, there is no more blood in the renal pelvis. Only the urine accumulates there drop by drop. The urine which is gathered in the renal pelvis moves to the bladder with the help of the ureter. When the bladder reaches its full capacity,

the urine is expelled from the body. Moreover, the urethra and vagina are two different openings in females while there is only a single opening in males.

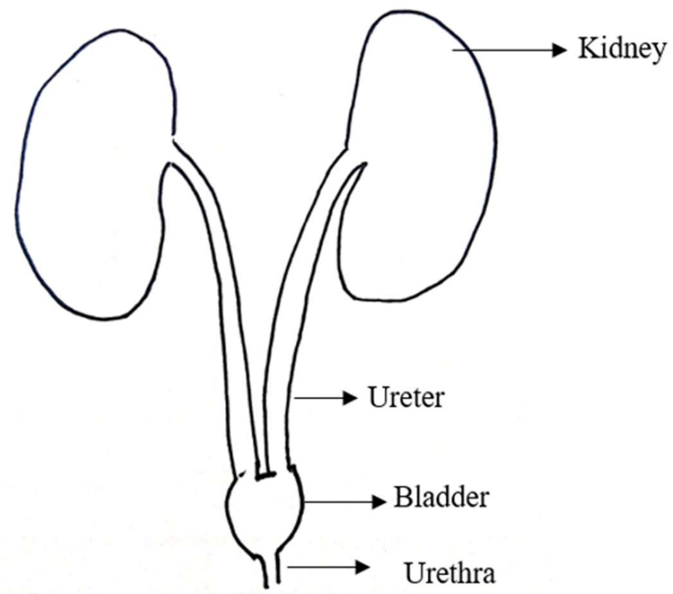

Figure 4.12 Drawing of Urinary System

Her drawings and explanations give clues about her understanding about the urinary system organs and structures in detail. She mentioned Malpighi pyramids, the renal pelvis, the cortex, and the nephrons by explaining their functions throughout the urine formation. However, she did not mention medulla and renal vein. Moreover, although she explained the role of renal artery and ureter, and nephrons she did not draw them.

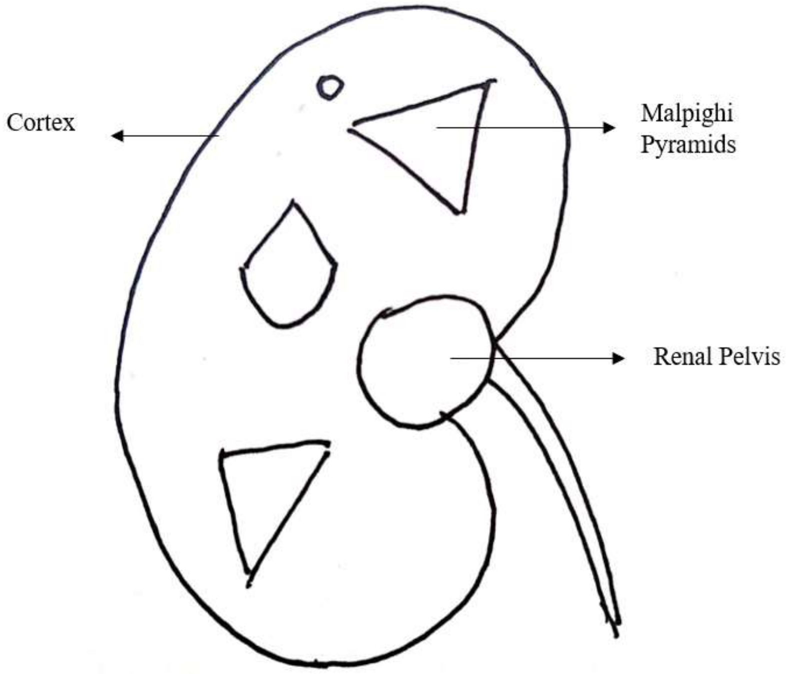

Figure 4.13 Drawing of Kidney

Afterwards, the organs that help urinary system organs were asked to Anna. She responded that *the liver transforms ammonia to urea and uric acid.* The large intestine, skin and lungs also have some functions during the excretion process in our body. Thus, different ways of excretions were also asked to Anna and her explanation is given as follows.

> The skin is a way of excretion for us. The way that the carbon dioxide is thrown out is also called excretion, but different types of excretion processes confuse the students after a while. So, I mention the urine that is excreted through the skin, and I do not mention any other forms of excretion as after explaining that the carbon dioxide is expelled through the skin, students get confused about almost all of these concepts [excretion, carbon dioxide]. That is why, I prefer not to mention them [different types of excretion]. However, the course books include the waste thrown from the large intestine as a different form of excretion.
>
> Researcher: What about the role of the large intestine in the urinary system?

> Anna: If the large intestine is associated with excretion, it is perceived as an excretion organ. However, the large intestine is an organ of digestive system. So, I prefer not to mention the large intestine here [in the Urinary System] as well as the lungs. As the defecation path in the large intestine and excretion are mistaken … I am talking about the skin… I say that some of the urea can also be excreted with the help of the skin. However, if the course book includes other organs, I explain them in a simple sentence as I must do.

Anna explained that the large intestine, skin, and lungs also have functions in the excretion process. However, she thinks that teaching large intestine, skin, and lungs as the different ways of excretion can confuse students since they are not included as the urinary system organs.

4.1.3.1.4.2 The Adaptation of the Urinary System

Then, the adaptations that occur in the urinary system was asked to her. Anna seems to be familiar with the urinary system adaptation that is related to prevention of water loss. Unlike animals that live in waters, the land animals convert ammonia to urea so that they can decrease water loss. Her sample transcript is given as follows:

> Ammonia is a toxic substance that is removed from the body with large amounts of water. For example, fishes can directly excrete ammonia. However, I know that it is a mammalian adaptation for ammonia to be transformed to urea first in order to reduce the water loss. I even know that birds excrete ammonia as uric acid and as mammals; we excrete it [ammonia] as urea.

Afterwards, she was asked about the health of the urinary system.

4.1.3.1.4.3 The Health of the Urinary System

In this sub-title, her understanding about the health of the urinary system is revealed. She was asked about our responsibilities to keep the urinary system healthy, institutions regarding the urinary system, urinary system diseases and the relationship between these urinary system diseases. She mentioned that to keep the urinary system healthy, we should drink water, exercise regularly and stay away from excessive sugary, salty, and greasy foods. Also, she listed the urinary system diseases which are renal failure, cystitis, nephritis. When she mentioned Dialysis centers, she was also requested to explain dialysis as a follow up question. Her explanations are given below.

> We should drink plenty of water and avoid very salty and greasy foods. We should avoid eating excessive amounts of sugar. We should eat healthy and exercise regularly… Dialysis centers are related to the urinary system…The dialysis is the name given to the process of filtering the blood when the kidneys fail to do so. Renal failure, cystitis, nephritis are the urinary system diseases… …Of course there is a relationship between these diseases… All of these diseases occur as a result of an organ's failure in that system, and it affects the system negatively.

Next, classroom observation notes during Anna's teaching of the urinary system is presented to compare her pre-interview data.

<u>*Classroom Observations Findings*</u>

Classroom observations show that Anna taught purpose of the excretion, purpose of the urinary system, the urinary system organs and relationship between these organs, the health of the urinary system, the importance of drinking water, the kidney transplantation. For instance, Anna started her lesson by asking *What does excretion means?* to the students. Then, Anna explained *feces* as the waste of digestion, CO_2 as the waste of energy, and *urine* as the waste of metabolism just like she stated in the interview. Also, during her teaching she mentioned ammonia as a waste that is needed too much water to be eliminated. It was noted to the classroom field notes that Anna showed the location of the kidneys in detail, and she added that being aware of the locations of the organs is very important.

Additionally, she explained urine as follows:

> Urine includes urea, uric acid, water, salt, and water-soluble vitamins which are vitamin B and vitamin C. However, the urine which belongs to a healthy person does not include the blood and the other nutrients. Having sugar in urine is recognized as a sign of diabetes.

She also mentioned chrono disease and urinary tract infection (UTI) during the classroom observations as disorders.

Summary of Anna's Finding about The Urinary System

In brief, according to both pre-interview and classroom findings, her knowledge of the urinary system seems beyond the curriculum. She is aware of excretion, purpose of the urinary system, the urinary system organs and relationship between these organs, the health of the urinary system and the adaptation process of the circulatory system.

So far, Anna's SMK regarding each system presented separately. Since human body system as a as complex system, the extent to which Anna understand human body system as a complex system was revealed. The findings were reported in next title.

4.1.3.1.5 Anna's Understanding of Human Body System as a Complex System

Anna was aware of human body system is a complex system since it has different organs and structures. She indicated an integrity and cooperation among system that constitute a human body. Anna has an ability to identify several components (i.e., organs, tissues) and process (i.e., respiration, circulation) within human body system.

She also expressed the relationship among components. Moreover, she has ability to organize systems' components and process within a framework of relationship.

First, Anna was asked to define a 'system'. She stated that the *system consists of combining different organs to perform the same function.* Then, following question was asked Anna to detail her response.

> Researcher: What is it that makes your example a system? Can you give an example?
>
> Anna: What helped me to create this definition...First, I thought about which components that constitute a circulatory system and how it worked. The fact that the organs that make up this system are working together helped me defining a system. The circulatory system is an example.

As it can be seen Anna mentioned that there are components that make up a system. She gave circulatory system as an example. She also defined human body systems as *There is a good division of labor has been made in our body to work regularly, to maintain life. That is, each step of this division constitutes the systems in our body.* Then, she was requested to list 12 words that come to her mind about the human body system to elaborate her response.

Table 4.23 Anna's Concepts Associated with Human Body System

Groups of concepts	**Corresponding Concepts**
Organ	Heart Lung
Tissue	Bone
Process	Respiration Circulation Movement
Other	Cooperation Organ Function Tissue Health Life

As shown in the Table 4.23, her response to WAT were grouped under four categories: the categories included *organ* (i.e., heart, lung), *tissue* (i.e., bone), *process* (i.e., respiration, circulation*),* and *other* (i.e., cooperation, health). After she listed her words, she was asked about relationship among these words.

> Anna: Tissues form organs to perform the same function and form the body in cooperation. Examples of these [tissues and organs] are bone, heart, lung. [Tissue and organs] form a healthy life and form a movement together. Circulation and respiration are also exampling of movement.

In attempt to get more information about the extent to which Anna understand human body system as a complex system was revealed with drawing a concept map and related questions. Her map is given in the Figure 4.14 below.

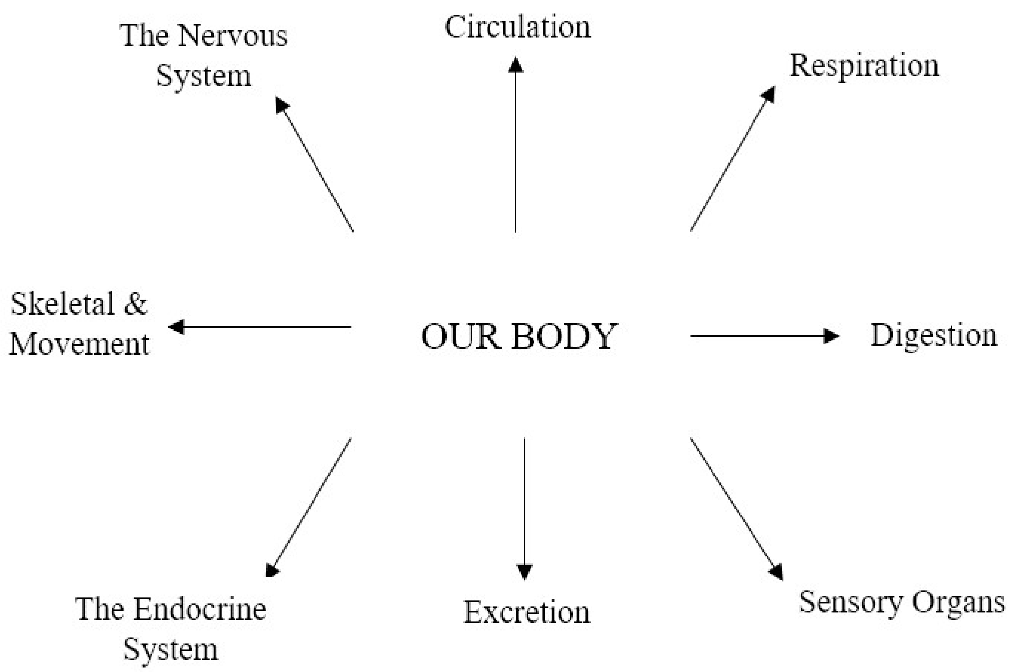

Figure 4.14 Concept Map of Human Body System

The figure given above shows that she did not use any linking words. Her map only includes name of systems and process happen in human body. Thus, the relationship between the human body systems was asked to her.

> Anna: They [the human body systems] work in connection with each other. That is, they [the human body systems] help each other. For example, gas enters the lungs with the help of the respiratory system organs and it [the gas] is transported to other systems through the blood. Naturally, the human body systems work interrelated and connected with each other.
>
> Researcher: So, how does the human body work?
>
> Anna: All these parts work individually, and all these parts form an organism. This means that the digestive system does its own function, the respiratory system does its own function, the skeletal and movement system does its own function. Thus, all together form a human body by working together.

Furthermore, Anna was aware of that human body systems are dynamic. Dynamism is one of the properties of complex systems.

> Anna: There is a constant flow in our body… I mean while the organism is asleep, the heart is working, the blood is pumping, and the breathing is continuing. All human body systems work constantly. In that sense, yes, it [human body systems] is dynamic.

Anna was aware of homeostasis and explained it as internal balance of the body.

> Anna: The homeostasis is an internal balance of the body a body. Hmm…I do not know the detail. Honestly, I knew the homeostasis, but I do not remember right now. I know that homeostasis means maintaining the body's internal balance. For example, if oxygen level decreases, breathing increased to get more oxygen is called homeostasis, as I know.

Moreover, when Anna was asked about her knowledge of curriculum, she expressed that human body systems are complex systems. Thus, the extent to which Anna understand human body system as a complex system was asked Anna. She thinks that there should be an integrity between the topics. She explained this integrity by giving an example of the relationship between the respiratory system and circulatory system. In addition to this, she exemplified the importance of the relationship between the respiratory system and gas pressure.

> Researcher: You have already mentioned that human body systems are complex systems. Why do you think so?
>
> Anna: The structure of human body is very complex. Even a single cell -tiny and invisible- [is a complex system], acts as an amazing factory… It is very difficult for a body to work alone…. [All organ systems work side by side]. For example, it is really difficult to teach the circulatory system without mentioning other systems… You should also mention another complex system, such as respiratory system, involving pressure of gasses. For instance, teaching of breathing requires the understanding of contraction of diaphragm muscle, relationship between volume and pressure. Otherwise, students only memorize the concepts such as the volume increases, the pressure decreases. However, that is not exactly the case. So, there are too many issues that are not fully understood by students. Students handle it through memorization. Is it [respiratory system] really understood? I am sure that they [students] will understand these concepts [diaphragm muscle contracts, the volume increases, the pressure decreases] in high school when they learn about the pressure concept.

Anna was asked about the relationship between the digestive system and the other human body systems. She indicated a relationship between the digestive system and the circulatory system. Also, she thought that there is a relationship between the digestive system and the respiratory system. Nevertheless, she did not mention that any relationship between the digestive system and other systems such as nervous system and musculoskeletal system.

> Anna: Of course, the produced ... more precisely ... fully digested foods are transferred to the cells through the blood. That is, it [digestive system] is

directly correlated with the circulatory system. Indeed, the most significant relationship between the digestive system and the circulatory system is the transfer of digested food through the blood. The implicit relationship between the digestive system and the respiratory system is like this; digested foods, such as carbohydrates, are broken down into glucose to react with the oxygen in mitochondria in the cell.

In summary, Anna was aware that human body system is a complex system and indicated the relationship among organs and organ systems in human body. She organized systems and its components and process within a framework of relationship.

In the next section, Anna's syntactic knowledge is analyzed.

4.1.3.2 Anna's Syntactic Knowledge

In this section, Anna's syntactic knowledge is presented. VNOS-C questionnaire was used to reveal her knowledge in terms of nature of science understanding in the context of human body systems.

At the beginning of the interview, the following questions were asked to Anna in order to determine her understanding of science:

"What do you think science is and what makes science (or a scientific discipline such as physics, biology etc.) different from other disciplines of inquiry (e.g., religion, philosophy)?"

> Anna: Hmmm... There is a cause-and-effect relationship in science. It is the cause of something that leads scientists to reach a conclusion. So, for example, philosophy or religion are more about feelings and our perceptions from our sensory organs… In philosophy or religion, decisions are generally made by taking [our] feelings and perceptions into consideration…Science, however, is more obvious, and certain, and unquestionable to some extent.

> For example, when you say, ‘this is white’, and provide enough evidence, it is easy for you to convince people that ‘this is white’. But, in order to convince people about the presence of God, you have to use different arguments. So, in its nature, science involves certain knowledge, has boundaries [delimited], and it depends on causal relationship.

These responses provide some clues about her understanding of NOS aspects. She asserted that science is more definite and unquestionable than other disciplines such as religion. She held common misconception that scientific knowledge is certain. She gave more details in her response by mentioning that although it [science] includes certain knowledge [which depends on evidence], other disciplines depend on more feelings and our perception provided by our sensory organs.

In order to elaborate on her previous response on certainty and empirical NOS, a series of question was asked to Anna.

> Researcher: Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom?

> Anna: I will explain this question with an example that I have always used in class. When I am teaching the students about the atom, I say that “What is inside my pencil box?”. The students predict and say, “There's a pencil, there's an eraser.” “How do you make sure that there is a pen in it?”, I ask to my students. As a response to my question, later, students touch and feel the pencil box. After that, they [students] also say pyrite (glue), although there is no glue in the pencil box. Later on, they [students] also add: *“Since you are a teacher, there should be a blue pen, a red pen, a pencil.”* I ask them whether or not they can guess the color. The students indicate that it could be yellow, it could be green, or it could be red. However, they do not mention that there could be a lipstick in my pencil box [I put lipstick in it, as well]. “So, how exactly can you predict what is in the pencil case just by touching? No, you

can also be sure if you look at inside [the pencil box]. This [uncertainty] is the current structure of the atom [represent current structure of the atom]. Although we know a lot of things [about the structure of atom], we are not sure because it [information about structure of the atom] can change." When describing the atom, I use this pencil box example very often. It [pencil box example] works very well. This [pencil box] explanation makes the subject [structure of the atom] clear in their [students'] minds.

Researcher: What specific evidence, or types of evidence, do you think scientists used to determine what an atom looks like?

Anna: Rutherford did experiment. In his gold foil experiment, he sent rays to a piece of gold foil [in fact, α-particles fired through thin gold foil]. And then, they [rays] returned back. I exemplify such experiments (i.e., Rutherford gold foil experiment) which were about atom. Scientists have utilized experimental methods, their observations, and they also have conducted many research studies by using microscopes. We have not fully examined the atom yet, but we are very close to discovering the atomic nebulae… I think scientists have decided on the structure of the atom through observations, inferences, and conclusions from their data.

To further clarify her understanding, the question of *"What is an experiment, and Does the development of scientific knowledge require experiments?"* was asked to Anna to deepen her understanding of empirical NOS.

Anna: Experiment is a process that is used to test the accuracy of knowledge. The development of scientific knowledge requires absolutely experiments. [Assume that] You have a question in your mind. To find an answer to that question or to test if that question is correct, you collect necessary documents and then you reach a conclusion. So, this is now knowledge that scientists reach at the end of the experiment. The results [that you reach at the end of the experiments] may be misinterpreted or include different types of errors, but at the end, the data you observe or obtain will ultimately lead you to a conclusion. Therefore, it is not possible to talk about scientific knowledge without experimentation.

Researcher: Can you give any examples about experiments conducted about the human body systems?

Anna: The human body systems are the most difficult topic for teachers to conduct experiments. You know, there are not many things we [as teachers] can do [experimentally] about the human body systems. In other words, this [human body system] is difficult topic to support with experiments at least during the 6^{th} grade. The experiment related to liver enzymes can be done if the students are more knowledgeable about the enzymes. Due to the lack of students' prior knowledge, the topic [human body system] cannot be supported by experiments at 6^{th} grade unfortunately.

Briefly, according to Anna, experiment is a process that is used to test the accuracy of knowledge, and absolutely necessary to develop scientific knowledge. She also stated that scientific knowledge requires experiments since experiments carry us to a conclusion. She believed that conclusions obtained by observations only may be misinterpreted or may include different types of errors. She thought that the human body systems are the most difficult topic for teachers to conduct experiments mainly due to the lack of students' prior knowledge.

Overall, Anna's responses to aforementioned questions reflect her understanding of empirical NOS, inferential NOS, and tentative NOS. For instance, she correctly stated that scientists use observations, experiment, and make inferences to enhance scientific knowledge. Anna reflects her understanding of inferential NOS by explaining the structure of the atom in her lesson with an example. However, since classroom observation is done while she was teaching human body system, there is no classroom observation data about the topic of the atom.

In the previous response, she explicitly emphasized that knowledge about structure of the atom can change. Therefore, the questions of *After scientists have developed* *a scientific theory (e.g., Atomic theory, evolution theory), does the theory ever change?* Was asked to Anna in order to unveil about her understanding of tentative NOS.

> Anna: Now, the atomic theory, as well as the theory of evolution involve scientific knowledge which was accepted in the time of that theory development…These theories are correct within the framework of this scientific knowledge...Scientific knowledge which is used while developing the theory may change; theories may change either. So… there are many things [atom models, assumptions about atom theories] about the atom, from Dalton's [atom model] to the modern atomic theory… But it does not mean that Dalton's atom model is wrong, whereas Rutherford's atom model is right. Dalton's model was correct according to observations which Dalton made by using his knowledge. But later, due to the addition of extra knowledge, the Dalton's model was revised, and Rutherford's model was proposed. Then, Bohr's model was put forward, I mean it [Rutherford's atom model] was developed. Again, it does not mean that Rutherford's model was wrong, only new knowledge was added. So, science develops continuously, but that does not mean that a theory is falsified. In other words, under the conditions of that time, this atom theory was true and valid, [therefore] it is necessary to examine the conditions of that time. Science develops through these processes... For example, years ago, we thought that the ulcer was caused by the acid of the stomach, and it was cured with stomach protectors. However, later on, it was discovered that a bacterium caused it, and it started to be cured with antibiotics... This is a development… [Think about astronomy], I mean, if Galileo had the knowledge that Newton had, he [Galileo] could have produced different things [knowledge], but Newton used the knowledge that is produced by Kepler, Copernic, and Galileo, while proposing his gravitation law and related evidence, Newton added the knowledge that was produced by the previous studies of Copernic, Kepler and Galileo. New knowledge was added to the previous one... Science

> advances and develops through the accumulation of truths... For example, in 2006, Pluton was denied as a planet. When I started teaching in 2003, I was teaching that there are nine planets. Pluto was one of the nine planets according to the knowledge on that day. Then, scientists and scientific communities changed the definition [of the planet]. So, pluton is, now, a dwarf planet. Students should learn those [development] processes. Because, in its nature, science can change…But how? Not by relying on the pseudoscientific knowledge... It [science] can change when the framework [perspectives], the scientific knowledge used while developing the theory, and the observations change.

Then, she was asked if there is a difference between a scientific theory and a scientific law, she responded as follows:

> Yes, there is [a difference between a scientific theory and a scientific law]. For example, gravity is a law…Wherever you go, the pen falls on the ground. However, the atomic theory may vary [depending on whose model you are examining]. For example, if you investigate Dalton's model, you say something different compared to those developed by Rutherford. However, this does not mean that theories are weaker than laws, but it is because scientific knowledge used while developing the theory is different. Laws are generally accepted, and they are unchangeable, but, of course, there is something like that: The law of gravity is the case for the Earth, but when you go to Mars, the speed at which that pen falls to the ground changes. The knowledge that we have been taught so far is: "When theories become certain [accepted], they become law". But today it is not the case…This knowledge [when theories become certain [accepted], they become law] has changed. Tentative nature of the scientific knowledge means that science has no definite boundaries... Laws are the collections of unchangeable knowledge, but theories are a kind of 'systems of thought' that are not falsified by experiments and observations. Theories are as valid as laws.

Her responses above also reflect Anna's understanding of empirical and tentative NOS. She correctly indicated that scientists' observations and their developing knowledge can revise the theories, and she detailed her indication by giving the history of atomic theory (e.g., Dalton, Rutherford, Bohr) as an example. Her explanations of the history of atomic theory give us clues about her understanding of empirical NOS since she mentioned Dalton's observations. On the other hand, she mentioned Galileo, Newton, Copernic, and Kepler as examples from the field of astronomy to provide more details about the development of scientific knowledge, but then, Anna did not indicate the scientists' creativity, inferences, and socio-cultural embeddedness while explaining the history of atomic theory. Anna seems confused about tentative NOS. Although, the tentative nature of scientific theories, she believed that theories are not falsified by experiments and observations. Moreover, she stated *science has no definite boundaries* even she expressed that *science involves certain knowledge, has boundaries* when she was explaining difference between science and other disciplines.

What is more, she was aware of the difference between a scientific theory and a scientific law. Still, believed that theories become laws when they are proved.

> Researcher: Well, can you give any examples about human body systems in terms of theories and laws?
>
> Anna: It is very difficult to give an example in the field of biology… For example, aspirin was used as a painkiller, and now a group of doctors says that aspirin has the potential to dilute the blood [to make the blood less viscous] … Let me think about] something that does not change. Concepts related to physics do not change, like the gas pressure. This knowledge, which depends on physics does not change…Take the mechanism of breathing. In order to change the pressure, you need to change the volume. It is [volume-pressure relationship] a law that does not change…But I do not know if there is any other law [related with human body systems].

> Researcher: so, can the relationship between the flow of blood and gravity be an example of theories or laws?
>
> Anna: There is an osmotic pressure [in blood flow]. Vessel pressure changes when the blood moves from thin vessels to thick vessels... Another example is blood pressure...All these concepts are explained by unchangeable laws and they are also connected to physics and chemistry again. Biology is an area that so many things need to be considered together. This [biology] challenges the students.

When she was asked about the examples from the human body systems, she stated that giving an example from the field of biology is difficult, but then, she indicated that volume-pressure relationship is a law by exemplifying breathing mechanism in the respiratory system. When the relationship between the blood flow and gravity was provided to her as a clue, she mentioned osmotic pressure as a law. Her assertion that *"Laws are certain"* shows her misconception because there is no certain knowledge including laws in science. While explaining the blood pressure, she said that *'All these concepts were explained by unchangeable laws.*

> Researcher: We mentioned above that scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
>
> Anna: Of course, scientists use their creativity and imagination. When assembling the dinosaur bones, there should be creativity as well as aesthetic knowledge. So, the model of the dinosaur is determined in this way because scientists bring together something that they have not seen [before]. As a result, without creativity, it is impossible for scientists to even think of these experiments. For example, I sometimes think that Kepler has formulated the Kepler law through solely observation, by using his sensory organs… Kepler discovered it [Kepler law]. Even today, we have difficulty even in

understanding the law… In short, creativity is absolutely necessary for scientists.

This question reflects Anna's understanding of creative and imaginative NOS. She states that scientists use their creativity and imagination when they [scientists] are at the thinking process of their scientific experiments. As a result, without creativity, it is impossible for scientists to even design these experiments. However, she did not emphasize that scientists' creativity is also crucial when they [scientists] construct hypotheses and interpret the data that they have obtained during their research studies. She also mentioned the assembly of dinosaur bones as an example to the fact that science requires creativity and aesthetic knowledge. Additionally, she gave Kepler laws as an example to imaginative power of Kepler while he was formulating the Kepler laws.

Anna was asked the following question in order to reflect her understanding of subjective NOS, inferential NOS, and socio-cultural NOS.

> Researcher: It is believed that about 65 million years ago the dinosaurs became extinct. Among the hypotheses formulated by the scientists to explain the cause of the extinction, two enjoy wide popularity. The first, formulated by one group of scientists, suggests that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggests that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?
>
> Anna: Differences in scientists' interpretation… scientists' foresight is the reason for different conclusions.… there was evidence of a combustion reaction because of the hit of the meteor or volcanic eruption. Can we say that one of them is more certain than the other? There should be more evidence to support [one of them]. So, this [differences in interpretation] is something related to different interpretations of the available data. At the

moment, both [explanations] are acceptable. It [cause of the extinction of dinosaurs] can be due to the meteorites or volcanic eruption unless new information is discovered. This is completely related to scientists' perspectives and knowledge they have…For example, my students are interested more in biological subjects, but the other teachers' students are more interested in physics. This is because of the differences among science teachers. Scientists, overall, are human beings. This difference [reaching different conclusions using same set of data] is the reason for them to have different interpretations.

This question represents Anna's understanding of subjective NOS. She correctly indicated that scientists are influenced by their perspectives and the knowledge they [scientists] have when they [scientists] interpret the data sets... She also supported that there should be more evidence to improve theories about the extinction of dinosaurs.

The following question was asked to Anna to elicit her understanding of socio-cultural NOS.

> Researcher: Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values, and intellectual norms of the culture in which it is practiced. Do you think science is universal, or is it affected by social and cultural values? Why?
>
> Anna: In fact, what I wanted to indicate in the previous question was that that two people can interpret the same data set differently because of their preliminary knowledge and scientific knowledge used while developing the theory. So, it would be difficult to think of science independent from the social contexts. This [science and social environment] is something

> intertwined, advancing together and changing together. I think science and the social environment are not independent or superior to one another. …. Universal… Gravity is a law no matter where you go. The pen falls on the ground everywhere. It shows that science is universal. There is no problem here. However, interpretations that scientists make, at least the acceptance of theories, develop in line with the social developments.

Anna's responses to this question give clues about her understanding of both socio-cultural NOS and subjective NOS. She was aware of the importance of subjectivity on scientific knowledge by saying; "Two people can interpret the same data differently due to their preliminary knowledge and scientific knowledge used while developing the theory." As she correctly stated, science and social contexts are changing together, and they [science and social environment] are not independent. Yet, when asked whether science is universal or not, she gave example that laws such as gravity operate similarly everywhere. As far as theories are concerned, she thought that theories are certainly related to the social contexts.

Summary of the Findings

To sum up, according to the evaluations of Anna's responses to VNOS-C questions, she seems aware of the tentative nature of science by indicating; *"It [science] can change with the framework [perspectives] changes, the scientific knowledge used while developing the theory changes, and the observations changes".* When she was asked about the changeability of theories, however she had difficulty in transforming her ideas into the definition of science because, while she was explaining the meaning of science, she stated that science involves certain knowledge. This shows the fact that she actually had a common misconception about the certainty of science field because "scientific knowledge is never absolute or certain." (Abd-El-Khalick, Lederman, Bell & Schwartz, 2000, p.39). However, she mentioned that the knowledge about atoms can change. On the other hand, she also said*; "Laws remain certain if the conditions remain the same (e.g., gravity)"* when she was asked about the differences between theories and laws. Under the light of these considerations, it can be understood that there was an inconsistency in her ideas about the tentative nature of science field. Anna's responses related to tentative NOS was summarized in the Table 4.24.

Table 4.24 Anna's Sample Statement in Tentative NOS

NOS Aspect	Sample Statement
Tentative NOS	➢ Science involves certain knowledge, has boundaries [delimited], and depend on causal relationship. ➢ Scientific knowledge which is used while developing the theory may change; theories may change either. ➢ Science develops continuously, but that does not mean that a theory is falsified. ➢ Science is advanced through an accumulation of truth. ➢ Laws are generally accepted, …unchangeable. ➢ Tentative nature of scientific knowledge means that science has no definite boundaries... ➢ Concepts related to physics do not change, like the gas pressure. This knowledge depends on physics, thus, does not change… ➢ Although we know a lot of things [about the structure of atom], we are not sure because it [information about structure of the atom] can change.

When she was questioned about the experimentation, Anna asserted that an experiment is a process which is used to test the accuracy of knowledge and she also supported that experiment is necessary to develop scientific knowledge. When asked about some example experiments on human body systems, she stated that the human body systems are the most difficult topic for teachers to do experiments because of students' inadequate prior knowledge [at 6^{th} grade]. In addition to this, when she was asked whether the theories ever change after scientists have developed a scientific theory, she stated that scientific knowledge develops based on experiments, observations, and inferences. Moreover, she also explained the importance of experimental methods and observations by mentioning Dalton's observations and Rutherford's Gold Foil Experiment to explain the development of atomic theory. She argued that if we are to teach students these topics [i.e., atom], students should also learn the history of the atom science. Anna's responses related to empirical NOS were shown in the Table 4.25.

Table 4.25 Anna's Sample Statement in Empirical NOS

NOS Aspect	Sample Statement
Empirical NOS	➢ Experiment is a process used to test the accuracy of information… ➢ … the data you observe or obtain will ultimately lead you to a conclusion. ➢ It is not possible to talk about scientific knowledge without experimentation. ➢ The human body systems are the most difficult topic for teachers to conduct experiments. ➢ Scientists have used experimental methods, used their observations, and conducted a lot of research studies by using microscopes. ➢ I think scientists have decided on the structure of the atom through observations, inferences, and conclusions from their data. ➢ Dalton's model was correct according to his observations developed by his knowledge.

When Anna was asked if there was a difference between a scientific theory and scientific law, she stated that they differed from each other. Moreover, she did not have the common misconceptions such as the following; *"Laws are theories that have been 'proven' by the accumulation of confirming empirical evidence."* (Lederman, & Abd-El-Khalick, 1998). Her assertion that theories are as valid as laws shows that she understands the fact that theories and laws are equally valuable. Nevertheless, she did not provide a clear explanation about the definition of law although she explained theories as a kind of systems of thought that are not falsified by experiments and observations. This represents a misconception because scientific theories can be falsified with the discovery of new evidence. Moreover, her assertion that ''knowledge in physic is certain than that of biology" reveals that she holds a common misconception. Anna’s responses related to Theory and Laws aspect NOS was shown in the Table 4.26.

Table 4.26 Anna’s Sample Statement in Theory and Laws Aspect NOS

NOS Aspect	Sample Statement
Theory and Law	➢ Gravity is law…. wherever you go, the pen falls on the ground. ➢ …The atomic theory may vary [depending on whose model you are examining]. ➢ …. this does not mean that theories are weaker than laws. ➢ Laws are generally accepted, …unchangeable. ➢ …theories are a kind of ‘systems of thought’ that are not falsified by experiments and observations. ➢ Concepts related to physics do not change ➢ Theories are as valid as laws.

When asked about how scientists were certain about the structure of the atom, Anna expressed that scientists decided on the structure of the atom through observations, experiments (i.e., Rutherford Gold Foil Experiment) inferences, and conclusions from their data sets. She expanded her answer with an example from her classroom practices. She asserted that she uses a pencil box and asks students what is inside the pencil box during the classes. She tries to figure out which clues the students follow and how they make inferences. With this activity, Ana tries to reflect how scientists do these scientific studies. Anna’s responses related to Inferential NOS were shown in the Table 4.27.

Table 4.27 Anna’s Sample Statement in Inferential NOS

NOS Aspect	Sample Statement
Inferential NOS	➢ I think scientists have decided on the structure of the atom through observations, inferences, and conclusions from their data.

When she was asked how scientists reach to different conclusions even though they have the same set of data, Anna acknowledged that scientists' foresight and their [scientists'] perspectives affect their interpretations. Anna's responses related to subjective NOS were shown in the Table 4.28.

Table 4.28 Anna's Sample Statement in Subjectivity NOS

NOS Aspect	Sample Statement
Subjectivity NOS	➢ Differences in scientists' interpretation… scientists' foresight is the reason for different conclusions.…

Anna expressed that science is affected by social contexts and they change in the same line. She acknowledged that they depend on each other. When asked whether science is universal or not, she explained it with the example of gravity, and she stated that wherever we would go, the pen would fall on the ground if it was dropped from the air. Thus, she argued that science was universal. However, science is not universal because it is a human endeavor. Anna's responses related to Socio-Cultural NOS were shown in the Table 4.29.

Table 4.29 Anna's Sample Statement in Socio-Cultural NOS

NOS Aspect	Sample Statement
Socio-Cultural NOS	➢ This [science and social environment] is something intertwined, advancing together and changing together. ➢ I think science and the social contexts are not independent from or superior to one another. ➢ Gravity is a law wherever you go, the pen falls on the ground. It shows that science is universal.

Anna asserted that scientist use their creativity and imagination. She thought that creativity is indispensable to design different experiments. She tried to justify her assertion with the example of scientists who try to combine the dinosaur bones using their imagination to create the models of dinosaurs that are even known today.

However, she did not point out that creativity is necessary for every phase of scientific studies. Anna's responses related to Creative and Imaginative NOS were shown in Table 4.30.

Table 4.30 Anna's Sample Statement in Creative and Imaginative NOS

NOS Aspect	Sample Statement
Creative and Imaginative NOS	➢ Of course, scientists use their creativity and imagination. So, the model of the dinosaur is determined in this way because scientists bring together something that we have not seen [before]. ➢ It is impossible for scientists to even design these experiments without creativity. In short, creativity is absolutely necessary.

Briefly, her ideas about the tentative NOS show that there was an inconsistency in her response. She mentioned that science involves certain knowledge while she also addressed science has no definite boundaries. Concerning Empirical NOS, she was knowledgeable about the fact that experiment is necessary to develop scientific knowledge. She also referred observations, inferences, and conclusions. She was aware of the fact that there is a difference between a scientific theory and scientific law and they are not superior to each other. However, she holds a common misconception that knowledge related to physics is more certain than about biology. She seems knowledgeable about of Inferential NOS shows that she mentioned observations, experiments (i.e., Rutherford Gold Foil Experiment) inferences, and conclusions that scientists made. Moreover, Anna's responses related to subjective NOS represent that she mentioned scientists' perspectives affect their interpretations. Therefore, she seems knowledgeable about Subjective NOS. Her responses to Socio-Cultural NOS revealed inconsistencies which means that while acknowledged that social context affects development of scientific knowledge, she also thought that science is universal. Finally, she was knowledgeable in terms of Creative and Imaginative NOS since she aware that creativity is absolutely necessary for development of science. In summary, she was able to explain creative and imaginative NOS, empirical NOS, inferential NOS and subjective NOS. She also had inconsistent explanations about tentative NOS, socio-cultural NOS and theory and law.

In this part, Anna's pedagogical content knowledge of human body systems and subject matter knowledge were explained in detail based on pre-interview, classroom observation and post-interview.

Next, Bethy's pedagogical content knowledge of human body systems and subject matter knowledge were represented.

4.2 CASE 2: Bethy's Pedagogical Content Knowledge of Human Body Systems and Subject Matter Knowledge

4.2.1 Bethy's Background

She graduated from the chemistry department, and she has pedagogical formation. The teacher has been teaching for 20 years in total. She has also been teaching for 18 years at a well-known private school in Ankara, where is the capital of Turkey. She claimed that she did not attend any conferences or training programs about human body systems.

She introduced her school as social. This description means that the students who are studying at this school follow cultural and social activities and this inclination actually results from their families. Their families are allegedly educated. According to her, the school is not crowded. The teachers who are teaching at this school are open-minded. Science courses at the school are taught according to the 2018 Science Curriculum [MoNE, 2018].

4.2.2 Bethy's Pedagogical Content Knowledge of Human Body Systems

4.2.2.1 Bethy's Orientation Towards Science

In this section, Bethy's orientation towards science is presented by mentioning her beliefs about the goals of teaching science. Her orientation was evaluated through interview questions and classroom observations. The data were, then, examined according to central goals and peripheral goals which were proposed by Friedrichsen and Dana (2005) to address teachers' beliefs about the goals of teaching science.

4.2.2.1.1 Bethy's Beliefs about the Goals of Science Teaching

Bethy's beliefs about the goals of science teaching are summarized in the Table 4.31.

Table 4.31 Bethy's Orientation Towards Science Teaching

Question	Interview (Reported-PCK)	Classroom Observation (Enacted-PCK)	Types of Goals
The purpose of teaching science	Make students science literate people	-	Schooling goal
	Gain some skills in science (i.e., Science Process Skills)	Gain some skills in science (i.e., Science Process Skills)	Schooling goal
	Connect the topics with students' daily lives	Connect the topics with students' daily lives	Schooling goal
	-	Increase students' curiosity	Affective goal
The role of teacher in science teaching	Orient students	Orient students	Schooling goal
	Be a group leader	Be a group leader	Schooling goal
Role of students	Be responsible of learning	Be responsible of learning	Schooling goal
Purpose of teaching Human Body Systems	Make sense of the signals coming from our body	Make sense of the signals coming from our body	Schooling goal
	-	Teach curriculum objectives	Subject matter goal

Bethy was asked about the meaning of science education, the goals of science teaching and the roles of teachers and students in order to find about her beliefs about the goals of science teaching. Bethy's answers reveal that her purpose of teaching science focuses mainly on scientific literacy and science process skills. She thinks that science topics are tools to develop students' abilities. Thus, her central goal emphasizes the schooling goal. She said that teaching science in the middle school helps students to make sense of the events (e.g., boiling water) occurring in nature. She also indicated that she specified her teaching aims according to her professional experiences, her pedagogical formation, and her students' feedbacks.

> Researcher: What does science teaching mean to you? What, in your view, are the purposes of teaching science?
>
> Bethy: ... For example, teaching Newton's laws, Mendel's laws are just tools for me [to teach science] … science teaching means creating a science literate person. [Teaching science is] for students to teach scientific process skills… for students to inform the stages and the variables of an experiment, to decide what kind of research should be done… So, in this sense, my purpose of teaching science is to make students science literate people by using science subjects as a tool. Also, [my purpose of teaching science is] to provide students to develop the necessary skills and get more qualified… This [purpose of teaching science] is to understand the nature, to make sense of events in nature… That is, science is a part of our lives.… For example, boiling water is a part of our lives and so it is also a subject of science… Thus, for students to make sense out of it [boiling water], we should teach science. Maybe we need to teach [science] even at an earlier age. By this way, the students would be able to learn how they should think, how they should create connections between the events…

Then, to elaborate on her responses, the following questions were asked to her:

> Researcher: You have already mentioned being science literate person. What does scientific literacy mean to you?
>
> Bethy: …What I mean by being a science literate person is that being able to answer reading comprehension questions, having the ability of conducting various experiments, having the necessary observational skills, having the

graphic reading skills, and getting students think critically… to become active in the stages of an experiment, to know how to plan the process… I think they are all part of being a science literate person.

Researcher: You also mentioned science process skills. What does science process skills mean to you?

Bethy: Scientific process skills are observing, experimenting, designing, interpreting of graphics, reading comprehension, and making inferences…

Researcher: How did you decide these purposes?

Bethy: I mean, of course my professional experience and my education had an effect on them. I am a teacher; that is why I have a pedagogical formation…I work with middle school students; thus, their curiosity and desire to understand the nature, and the questions that students ask to have brought me to this point.

Her enacted-PCK shows that Bethy's central goals seem to be more related to the subject matter goals as she emphasized transferring scientific knowledge to her students. Moreover, she gave common daily life examples to connect the topics with students' daily lives. This proves that Bethy's central goals also reflect the schooling goals just as she mentioned in the interview.

Another important point is that, according to her reported-PCK, Bethy stated that a teacher should be a leader for her students. That is, according to Bethy, a teacher should show the ways of accessing information instead of giving the information directly.

Researcher: What is the role of teacher in science teaching?

Bethy: So, I think we can always think of the role of the teacher [pause] as a group leader…A teacher should first orient the students... I think it is very important to show the ways of accessing information instead of just giving it directly to them. For example, instead of saying "We are going to do this experiment", the teacher should say "We have this problem and let us find a solution all together" or, "Let us test it together". That is my point of view all the time, and my main goal is to teach students how to think. The role of the teacher should be the one who is guiding, supportive, and eye-opening. I do not think there should ever be any direct information transferred to students. You know, I always try to teach [students] how to catch a fish, instead of feeding them with fish.

In addition to this, Bethy thought that students must be responsible for their own learning. Bethy's explanation clearly puts forward the emphasis she puts on the students' responsibility of getting ready for the lecture.

> Researcher: What is the role of students in science teaching?
>
> Bethy: … Learning is the responsibility of the learner. In other words, [the role of the student is] to evaluate the process well, to attend to the lessons prepared, to acknowledge future tasks during the course. In order to meet our expectations, students should come to the class with the materials and the equipment we want from them in order to follow the lecture properly, and to actively participate in the lesson as it is very important to contribute to it. Other than that, [pause] I think it is important for the students to support the leader in numerous ways. Sometimes we give our students the role of the teachers. When students are curious and willing, they can do all kinds of tasks very well. Thus, curiosity is quite important.

During the classroom observations, Bethy started teaching each human body system with questions. These questions were related to the topic being taught. For example, when she was teaching the digestive system, she asked, "Why do living creatures feed?" These kinds of questions arouse students' curiosity and students try to explain each question accordingly. It shows that her peripheral goals are affective goals. Students attend to the classes already having the answers to these questions. This procedure enables students to get prepared for the lecture. In such cases, as Bethy stated in the interview, she is the leader who is orienting the students. However, it does not mean that the students are always active participants during the class. They just come to class ready to learn as Bethy wants them to do so.

In addition to the previous questions, Bethy was also asked about the purpose of teaching human body systems. She indicated that her main goal was to raise the students' awareness about their own body. She believes that if students understand the signals coming from their body, they might plan their life accordingly. This shows that her central goal is in accordance with the schooling goals.

> Bethy: So, as a result, we are living creatures, and we need to get to know our own body, and what is happening inside our body. In other words, we need to make sense of the signals coming from our body, and we also need to understand the reasons why some particular incidents are occurring in our body in order to diagnose any future illness beforehand. In terms of our nutritional habits and lifestyles, we think it is important to know ourselves first, to know the benefits of sleep, and to know our development progress. In order for students to know themselves better and to make sense of occurrences in their body, human body systems must be in the science curriculum.

Her enacted-PCK shows that Bethy's central goals in the classroom is also subject matter goal due to the fact that she taught human body systems by utilizing lectures, questioning, and discussion methods related to scientific facts.

In conclusion, Bethy's responses have shown that her central goal is in line with the schooling goals since she mostly referred to scientific literacy and science process skills in her comments. In addition to that, her enacted-PCK reveals that her purpose of teaching science is to transfer the course objectives to the learners and enable them to relate this information to their daily lives. For these reasons, her central goals seem to be both subject matter goals and schooling goals. Moreover, according to Bethy, the role of teacher in science teaching is that of a leader while she also keeps the students responsible from their own learning process. Bethy also cares a lot about how curious her students are. Thus, her peripheral goal seems to be affective goal.

Bethy's knowledge of the curriculum was presented under the next sub-title.

4.2.2.2 Bethy's Knowledge of the Curriculum

Bethy's knowledge of the curriculum was analyzed through pre-interview questions, classroom field notes, and post-interview questions. First, Bethy's knowledge of the goals and objectives about human body systems, and then, her knowledge of the materials is presented in the following sections.

4.2.2.2.1 Bethy's Knowledge of the Goals and Objectives about Human Body Systems

Bethy correctly stated the place of the human body systems in the science curriculum. However, she did not remember the correct order of the human body systems as they are presented in the curriculum. She tried to remember the order by referring back to the relationship between these systems.

At first, Bethy was asked about the place of digestive, circulatory, respiratory, and urinary systems in the science curriculum. She correctly provided this information by saying; "*It is in the 6th grade, given within the 2nd unit. I think that we start with skeletal system, then respiratory system, then urinary system, then circulatory systems. However, I am not very sure*".

After putting these systems in order, she was asked whether this order was appropriate or not as the following excerpt from the interview shows:

> Bethy: First of all, I do not know if I told you the correct order, but if you would ask me, I would start by explaining the skeletal system… wait a minute, let me plan that in my mind… then… there may be circulation, respiration, and digestion because there are successive events that support each other... It is hard to understand each system without having an idea of all the others. I would start with circulation. For example, our body needs to produce energy. There is energy production through respiration, and we need

> nutrients for that energy. Thus, students need to know how we digest nutrients and how these nutrients get into the bloodstream. Afterwards, students should know that some gases which are taken during the respiration play some roles in the circulation, and blood transportation. Moreover, they should also be knowledgeable about the exchange of carbon dioxide and oxygen in the alveoli…Excretion is very important because blood will go to the urinary system to be oxygenated. So, it is simultaneous…As my final decision, I will put them in the order of digestion first, then circulation, thirdly respiration, and lastly urinary system.

Although Bethy seemed confused at first, she finally provided the correct order. Her response about the order of the human body systems is consistent with the order given in the curriculum. Just as it is stated in the science curriculum [MoNE, 2018], she thinks that human body systems should be consecutively taught in the order of digestive system, circulatory system, respiratory system, and urinary system. Her responses to previous question represented her understanding of horizontal relationships as well.

The next question aimed to reveal her horizontal curriculum knowledge about the order of units at fall semester. As her responses reveal, Bethy was aware of the fact that the solar system and the eclipses were taught before the human body systems. However, she said that she did not remember the upcoming unit after the human body systems and proposed the unit about matters as an answer although the correct answer would be the unit of force and movement (MoNE, 2018, p.13).

> Researcher: What are the units before and after the human body systems?
>
> Bethy: Now we are teaching the planets first at the 6^{th} grade, then we will teach the eclipses, then we will teach the human body systems. Later on, I think we will explain the matter and its components, but I cannot exactly remember that.

As a follow up question, Bethy was asked about the appropriateness of this teaching order [solar system/human body systems/matter]. She also thinks that if the connection between the units were created in a more effective manner, it would produce better learning outcomes for the students.

> Bethy: …I also believe that it is good to have a break from biology topic and switch to chemistry topic. I mean, not always, but it might be good for students to get to know another branch of science. I wish the connections were better between the topics, but it is still a good time for an interval.

Next question reveals Bethy's knowledge of vertical curriculum. Bethy thought that the topics in the science curriculum were connected to each other. She thought that in the previous science curriculum [MoNE, 2013], students used to learn first the process of excretion and the organs that urinary system includes at 5th grade, but now, based on MoNE (2018), they do not learn these systems in the same way.

> Researcher: Are the human body systems, specifically the digestive/ circulatory/ respiratory and urinary system, associated with other units or grade levels in science curriculum?
>
> Bethy: …Topics should taught be gradually in a well-structured order. For example, in elementary school at 3rd grade, the parts of the body can be taught as the first subject. Then, the pathway of air going inside the body, and the state of our lungs while breathing can be included to make an introduction to respiratory system…Thus, it [the order of topic in the curriculum] needs a good organization…In the previous science curriculum, students used to learn the urinary system in the 5th grade, but not as a system. They used to learn the structures and the organs in the urinary system. This was very effective. After this background information provided to students, it would be easier to teach 7th graders because these students would already know kidney, ureter, urethra, or about oxygenated blood…

The data above clearly shows that Bethy supported the idea of teaching these topics gradually as it will be more sensible. That is, according to her views, the science curriculum should be created in a spiral nature. She horizontally associated circulatory system with respiratory, digestive, and urinary system. However, she did not mention the nutrients unit in the 4th grade which is also associated with digestive system. In addition, although Bethy did not mention that students at 6th grade will not learn cell topic, which is offered at 7th grade, before learning about the human body systems as vertical relationships in the interview, she addressed nutrients (i.e., carbohydrates, proteins and fats) in the classroom as pre-requisite knowledge for students to learn human body systems.

The next question aimed at evaluating Betty's knowledge of the objectives given in the curriculum about human body systems. Bethy correctly stated that students should know the organs that make up that particular system, the structure of these organs and know how they work. In addition to these objectives, considering the *digestive system* in particular, she stated that students ought to know chemical and physical digestion and the overall digestion process. Moreover, she added that students should also know about systemic circulation, pulmonary circulation, blood groups, and blood transfusion in terms of the *circulatory system*. Additionally, considering the *respiratory system,* she asserted that they should be knowledgeable about the process of breathing. Finally, she acknowledged that students should be aware of the infiltration process in the *urinary system*. Bethy complained that it was difficult for students to understand the concepts related to human body systems in much detail. According to her, it was enough for students to know why human body systems (i.e., digestive, urinary, circulatory) exist and which structures and organs these systems include as well as their functions. Her knowledge of goals and objectives is summarized in Table 4.32.

> Researcher: What are the basic prescribed objectives about the human body systems in the science curriculum?
>
> Bethy: For example, the objective in the *digestive system* is… what physical digestion means, mechanical digestion, chemical digestion. What is the path taken by the nutrients we take into our mouths [digestion process], what

> happens to these nutrients both mechanically and chemically? In fact, students should also learn the processes of digestion, absorption, and elimination... We [she and her colleagues] pay attention to the limitations. In the same way in the *circulatory system*; students will recognize the structures and organs involved in the circulatory system, know the functions of each of them, systemic circulation, pulmonary circulation, blood groups, and blood transfusion... what else… In the *urinary system*, the structures and organs involved in excretion, the path of infiltration process, reabsorption, the structures involved in this infiltration, the nephrons… we do not teach the structure of the nephrons at any time. However, sometimes, the books we use include a huge nephron structure, so it puts you in hesitation. Also, for the *respiratory system*, we describe the process of breathing in the same way from the moment the air enters through nose to alveoli, the gas changes, the structure and the functions of nose, trachea, lungs, and the structures inside our lungs.
>
> Researcher: Can you order the objectives based on their importance?
>
> Bethy: … the student should know how this system (i.e., digestive system) works, why our body needs this system (i.e., digestive system), what structures and organs this system (i.e., digestive system) includes … what are the functions of organs… However, it is enough for me to say that it filters the blood [Bethy is talking about the urinary system here] … And I also think that these topics are overly detailed for this age level. It is enough for students to recognize and know the functions of the organs and her/his body in the briefest way possible…

Bethy thinks that it is very important for students to transfer their knowledge about the human body systems to their daily lives.

> Researcher: What do you expect your students to be able to do with these objectives?

Bethy: …If students can adapt and transfer their knowledge of human body systems to their daily lives, it is very valuable for me. For example, without having a qualified training, the use of first aid is quite inconvenient, but it is possible that students may utilize this ability in non-fatal accidents in case their family needs it. Moreover, it is important for the students to know which doctor to go to, and to know that they should not talk while they are eating… It is even important that the students know how to open and close the trachea... I mean, I do not think they have to choose their careers in this subject area (i.e., being a doctor). I think that recognizing their own bodies, evaluating the signals coming from their body, and receiving messages from their bodies in a correct way may be the reasons why the curriculum gives these topics to everyone in middle school whether or not they are studying in the field of science…

It can be clearly seen that Bethy's responses also support her orientation towards science teaching. She linked human body systems and students' daily life experiences in order to explain the importance of these learning objectives.

In addition to the objectives of the human body systems, Bethy was also asked to explain the limitations and misconceptions about the human body systems. Although Bethy was not fully sure, she correctly indicated that the science curriculum [MoNE, 2018] did not include any misconceptions. She argued that they [science teachers' committee in her school] paid attention to consider the misconceptions in their lesson plans even though the science curriculum does not mention those. Furthermore, she was also aware of the restrictions that were posed by the science curriculum [MoNE, 2018]. For example, she stated that science curriculum does not allow the teachers to talk about the structure of nephrons.

Researcher: Does the curriculum include limitations and misconceptions about the human body systems?

Bethy: Honestly, I am not very competent on this issue right now... The curriculum restricts us like "you should not mention this" ... However, I think

> I remember that the curriculum does not address the misconceptions. So, misconceptions are something that we [as a school] dwell on… One of the restrictions says, "Do not get into the structure of the nephrons." …The curriculum is more task-oriented, but I do not remember much about the others.

Her enacted-PCK show that she also avoided mentioning the structure of the enzymes, the chemical structure of the organs [the digestive system], lymphatic circulation and molecular basis in blood groups [the circulatory system] as stated in the Table 4.33. However, she went beyond the curriculum by teaching the name of four chambers of the heart [the circulatory system], the gas exchange mechanism [the respiratory system].

Table 4.32 Bethy’s Knowledge of Goals and Objectives

Human Body Systems	**Interview (Reported-PCK)**	**Classroom Observation (Enacted-PCK)**
Digestive System	Know the organs that make up that the system and the structure of these organs Know how organs work Know chemical and physical digestion Know the overall digestion process	Explain the structures and organs of the digestive system by using models. Infer the nutrients must be digested physically (mechanical) and chemically in order to enter bloodstream. Explain the functions of the digestive organs.
Circulatory System	Know the organs that make up that the system and the structure of these organs Know how organs work Know about systemic circulation and pulmonary circulation Know blood groups Know blood transfusion	Explain the structure and organs of the circulatory system by using a model. Examine the systemic and pulmonary circulation on the scheme and explain their functions. Define the structure and functions of blood. State the transfusion of blood between blood groups. Evaluate the importance of blood donation for society.
Respiratory System	Know the organs that make up that the system and the structure of these organs Know how organs work Know about the process of breathing	Explain the structure and organs of the respiratory system by using models.

Table 4.32 (continued)

Urinary System	Know the organs that make up that the system and the structure of these organs Know how organs work Know about infiltration process	Explain the functions of the urinary system organs. Explain the structure and organs of the urinary system by using models.

Table 4.33 Bethy's Knowledge of Restrictions Posed by Curriculum

Human Body Systems	Interview (Reported-PCK)	Classroom Observation Enacted-PCK
Digestive System	-	The chemical digestion equations Structure of enzymes, their mechanism of action Structures of liver and pancreas
Circulatory System	-	Lymphatic circulation Structures of arteries, veins, and capillaries Structures of blood cells The transportation of gases with hemoglobin Molecular basis of blood groups
Respiratory System	-	The gas exchange mechanism and the transportation of respiratory gases through blood
Urinary System	Structure of the nephrons	Structures of the large intestine, skin and lung

In summary, Bethy seems knowledgeable about the place of the human body systems in the science curriculum. She mentioned vertical and horizontal connections of human body system. Although she did not remember the order of the digestive, circulatory, respiratory, and urinary system in the curriculum, she was eventually able to figure out the correct order. Bethy did not state all the objectives related to modelling (i.e., the explanation of the structure and organs of the circulatory system by using models) in the interview. However, her enacted-PCK shows that she covered all the objectives that are proposed in the curriculum. She was also partially able to cover the restrictions given in the curriculum both during in her reported-PCK and enacted-PCK. Moreover, she was aware of the fact that science curriculum does not cover any misconceptions about the human body systems.

Bethy's knowledge of materials is presented in next sub-title.

4.2.2.2.2 Bethy's Knowledge of the Materials

This section covers the description of Bethy's knowledge of the materials in the Table 4.34.

Table 4.34 Bethy's Knowledge of the Materials

Materials	**Interview (Reported-PCK)**	**Classroom Observation (Enacted-PCK)**
Websites	Mentioned	Observed
Visual materials – Lecture slides – Animations – Drawings – Models	Mentioned	Observed
Human Body System Booklet	Not mentioned	Observed
Visual press	Mentioned	Observed
Science textbook	Not mentioned	Observed

She was questioned about the sources she utilizes in her teaching and her aims of using various sources especially when she teaches the human body systems. Bethy stated that she benefits from written sources, websites, and visuals such as animations to provide visual diversity and widen the horizon of her teaching.

> Bethy: I mean, first of all I examine all the books on the market. I mainly benefit from the written visual press. Then I cover internet resources such as the TUBITAK website, and the websites related to science teaching. I use biology animations… Sometimes we [as school] create animations to support our lessons with visuals, even though our technological competence is not always enough for it. Sometimes I use ready-made animations and animations made available to everyone by other teachers... [I use these sources] to create visual diversity while reinforcing the target content… In other words, I use different sources when I prepare the hand-outs that I benefit from in order to explain the target subject in a more comprehensive manner and to make the topic easier to remember. Different resources open your horizons and give ideas about classroom activities. Students will also be more attracted, and they will enjoy the activities that make their learning more permanent...

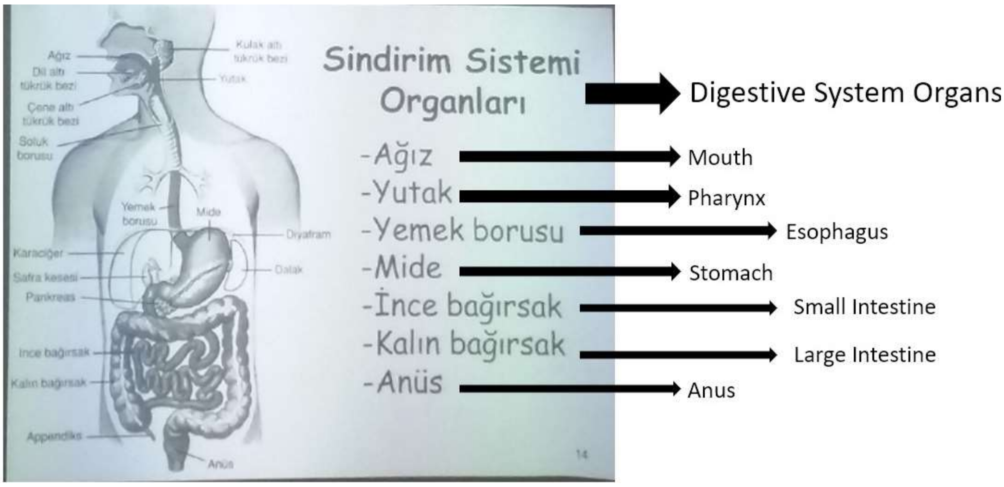

Figure 4.15 A Picture of Digestive System Organs Included in Bethy's Lecture Slides

In the classroom, Bethy used animations from various internet sites to reinforce the topics in the classroom as she stated in her interview. She benefitted from the visuals while preparing lecture slides. For example, Figure 4.15 is given below to exemplify a picture of digestive system organs included in Bethy's lecture slides. In addition, she used textbook to give students homework.

She also used the blackboard when she wanted to reinforce the topic through her drawings. Figure 4.16 given below exemplifies Bethy's drawing while she was teaching heart.

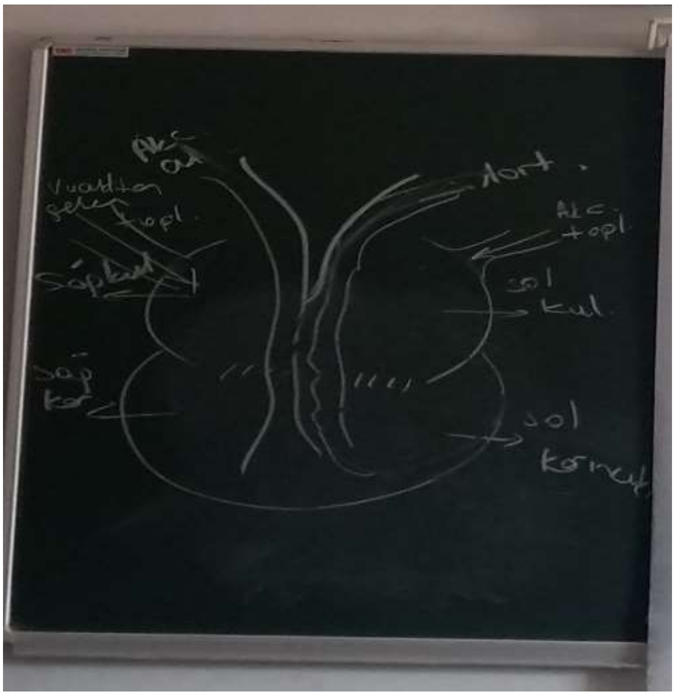

Figure 4.16 Bethy's Drawing of a Heart

Bethy also used Human Body System booklets which the science teachers in her school prepared as the primary source although she did not mention this booklet in the interview.

In summary, Bethy seems aware of the place of the human body systems in the science curriculum, vertical and horizontal connections of human body system. In her teaching, she addressed all the objectives that are posed by the curriculum. She was also partially able to follow the restrictions given in the curriculum both during the interview and her teaching. Concerning her knowledge of the materials, she used her own resources, ready-made animations, visuals and slides.

Bethy's knowledge of students' understanding of science was presented under the next sub-title.

4.2.2.3 Bethy's Knowledge of Students' Understanding of Science

In this section, Bethy's knowledge of requirements for learning human body systems and knowledge of students' difficulties while learning the human body systems were presented to examine her knowledge of students' conception of science.

4.2.2.3.1 Bethy's Knowledge of Requirements of Learning Human Body Systems

Bethy's knowledge of requirements for learning human body systems is summarized in the Table 4.35.

Table 4.35 Bethy's Knowledge of Requirements for Learning HBS

Interview (Reported-PCK)	Classroom Observation (Enacted-PCK)
-	Cell-tissue-organ-system-organism relationship
Classification of nutrients	Classification of nutrients
The name of the structures and the organs that make up a system	The name of the structures and the organs that make up a system

In this sub-title, Bethy explained that the science teachers' committee prepares their lesson plans according to students' prior knowledge by analyzing the current science curriculum. Thus, according to her, it is not quite necessary for students to attend the lectures with the necessary prior knowledge. However, Bethy thinks that it will be even better if the students identify the classification of the nutrients in order to understand the physical and chemical digestion in a better way.

> Researcher: Now, let us talk about students. What prior knowledge should students have to understand the digestive/circulatory/respiratory/urinary systems?
>
> Bethy: It is important that students should know the classification of nutrients and give examples of carbohydrates, proteins, fats to understand digestion process... Other than that, it is enough for them to know the name of the structures and the organs that make up the particular system before learning about them in more detail. We prepare our lesson plans according to current science curriculum. For example, we [Bethy and her colleagues] examine what students learned at 3rd or 4th grade. Thus, if the students lack the necessary background knowledge, we are able to reshape our lesson plan… I think the essential prior knowledge can be given while making an introduction to the upcoming topics. I do not think that prior knowledge affects the actual learning process.

During classroom observations, Bethy asked her students whether they know how to classify nutrients or not before she introduced the digestive system. The students indicated that they did not learn anything about that topic before. They said they were all familiar with the classification of the nutrients from the poster hanging on the cafeteria wall. Moreover, while she was teaching the blood cells, Bethy addressed the lack of knowledge of cell-tissue relationship as a deficiency for students, even though she did not mention that in the interview.

> Bethy: Blood is a tissue which is composed of blood cells and matter which fills between these cells. For example, this is our skin. What does comprise the skin? There are skin cells. Of course, unfortunately, since you have not learned this relationship, it is necessary to explain the background knowledge to you first. Just as the fact that the building blocks of proteins are amino acids, our building blocks are cells. Cells work together to form us. But of

course, cells come together to form the tissues, the tissues work together to form organs, and the organs do the same to form up the systems in our body such as the respiratory system, the nervous system, and the circulatory system. These systems, in the end, make up the organism.

Furthermore, before teaching systemic and pulmonary circulation, Bethy attracted students' attention by saying; "*You cannot understand systemic and pulmonary circulation without learning about vessels".*

Bethy's knowledge of the difficulties that students have regarding the human body systems was reported in following section.

4.2.2.3.2 Bethy's Knowledge of Students' Difficulties

Bethy's knowledge of the difficulties that students have regarding the human body systems was summarized in the Table 4.36.

Table 4.36 Bethy's Knowledge of Students' Difficulties and Misconceptions

Human Body System	**Students' difficulties (Reported-PCK)**	**Students' misconceptions (Reported-PCK)**
Digestive system	Physical digestion of fats with bile	-
Circulatory system	The pathway of systemic and pulmonary circulation	"Universal recipient and universal donor" used in blood transfusion
Respiratory System	Gas exchange in the alveoli	-
	Establishing the relationship between the respiratory system and digestive system	-
Urinary system	Identifying the names of the vessels such as renal artery, renal vein	Feces is the result of excretion

Bethy stated that students usually had difficulty in understanding the circulatory and the respiratory system. She gave especially systemic and pulmonary circulation as an example for circulatory system and gas exchange in the alveoli for respiratory system. She thought that the easiest system was digestive system among human body systems for students to understand. However, she said that most of the students had problems to understand that bile was responsible for the physical digestion of fats. Bethy stated the students' tendency of connecting the bile with chemical digestion because of secretion. Moreover, in her opinion, the reasons behind students' difficulty were the following: Students' age, more detailed descriptions of human body systems, and the usage of Latin terms.

First, Bethy was requested to explain what were the concepts that the students had difficulty in understanding about the digestive / circulatory/ urinary and respiration systems. The reasons behind students' difficulty were explained as follows:

> Bethy: …I think that as a teacher the human body system is very complicated and comprehensive… especially for the 6th graders... Students have difficulty in understanding the circulatory and respiratory system since there are more details embedded in them... For example, gas exchange in the alveoli is very difficult for a student to understand… very difficult…Students also have especially hard time in understanding the pathway of the systemic and pulmonary circulation. Furthermore, students are confused while identifying the names of the vessels such as renal artery, renal vein… Digestive system is the easiest system in the human body for students. Students generally find it difficult to understand the chemical digestion, the process of breaking down nutrients into their building blocks… Students mistakenly think that the physical digestion of fats occurs with the help of the bile because they think that bile is responsible for chemical digestion by the help of the secretion. I support it with some activities, visuals, animations… Moreover, students are still very young cognitively to embody these abstract terms. The Latin names

> of the concepts are also quite unfamiliar to students. All in all, I do not think that the lack of prior knowledge is a problem for students in science classes.

During the classroom observations, Bethy uttered; "*You will learn the most important topic of the circulatory system"* before she started teaching systemic and pulmonary circulation. Then, Bethy warned students about the figure of the heart by saying; "*To learn systemic and pulmonary circulation, you should know the figure of the heart properly".*

During the pre-interview session, Bethy's knowledge about students' misconceptions regarding the digestive/respiratory/urinary and circulatory system was questioned. She mentioned that the fact that feces is the result of excretion is also one of the biggest misconceptions. According to her, students also have a misconception about blood transfusion. Students think that there are phrases like "universal recipient and universal donor" when they refer to blood groups. In addition to these, students also have difficulty in establishing the relationship between the respiratory system and digestive system. However, she also indicated that when she and her colleagues were preparing lesson plans, they would pay attention to focus on misconceptions and make topics more understandable for the students. Bethy's responses also revealed one of the sources of misconceptions was external factors such as students' family.

> Bethy: …For example**,** when we mention excretion, the students always think it as a result of the digestive system, a solid waste (feces). Students do not know that the result of excretion is actually urine. This is a huge misconception. Students also have difficulty in establishing the relationship between them. So here is the respiration… what does respiration mean? It means to produce energy. But they have difficulty in establishing its relationship with the digestive system. This is the case for them, but the purpose of the excretion is to oxygenate the blood, and our kidneys have this function. In the same way, there are misconceptions in the circulatory system, such as blood transfusion. In fact, back in the time when I was a student, it was said that every blood group was able to transfuse blood with one another. However, the current knowledge about the blood transfusion is totally different… The blood can only be transfused within the same group. For

example, even if you explain this issue in the correct way in the classroom, when students return to their homes, they may hear statements like; “No you are wrong. There is also the concept of “universal donor and universal recipient”. Unlike what we teach, students learn that “Type 0 blood can be transfused to all the others” ... Thus, there are also some external factors affecting our teaching…

As a follow up question, Bethy was requested to explain the strategies that she follows determine the common misconceptions in the classroom. She expressed those misconceptions were being revealed through the questions asked by the students.

> Bethy: Misconceptions arise when students ask questions. Sometimes, I try to figure them out with the questions I ask to myself. For example, when I ask them, what excretion is, or what is the purpose of it, the students can incorrectly refer to the product. After these procedures, I also ask if there is a relationship between the excretion and the digestive system. I ask questions about the excretion product and digestive system waste. I mean, first of all; I check their prior knowledge.
>
> Researcher: When do you reveal students’ misconceptions?
>
> Bethy: I ask the questions at the beginning of the lectures in order to reveal possible misconceptions. What is more, I also ask some questions to reveal students’ prior knowledge during the elaboration phase.
>
> Researcher: Do you try to eliminate the misconceptions you determine? If yes, how?
>
> Bethy: Of course, misconceptions need to be eliminated. Otherwise, students continue learning with major misunderstandings... We use mostly direct-teaching method, maybe I do a small activity... I assign homework to the students who have such misunderstandings such as investigating the difference between digestion and excretion. We also have extra worksheets and activities that are planned to deal with these common misconceptions.

Researcher: Do you think that only explanations are enough to eliminate these misconceptions?

Bethy: Of course, making explanations is not enough to eliminate misconceptions. It should be supported with activities. I use animations, visuals.

In classroom observations, it can be said that students had difficulty in understanding blood vessels in circulatory system. Bethy repeated blood vessels before teaching pulmonary and systemic blood circulation. In addition, students were also confused about gas exchange in the alveoli while she was teaching.

Moreover, it was noticed during the classroom observations that there was a problem in students' understanding of the outcome of the urinary system. When she was asked what the outcome of the urinary system was, students provided "*feces*" as an answer, and this was in line with Bethy's prediction during the pre-interview. She preferred questioning and direct teaching methods to eliminate these misconceptions.

The classroom field notes also indicate that Bethy warned her students to avoid using the terms such as clean and dirty blood in addition to these misconceptions that she mentioned in the interview.

To summarize, Bethy thought that students should know cell-tissue-organ-organism before starting human body systems. Moreover, she thought it will be better if the students know classification of nutrients before digestion, vessels before circulation. Moreover, data show that students have difficulty to understand gas exchange in the alveoli, physical digestion of fats with bile, systemic and pulmonary circulation. Bethy also indicated that result of excretion, the terms which are universal donor and universal recipient are misconceptions that students have.

Later on, Bethy's knowledge of instructional strategies was questioned, and the relevant data is presented in the next section.

4.2.2.4 Bethy's Knowledge of Instructional Strategies

Bethy's knowledge of instructional strategies was analyzed through pre-interview, post-interview, and classroom observation field notes. In this section, Bethy's knowledge of instructional strategies was reported with two subtitles which are the knowledge of subject specific strategies and the knowledge of topic specific strategies.

4.2.2.4.1 Bethy's Knowledge of Subject-Specific Strategies

In this sub-title, Bethy's knowledge of subject specific strategies is presented. It was summarized in the Table 4.37.

Table 4.37 Bethy's Knowledge of Instructional Strategies

Dimension	Interview (Reported-PCK)	Classroom Observation (Enacted-PCK)
Instructional Strategies	5E&7E Learning Cycle Questioning Experimentation* Modelling* Demonstration* Peer learning Rhyming Activity worksheets Research homework Drawing* Note taking	5E&7E Learning Cycle Questioning Experimentation* Modelling* Drawing* Demonstration* Activity worksheets
Purpose of using the strategies	Capture students' attention Promote students' learning Give students responsibility	
Source of using the strategies	Her own learning styles Her previous experiences Experts to develop methods Teacher-training programs	

*Represents topic-specific strategies

Bethy's responses show that she uses 5E learning cycle model in her classroom since she believes that curiosity makes learning easier. Moreover, Bethy stated that she uses questioning and peer learning methods in her classes. In addition, although there were no chances to observe, Bethy said that she also uses rhyming to teach the features of solar system. She benefits from her own learning styles, her previous experiences, and experts to develop these methods. Bethy also said that she does not plan activities alone. The school where she is currently teaching has a group which includes the science teachers, a program specialist and an assessment and evaluation specialist. Therefore, lesson plans are prepared as an outcome of a group work. Bethy argues that teamwork is better even though she also relies on her own experiences.

> Researcher: What instructional methods do you use to teach science in general?
>
> Bethy: Let me tell you how we prepare our plans. All the science teachers in our school state their own opinion with the help of their experiences… We have one measurement-assessment specialist and one program development specialist. We make suggestion to make learning permanent... instructional methods…Now, let me tell... Questioning is important. What else… I use activity worksheets. I also give extra research homework for students…. I use colorful chalks when I write on blackboard... I use rhyming to tell the planet's distance from the sun. I use drawing, note-taking to summarize a topic. I use peer learning… Now, we [teachers in her school] use 5E learning cycle model for each subject. In this model, it is very important to draw students' attention. First of all, it is quite necessary to confront the students with some problems. After that, we enable students to connect their previous knowledge with their daily lives. Then, there is an exploration process there. We organize some activities where they can utilize what they have learnt before in order to promote teaching and learning... For example, I want students to produce an article, a cartoon, a poem, a project, or a model…Then, there is an evaluation.

We make an evaluation at the end of each topic to identify misunderstandings and then deal with them.

Researcher: Why do you choose these instructional strategies?

Bethy: I prefer using these instructional strategies since learning requires curiosity... Also, 5E learning cycle enables students to take responsibility. It makes our jobs easier since students try to solve the problems when they face it.

Researcher: How did you learn using these instructional strategies?

Bethy: Actually, it is quite related to already existing experience. Since I had been a student before, I benefited from rhyming, diagrammatizing, drawing with colorful pencils. Thus, our own learning and teacher-training programs help me utilize these instructional strategies.

Bethy was also questioned about the strategies she follows when there was a confusion in between the students about the topics she teaches during the class. She asserted that she believes in her abilities to provide an alternative explanation spontaneously in the classroom. Also, she was asked how she decided on whether her students understand the topic. She expressed that she makes such decisions according to students' reactions during the class, their responses to questions and students' achievements on formal exams.

During the classroom observations, although the 5E instructional model stages were followed, teacher-centered lecture style was also observable because students did not explore the course objectives own their own. Apart from that, the overt questioning method dominated Bethy's teaching. She distributed some questions to students which are related to curriculum objectives at the beginning of the lessons to reveal students' prior knowledge and make them ready for lesson. Moreover, she asked questions in the middle of the instruction to assess students' learning. There are some examples given in the Table 4.38. Moreover, she used demonstration, and modelling in her instruction about HBS. Additionally, she used power point presentations. Some examples are shown in the Table 4.38.

Table 4.38 Examples of Questions about Each Topic

Name of Topic	**At the Beginning of The Instruction**	**At the Middle of The Instruction**
Digestive System	What does digestion mean to you?	Why do living things feed?
Circulatory System	Why we need circulatory system?	What does capillary mean to you?
Respiratory System	What does respiration mean to you?	How breathing occurs?
Urinary System	What is the outcome of the urinary system?	How your kidneys filter blood?

To summary, Bethy's pre-interview and observation data indicated that she used different methods such as questioning, and demonstrations. Although students answered all questions, her teaching seems to be dominated by the teacher.

Later on, Bethy's Knowledge of Topic-Specific Strategies is represented.

4.2.2.4.2 Bethy's Knowledge of Topic-Specific Strategies

In this section, Bethy's knowledge of topic-specific strategies was highlighted under two subtitles which are knowledge of representations and knowledge of activities of the human body systems.

4.2.2.4.2.1 Bethy's Knowledge of Activities

Bethy's knowledge of activities about the human body systems [digestive, circulatory, respiratory, and urinary system] was presented in the Table 4.39.

At the beginning, instructional strategies that she used while teaching human body systems, especially digestive/respiratory/circulatory and urinary system, were asked to Bethy. She stated that she uses demonstration to make human body systems more concrete. She also prefers activities related to classification of nutrients, urinary system modelling and fill in the blanks of digestive system model.

> Bethy: We [science teachers in her school] make heart and kidney dissection and use respiratory system models to make topics more concrete…Moreover, there is an activity called *My Sandwich*. At the end of the digestive system, students prepare a sandwich. This activity [My Sandwich] helps students to reveal what they have learnt and what has remained in their minds after the lecture. First of all, students take notes of the ingredients in that sandwich. There is also a blank worksheet. The students repeat the digestion of the food, physical digestion, chemical digestion while eating the sandwich they have prepared and fill in the worksheet... Moreover, we assigned our students to create urinary system model last year. Students used whatever materials they wanted. They used water, cotton, coffee filter and serum pipes which serves as a ureter... then, they tried to filter the dirty water with the help of strainers and coffee filters. By this way, we are trying to ensure that the knowledge is permanent, and that learning is at the highest level.

Table 4.39 Bethy's Knowledge of Activities

Interview	**Classroom Observations**	**Related Topic**	**Purpose**
Demonstrations *Heart* *Kidney*	Demonstrations *Heart* *Kidney*	The parts of heart The parts of kidney	Make topics more concrete on students' mind
Activities	Activities		
"My Sandwich" Activity	*"My Sandwich" Activity*	Digestion of Nutrients	Summarize classification of nutrients and digestion process
Making a Model *Urinary System*	-	Urinary System	Make learning more permanent
-	Eating a Biscuit	Digestion Pathway of Nutrients	Warm up students to instruction

Moreover, she also conducted a heart dissection while she was explaining the circulatory system, kidney dissection in the urinary system with the students, which supported her statements during the interview. While they were doing the heart dissection, Bethy paid attention to whether students were conscious about the chambers or not while examining the heart.

Furthermore, it was noticed during the classroom observations that the teacher did the "My Sandwich" activity about the classification of nutrients to summarize the classification of nutrients and the digestion process.

Although Bethy stated that she wanted her students to create a urinary system model as an additional activity, she did not do that in the classroom as was observed. Thus, during post-interview, Bethy was asked the reason why she did not do this activity. She said that she did not have enough time that students present their urinary system model in the classroom thus, she did not prefer doing this activity in this year. Bethy's knowledge of representations is shown in the next subtitle.

4.2.2.4.2.2 Bethy's Knowledge of Representations

Bethy's representations such as metaphors, figures, drawings, and simulations that she used while teaching digestive/circulatory/respiratory and urinary systems were presented in Table 4.40.

Table 4.40 Bethy's Knowledge of Representations

Name of Representations	**Examples from Classroom Observation Implementations (Enacted-PCK)**
Illustrations	
Visuals	
Photos	Digestive system organs
	Respiratory system organs
	Urinary system organs
	Gas exchange process
Simulations	Physical and chemical digestion
	Heart pumping mechanism s
	Systemic and pulmonary circulation
	Heart dissection
Models	Respiratory system model
	Kidney model
Drawing	Digestion of fats
	Heart
	Gas exchange process in the alveoli
	Parts of kidneys
Daily Life Examples	Function of proteins
	Physical digestion of fats

Table 4.40 (continued)

Comparisons	Physical digestion in stomach with swash with forming buttermilk Esophagus with gateway Veins with a net Heart with water tank

In the classroom, Bethy used visuals about digestive system organs, respiratory system organs, urinary system organs, gas exchange process. She showed simulations about physical and chemical digestion, heart pumping mechanism, systemic and pulmonary circulation, and heart dissection. Also, she preferred using respiratory system model and kidney model.

Bethy used daily life examples. For instance, she said: "*When our legs/foots or arms are broken, doctors say that you should eat protein-rich foods, which shows the constructive-restorative properties of proteins*.

Moreover, in the classroom, Bethy preferred using comparisons or metaphors. For example, during the explanation of physical digestion in stomach with swash, Bethy gave buttermilk as an analogy. Also, when she explained the role of esophagus, she said; "*Esophagus is like a gateway for digestion*.". Furthermore, in order to make the target topic easier to understand, Bethy said that the shape of the red blood cells was similar to the shape of our fingerprints when we put them on dough. She also uttered the following expression to give support her arguments about vessels: "*Bleeding occurs when a needle sticks into our hands, which shows that the veins surround the body like a net*". Moreover, when the students asked if there was a blood circulation in the heart, Bethy responded to this question by giving the analogy of pumping water out of water tank.

During the classroom observations, Bethy divided a paper sheet into small pieces. Then, she asked students to compare these small pieces of sheets with fats. In addition to that, she also gave the broken glass example in order to contextualize the subject, which was the physical digestion of fats in bile clearer.

She also demonstrated the respiratory system model given in the Figure 4.3 and kidney model given in the Figure 4.4.

Bethy supported that experiences affect her teaching. According to her, examples from daily life can grasp students' attention. For example, she exemplified the health of the digestive system by referring back to the operations in the stomach.

> Researcher: Do you have a digestive system disease or does anyone in your family/around you have such kind of illness? Does it [disease] affect your teaching?
>
> Bethy: Yes, my mother had an operation on her stomach. I received an ulcer treatment. I have an acidic reflux disorder. The acidic reflux results from eating at night. Some nutrients trigger the acidic reflux…of course, it [Having these diseases in our daily life] affects my lectures and makes it easier for me to provide more concrete and understandable examples. Since you are continuously communicating with the doctor about this [disease], you have more accurate information, and you can transfer them to the students more easily. Subjects that we experience in our daily lives may affect the students more quickly and increases their interest. After all, they [students] try to give an example to this situation from their own families. Even students who do not attend the lessons regularly begin to participate in the classroom discussion in an excited manner because I am also quite eager to learn about their lives.

To summarize, in line with Bethy's pre-interview and observation data pointed out that she preferred using different methods such as questioning, demonstrations and representations such as daily life examples, visuals, and comparisons. She used activities such as organ dissection. Furthermore, she used many daily life examples and visuals for digestive, circulatory, respiratory, and urinary systems. In the light of these information, Bethy seems knowledgeable enough about instructional strategies.

Bethy's knowledge of assessment strategies was reported in next section.

4.2.2.5 Bethy's Knowledge of Assessment Strategies

Bethy's knowledge of assessment strategies was revealed through pre-interview, classroom field notes and post interview. The collected data in this section is divided in two sub-titles which are knowledge of assessment methods and knowledge of science learning dimension to assess.

4.2.2.5.1 Bethy's Knowledge of Science Learning Dimension for Assessment

Bethy's knowledge of science learning dimension for assessment is summarized in the Table 4.41.

Table 4.41 Bethy's Knowledge of Science Learning Dimension for Assessment

Knowledge of Dimension of Science Learning to Assess	**Interview (Reported-PCK)**	**Classroom Observation (Enacted-PCK)**
Conceptual understanding	Mentioned	Observed
Science process skills	Not mentioned	Not observed
NOS Understanding	Not mentioned	Not observed

Bethy focused on students' conceptual understandings while she was ignoring the nature of science, and science process skills. She paid attention to the objectives given in the curriculum about the human body systems.

> Researcher: What exactly do you want to evaluate while assessing students' understandings of human body systems [digestive, circulatory, respiratory, urinary system]?
>
> Bethy: Our aim is to assess whether the students understand the purpose of digestion, breathing, circulation and excretion. What else…What are the functions of each organ that is responsible for these events [digestion,

> breathing, circulation and excretion]. We aim to assess our objectives since we plan our lesson in line with them.

Bethy did not emphasize the nature of science understanding while she only mentioned conceptual understanding. Also, she did not mention it (SPS) in the assessment part. However, Bethy mentioned the importance of scientific process skills (SPS) when she was questioned about the purpose of science teaching at the beginning of the pre-interview session.

> Researcher: When does learning happen in class? Can you feel whether or not students grasp what you are talking about?
>
> Bethy: Hmm, that is a nice question. Actually, evaluating the topics that include mathematics is easier since when we start to solve problems, I can evaluate whether or not students apply their knowledge to these problems. For other topics that do not include mathematics, students' participation and the number of correct answers indicate the percentage of learning. Besides, the eye contact with the can be quite useful to assess them in an informal manner. However, for most of the time, the concept of learning becomes clearer during the experiments you conduct on the subject or in the formal exams you apply.
>
> Researcher: When do you assess your students?
>
> Bethy: It depends on our planning. First of all, the questioning method that I use at the beginning of the lesson aims to assess the prior knowledge and attention levels of the students. I also assess students at the end of each topic and at the end of each unit. The questions that I use at the end of the topic are used to see whether or not the students grasp the target subject. However, all types of assessments have different purposes such as engaging with daily life or evaluating the process of learning.

According to classroom observation data, to assess her students' conceptual understanding, Bethy did quizzes at the end of each human body system [digestive, circulatory, respiratory, and urinary]. Questions related to each system were given in Table 4.8.

Then, at the end of the human body system, Bethy asked thought-provoking questions which something was explained in detailed in Case 1 (see Anna's Knowledge of Science Learning Dimension for Assessment).

4.2.2.5.2 Bethy's Knowledge of Assessment Methods

Bethy's knowledge of assessment methods is presented under this title. Data gathered through pre-interview session and classroom observations show that Bethy mostly used traditional assessment methods such as multiple-choice exams, quizzes, and written exams. Quizzes included short-answer questions, matching activities, and true-false questions. Moreover, she preferred peer-review and performance evaluations as an alternative assessment method. She preferred both formative assessment and summative assessment.

Bethy's knowledge of the assessment methods is summarized in the Table 4.42.

First of all, she was asked about the assessment techniques she uses to assess her students' understanding.

> Bethy: We have some decisions that we make as a group (science teachers in her school). For example, I make quizzes at the end of each chapter, at the end of each unit. There are also written exams. Moreover, I use questioning at the beginning of the lesson by stating the problem situation. What else…There are also peer assessment methods, that is, students evaluate each other in group work through the papers I prepare at work. Likewise, I evaluate their participation in group work. In fact, I always observe and evaluate them in classroom.
>
> Researcher: Why do you prefer using these methods, is it a personal decision or is it a decision taken by all the science teachers?

Table 4.42 Bethy's Knowledge of Assessment Methods

	Interview (Reported-PCK)	**Classroom Observation (Enacted-PCK)**
How to assess?	Thought-provoking questions Multiple choice questions Quizzes Formal exam Performance evaluations	Short-answer questions (Fill in the blank) Thought-provoking questions Multiple choice questions Quizzes (short-answer questions, matching activities, and true-false questions) Formal exam Performance evaluations
When to assess?	Formative Summative	Formative Summative
The reason of using strategies	Arise prior knowledge Identify incomprehensive topic and give feedback Help to review instructional strategies Determine how much the student has learned Provide students to use apply knowledge Multiple choice assessment Evaluate students' understanding related to objectives Provide students to evaluate each other Evaluate students' progress	

Bethy: Actually, our aim is to identify those who cannot learn, who somehow cannot benefit from the activities we do… Our aim is to make a topic understandable. Evaluating students frequently enables me to reach more students ... That is why these feedbacks are important for me to shed light on myself again, to review my instructional methods.

Researcher: How do you use these results? What do these results mean to you?

Bethy: So, as I said, I finally understand how much has been learned and how useful my method is.

During her teaching, she used to fill in the blank activity to examine students' prior knowledge about digestive system in the classroom. The activity sheet about digestive system is given in the Figure 4.17 below. This sheet includes digestive system, but the organs are not labelled. The teacher wants students to fill them before talking about the digestive system.

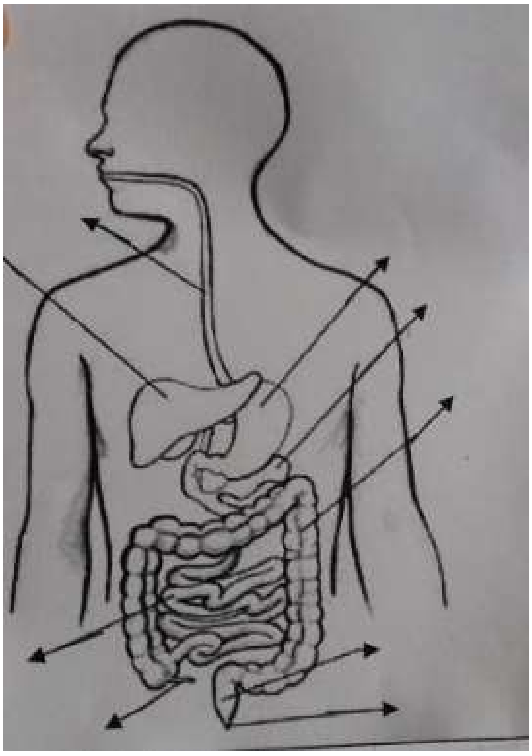

Figure 4.17 The Body Shape

At the end of each human body system, she prepared some mini quizzes. Moreover, she used thought-provoking questions, written exams, and performance evaluations while assessing her students. Bethy utilized these types of questions in order to increase students' understanding of the human body systems. Then, there were written exams which included the first two units that were the solar system and human body systems as a summative assessment method. Moreover, there were also performance evaluations with their criteria prescribed to evaluate students' progress in the classroom (see Anna's knowledge of Science Learning Dimension to Assess).

In conclusion the analysis of Bethy's data collected through the pre-interview session and classroom observations show that there is a relationship between her assessment strategies and her objectives, which are the structure of the organs, the functions of the organs, and how do organs work. Bethy seemed knowledgeable enough about various assessment strategies. She used both traditional methods such as multiple-choice questions and alternative assessment methods like performance assessment while she was evaluating her students according to the objectives given in the curriculum [MoNE, 2018]. She preferred both formative and summative assessment.

Later on, Bethy's subject matter knowledge of human body systems is presented.

4.2.3 Bethy's Subject Matter Knowledge of Human Body System

Bethy's subject matter knowledge is examined as syntactic knowledge and substantive knowledge. First, her substantive knowledge is highlighted.

4.2.3.1 Bethy's Substantive Knowledge of Human Body System

Bethy's substantive knowledge of human body systems is evaluated with respect to four systems which are digestive system, circulatory system, respiratory system, and urinary system followed by her understanding of Human Body System as a complex system.

4.2.3.1.1 Bethy's Knowledge of the Digestive System

The data about Bethy's knowledge of the digestive system were collected through pre-interview questions including concept maps, drawings, and word association tests, as well as classroom observations. Her interview data analyses and classroom observation findings are respectively presented in the Table 4.43.

Bethy's knowledge of the digestive system during interview is presented below under three subtitles which are *Understanding the Digestive System and Its Components*, *The Adaptation Process of the Digestive System*, *The Health of the Digestive System.*

4.2.3.1.1.1 Understanding the Digestive System and Its Components

In this subtitle, Bethy's understanding of the digestive system and its components are demonstrated. Overall, she mentioned four stages of food processing, stating that foods we eat are digested, absorbed, and the feces are eliminated at the end of the process. She correctly explained that digestion is a process which includes chemical and physical breakdown of nutrients, and the difference between physical and chemical digestion by giving examples. She mentioned mouth, esophagus, pharynx, small intestine, and large intestine, anus as the components of the digestive system. Bethy also seemed aware of that gallbladder, pancreas, and liver are accessory digestive system organs.

She explained the roles and the structures of the organs in the middle school level. Additionally, she properly explained the function of the digestive system by mentioning the ATP requirement of the body and the energy generation process taking place in mitochondria in our cells during the respiration process. However, she incorrectly mentioned enzymes as secretions.

Specifically, as a first question, she was asked to express her opinions on what happens to the foods we eat. Then, she was requested to provide her understanding for the term "digestion".

Table 4.43 Summary of Bethy's Knowledge of the Digestive System

Categories	**Bethy's Knowledge of the Digestive System**
Digestion	− A process of chemical and physical breakdown of nutrients − Physical and chemical digestion
The Role of the Digestive System	− To enable nutrients entering the bloodstream to make up for the requirements for the production of ATP
The Digestive System Organs	− Mouth − Esophagus − Pharynx − Stomach − Small Intestine − Large Intestine − Anus
The Accessory Organs	− Gallbladder − Pancreas − Liver − Salivary Glands (*classroom observation only*)
The Adaptation of the Digestive System *(interview only)*	− Being appendicitis is dysfunctional − Number of teeth − Getting smaller of mouth, teeth, and jaw structure

Table 4.43 (continued)

The Health of The Digestive System	*Disorders* − Acid-reflux − Gastritis − Ulcer − Colon cancer − Esophageal cancer − Tongue cancer − Throat cancer − Colitis *Conditions for healthy digestive system* − Staying away from spicy, sour, acidic foods − Avoiding from extreme hot or cold foods − Chewing food well − Eating good carbohydrates, and protein − Doing sports − Doing dental checks on time

Bethy: What happens to the foods we eat…The foods we eat are digested, absorbed, and they enter the bloodstream. Then, digested foods are eliminated through the feces. The digestion is a process of chemical and physical breakdown of nutrients.

To reveal her understanding about digestion in a more comprehensive manner, the types of digestion were directed to Bethy as a follow up question, after stated that *there are physical and chemical digestion,* she explained the difference between two processes. She seemed knowledgeable enough about these processes as she provided the examples such as the breaking down of fats into smaller pieces or breaking down of proteins into building blocks with the enzymes found in digestive juice.

Bethy: Of course, there is a difference between physical and chemical digestion. The physical digestion is a mechanic process. I mean, in the physical digestion, the large molecules breakdown into only small molecules. However, in the chemical digestion, there is a process that the large molecules breakdown into their building blocks. For example, the carbohydrates are converted into glucose… The proteins are transformed into the amino acids, and the fats are converted into the fatty acids and the glycerol. I mean, there are secretions in the chemical digestion process and these secretions play a role in breaking down of the molecules into their building blocks. The fact that the fats are broken down into smaller pieces with bile can be an example of physical digestion, or the bread I eat is broken down into smaller pieces with the help of teeth, tongue, and saliva; that can also be given as an example of physical digestion. The breakdown of proteins into building blocks by the enzymes in digestive juice is an example of chemical digestion.

Since Bethy mentioned enzymes, she was requested to explain the meaning of an enzyme. Bethy explained them as *a secretion*. She did not mention that enzymes were proteins. However, she gave only one example (i.e., lipase).

> Bethy: Enzymes are the secretions which are responsible for breaking the large molecules into their building blocks. Enzymes are produced from our organs and our bodily structures. I remember lipase enzyme.

Then, Bethy was asked to write 12 words about digestion and digestive system to elaborate on her response. First, Bethy listed the words about digestive system (See Table 4.44). These words were grouped in three categories. The categories included *organs* (i.e., Mouth, Esophagus, Pharynx), *molecules* (i.e., Proteins, Fats, Carbohydrates), and *processes* (i.e., Digestion, Elimination**).**

> ... When you said *digestion,* the nutrients entering the bloodstream by physical and chemical process, breaking down of food, digestion of food and absorption came to my mind. When you said *digestive system*, the structures and the organs that composes the digestive system and processes came to my mind. Well as I always say the relationship…for example, for the respiration… The nutrients enter the bloodstream so that our cells generate the energy. That is, that nutrients get through our cells for a reason. I mean there is a relationship among systems. However, the *digestion* is a process in itself.

Then, she elaborated on her response as follows:

> The digestion is a process that is making the nutrients enter the bloodstream with the help of digestive system organs. Nevertheless, *the digestive system* is related with the structures, organs and as well as the processes that are occurring there. Role of the digestive system is to enable the nutrients to get into the bloodstream…In addition, there is a relationship between the digestive system and other systems…We need energy, and this energy is produced by what we eat. Thus, the nutrients should reach our cells to generate the energy. This [reaching nutrients to our cells] is only provided by the blood. Thus, the reason why we need the digestive system is to enable nutrients getting into the blood to make up for the requirements for the production of ATP. Then, the purpose of the digestive system is generating energy.

Table 4.44 Bethy's Concepts of Digestive System as Shown in WAT

Groups of concepts	Corresponding Concepts
Organ	Mouth Esophagus Pharynx Small Intestine Large Intestine
Molecule	Proteins Fats Carbohydrates Water Minerals
Process	Chemical digestion Physical digestion Digestion Elimination Reabsorption of water

So far, Bethy mentioned mouth, esophagus, pharynx, small intestine, and large intestine as the digestive system components. Then, Bethy was also asked to draw a concept map (see Figure 4.18) of the digestive system to understand her knowledge of the digestive system in detail.

> Bethy: Nutrients are taken into mouth. There is pharynx, esophagus, stomach, small intestine, large intestine, and anus, respectively. There are teeth and tongue in the mouth. The secretion produced in the pancreas is stored in the gallbladder. Bile stored in the gallbladder comes to the small intestine. It sends pancreatic secretion to the gall bladder, then the bile stored there goes to the small intestine. The pancreas also sends the pancreatic juice to the small intestine. Since gastric juice is the secretion of the stomach, I did not want to mention it specifically.

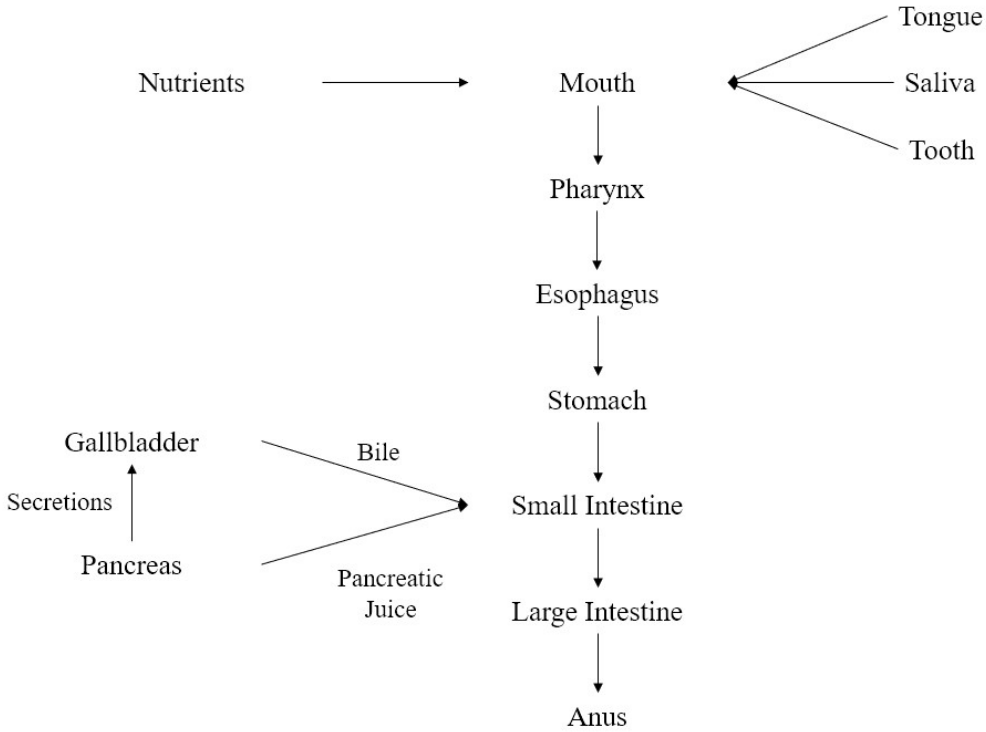

Figure 4.18 Bethy’s Concept Map about Digestive System

As it can be clearly seen above, her map included all the organs (i.e., mouth, esophagus, pharynx) that make up digestive system and organs (i.e., gallbladder, pancreas) that help digestive system as well as teeth, tongue, and saliva. Then, she was requested to draw the digestive system in order to reveal her understanding of it in more detail. As seen in Figure 4.19, Bethy did not exactly include the drawing of organs, but she explained the organs that make up the digestive system by using a flow chart. She explained her drawings by giving the details of the organs that make up the digestive system and how do carbohydrates, proteins and fats are digested**.**

> Bethy: Each organ has different role. The mouth digests [foods] both physically and chemically. In the mouth, both the physical digestion of carbohydrates with the help of teeth, tongue and saliva, and the chemical digestion of carbohydrates take place. Then, the nutrients get through the pharynx. I think the pharynx is like a door. There is no physical and chemical digestion occurring in the pharynx. The next stop of the nutrients is the

esophagus. Then, nutrients are propelled with peristalsis downward throughout the esophagus. There is also no physical and chemical digestion in the esophagus. Only the transfer of the nutrients take place in the esophagus and the pharynx. We think them [the esophagus and the pharynx] like a passageway. Then, the chemical digestion of the proteins take place in the stomach with the help of some secretion. The stomach digests [foods] both physically and chemically. More precisely, the chemical digestion of proteins begins in the stomach. The nutrients are transformed into the chyme with the help of gastric juice, and they are broken down into the small particles in the stomach. There is an absorption in the small intestine. In addition, the digestion of foods is completed in the small intestine. The large intestine is an organ where the feces are stored, and water is absorbed. Then, the anus eliminates feces. However, I do not know the structure of the organs since it is not my special interest, but I know that the esophagus and the stomach have muscular structures. They [the esophagus and the stomach] relax and contract. The esophagus is like a hose. The small intestine is very long, and its folded structure helps it to fit in our body. The villi extend the surface area and absorption. In the mouth, there is a tongue, and there are teeth as well as epithelial cells. I do not know any more details; I only know enough to teach the concepts. Well, we do not mention the structures of organs while teaching. The chemical digestion of the nutrients which are proteins, carbohydrates and fats are completed in the small intestine. However, both the physical and chemical digestion of fats take place in the small intestine. The physical digestion of fats take place in the small intestine with the help of the bile. On the other hand, the chemical digestion of fats take place with help of the enzymes in the pancreatic juice. The absorption of the water, minerals and vitamins take place in the large intestine. As a matter of fact, there is no chemical and physical digestion of water, minerals, and vitamins since they are already composed of small molecules. Finally,

> although most of the absorption occurs in the small intestine, the water is also absorbed in the large intestine. The feces are eliminated through the anus.

She was able to explain the role of the mouth, the pharynx, the esophagus, the stomach, the small intestine, the large intestine, and the anus. Moreover, she indicated the role of gastric juice and the pancreatic juice throughout the digestion process.

Then, as a follow up question, the relationship between the organs that make up the digestive system was asked to her. She indicated her ideas as follows:

> Each organ has a similar role. I mean they are specialized in serving a similar purpose to complete digestion. All of these organs take part in different parts of the digestive process.

Moreover, she was asked about saliva as she mentioned it during the interview. She defined the role of saliva as with the following sentences:

> The saliva helps moisturizing and limbering the food. In addition, the saliva breaks down starch thanks to amylase enzyme.

It can clearly be seen that Bethy came to the realization of the saliva's function of moistening food and starting the chemical digestion of carbohydrates even though she did not mention that saliva also has the function of defensing and tasting. So far, although she mentioned saliva, she did not address the salivary glands. However, she mentioned liver and pancreas while she was creating her concept map. Thus, in addition to the organs and structures which constitutes the digestive system, she was also asked about the accessory organs that help the digestive system to get more details of her understanding. Bethy seemed aware of the fact that pancreas, and liver are accessory digestive system organs.

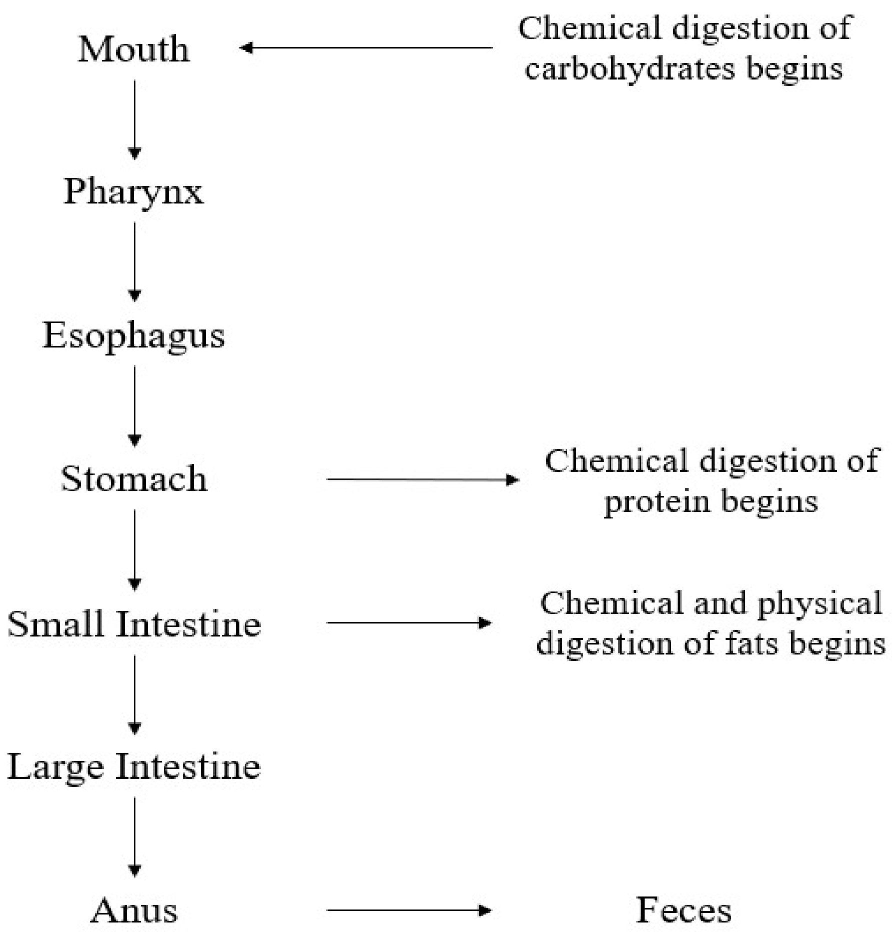

Figure 4.19 Bethy's Drawing of Digestive System

Regarding the bile, she previously indicated that it was secreted from pancreas. Then, she recognized her mistake and corrected it by saying; "*Bile is secreted from liver while it is being stored in gallbladder"*. She also knew that the liver had many functions including the adjustment of blood sugar levels and conversion of carbohydrates into fats.

> Bethy: Of course, there are liver and pancreas. The liver produces the bile. I understood my mistake here… the bile is stored in gallbladder. Moreover, the liver has many roles, but I have difficulty in remembering all of them. I always revise this topic before starting to teach it. The liver adjusts the blood

sugar levels and converts carbohydrates into fats. The liver has many functions. In addition, since the pancreas secretes both internally and externally, it has role on hormones, and it produces pancreatic juice.

As a follow up question, the relationship between structures and organs that make up the digestive system and accessory digestive system organs was asked to Bethy. She explained that the accessory digestive system organs help the accomplishment of the digestion process digestion with their secretion.

Since Bethy related *the purpose of the digestive system with the generation of energy* while she was explaining her wordlist, she was asked about how foods we consume are converted to energy in order to get more detailed information about her knowledge of the role of the digestive system. She stated that the foods we eat are converted to energy through respiration in the mitochondria of the cells. In addition to these, Bethy was asked about the changes occurring in our body during the digestion process. She explained the blood pumping and the secretion of hormones change during the digestion. Even though she was not sure, she tried to make inferences.

> Bethy: For example, the first thing that comes to my mind is feeling sleepy… Blood is pumped to this area. The blood circulation can become faster. The heartbeat can be faster. Hormone secretion can be affected. However, I do not know more details as a teacher who graduated from a chemistry department.

4.2.3.1.1.2 The Adaptation of the Digestive System

After she explained the digestive system and its components, the adaptations that occur in the digestive system was asked to Bethy. She mentioned function of the appendicitis and the changes that occurred in the structure of mouth, teeth, and jaw as examples of evolutionary adaptation. In addition to this, she correctly addressed that changing the number of teeth could also be an example of adaptation.

Bethy: For instance, there is an appendicitis issue. At the moment, the appendicitis has no role in our body, but in the past, it was said that the appendicitis had an important role especially when someone was fed with too much raw grass. Apart from that, our mouth, teeth, and jaw structure are getting smaller and smaller, and this is because we are now consuming more cooked foods. [Thus]There is less need for chewing... Therefore, our jaw and tooth structure also changed in the evolutionary process. Maybe number of our teeth...

It can be said that she correlated these adaptations with humans' diet (Reece, 2016). Then, the questions that are related with the health of the digestive system were asked to Bethy**.**

4.2.3.1.1.3 The Health of the Digestive System

She seemed to be aware of how to keep the digestive system healthy and clearly emphasized digestive system disorders. For instance, she mentioned acid-reflux disorder, gastritis, ulcer, colon cancer, esophageal cancer, tongue cancer, and throat cancer as the digestive system disorders. She briefly stated that there was a relationship between the digestive system diseases.

Researcher: What should we do to keep the digestive system healthy?

Bethy: The health of the digestive system… We should pay attention to eating healthy. We should stay away from spicy, sour, acidic foods and avoid consuming extreme hot or cold foods. We should chew food well, eat good carbohydrates and protein. What else… We should do sports. When we talk about the health of the digestive system, we should also consider the dental health. Dental checks should be done on time, and tooth brushing processes should be followed after eating, … Consuming extremely hot foods can irritate the esophagus, thus we should pay attention to it. In addition, drinking orange juice on an empty stomach [hungry]causes an increase in stomach acid, so you need to be careful about them. I cannot say more.

Researcher: What are the digestive system diseases? Is there any relationship among them?

Bethy: Acid-reflux, gastritis, ulcer, colon cancer, esophageal cancer, tongue cancer, throat cancer…Colitis in the large intestine… Well, the causes of cancer are still under investigation. For example, of course, there is a relationship between gastritis and ulcer because the first stage of the ulcer may be gastritis. Moreover, not being able to control the stomach acid cause the stomach surface to wear and tear, and after a certain period of time, it causes wounds to form. So, I think there is a relationship between diseases, but I do not know what the relationship between colitis and other diseases is…. However, does just consuming or drinking hot food and beverages cause cancer in the pharynx or in the esophagus? I am not very knowledgeable on this issue.

To summarize, overall interview findings regarding Bethy's knowledge of the digestive system indicate that Bethy seems knowledgeable about the organs that constitute the digestive system, including accessory organs except salivary glands; knows the general function of digestive system and how the foods are digested; some types of evolutionary adaptations associated with digestive system and the health of the digestive system.

In the next part, Bethy's classroom finding is presented and compared with the findings with her interview data.

Classroom Observation Findings

In line with the interviews, it was noted in classroom observations, , that Bethy taught her students the reasons why organisms need to take food, the classification of nutrients (i.e, carbohydrates, proteins, and fats), the function of nutrients in our body, the terms such as the large molecules and building blocks, role of enzymes, types of digestion, and the functions of the organs (i.e., mouth, esophagus, stomach) that constitute the digestive system and accessory digestive system organs (i.e., liver, pancreas).

Bethy's explanation of physical and chemical digestion is given below as an example:

> Each enzyme has a different function, and their working principles are different. We classify digestion as physical digestion and chemical digestion because when we ingest nutrients, they do not suddenly break down into building blocks, right? Separating nutrients into building blocks requires a process. In this process, a number of events called physical digestion and chemical digestion take place. First of all, what does physical digestion mean? Imagine that I eat a slice of meatball. When I bite the meatball, it is divided into small pieces with the help of my teeth. It is moistened and lubricated with the help of saliva, and it is swirled into my mouth with the help of my tongue. These processes represent the physical digestion. Later, the broken-down nutrients that will reach to the stomach become moistened since the saliva lubricated them. Before reaching to the stomach, it [the broken-down nutrient] passes through the pharynx, esophagus and reaches the stomach. The stomach contracts and relaxes. Do you know about buttermilk? Imagine that you are shaking the buttermilk in one liter of jar in your homes. You put yoghurt, salt, and water in this jar to make buttermilk and then shake it. In this situation, the stomach does this shaking by contracting and relaxing, and this is an example of physical digestion. Enzymes are involved in chemical digestion. Enzymes are present in some fluids such as saliva, pancreatic juice secreted by the pancreas and gastric juice secreted by the stomach. Enzymes start the process of breaking down nutrients into their building blocks.

Contrary to interview session, Bethy mentions salivary glands while teaching digestive system.

> Bethy: What does saliva do? It moistens the nutrient. There are salivary glands under the ear, under the chin and under my tongue. The nutrients are softened with the help of these salivary glands.

In addition, during her teaching, she explained pharynx and the process of absorption in a very similar way to her interview response.

> Bethy: The pharynx is a transition point just after the oral cavity. There is neither physical nor chemical digestion here because the bite I eat immediately passes from the pharynx to the esophagus. Just as I cannot leave the door of the school without leaving the classroom door, the pharynx is just a gateway. Nutrients which are crushed into their building blocks are ready to enter the bloodstream. Well, there is a statement that *the absorption of nutrients that are divided into building blocks takes place in the small intestine* on the board. The absorption refers to the process of the entrance of the building blocks of nutrients into the bloodstream.

General Summary of Bethy's Finding about The Digestive System

In brief, Bethy's classroom observations and interview findings are compatible with each other. She overcame the deficiencies that she did not mention in the interview. That is, during her teaching, she explained salivary glands unlike her interview responses. Moreover, her knowledge of the digestive system is consistent with middle school science curriculum. To sum up, she mentioned all the related concepts that she had to teach. Thus, Bethy seems quite knowledgeable about the digestive system. In response to above explanation, Bethy's understanding of the relationship between digestive system and circulatory system as well as other body systems were elaborated by asking related questions. Following section present not only the nature of this relation but also her knowledge on that circulatory system.

4.2.3.1.2 Bethy's Knowledge of the Circulatory System

The data about Bethy's knowledge of the circulatory system is collected through pre-interview questions including concept maps, drawings, and word association tests, and classroom observations. Her interview data analysis and classroom observation findings are summarized in the Table 4.45.

Table 4.45 Summary of Bethy's Knowledge of the Circulatory System

Circulation	− Pulmonary Circulation − Systemic Circulation
The Role of the Circulatory System	
Interview only	− transport blood to the body cells
Classroom observation only	− carry molecules that is formed at the end of the digestion − carry oxygen which is inhaled with the help of the respiratory system − carry hormones from secretory glands to the target organs − provide water balance of the body − protect the body temperature
Both	− carry metabolic wastes of the cells to the urinary system − carry carbon dioxide formed in the cells to the respiratory organs
The Circulatory System Components	− Blood Blood cells *White blood cells* *Red blood cells* *Platelets* Plasma − Vessels *Arteries* *Veins* *Capillaries* − Heart

Table 4.45 (continued)

The Health of The Digestive System	*Disorders* Atherosclerosis Heart Attack *Conditions for healthy circulatory system* - pay attention nutrition - do exercises

In this part, Bethy's knowledge of the circulatory system is presented. Bethy's interview findings are divided into two titles which are as follows: *Understanding of The Circulatory System and Its Components*, *The Health of The Circulatory System.*

4.2.3.1.2.1 Understanding of The Circulatory System and Its Components

This part includes the related data findings about Bethy's understanding of the function of the circulatory system, organs and structures that constitute the circulatory system, blood groups, blood transfusions, systemic and pulmonary circulation. She explained that the circulatory system was necessary to transport blood to the whole body. Furthermore, Bethy's answers showed that she was aware of the fact that the circulatory system consists of the blood, vessels, and a heart. Moreover, her explanations showed that she was aware of the functions of blood, blood cells, blood groups, Rh factor and Rh incompatibility, blood pressure and pulse. She was also able to identify different circulation processes.

Firstly, Bethy was questioned about her understanding of the circulatory system, the function of the circulatory system in the body and the reason why we need the circulatory system. The questions aimed at highlighting how much she knows about this particular system. According to Bethy, the main function of the circulatory system was transporting blood to the body cells. Moreover, she mentioned that the blood becomes oxygen rich thanks to the circulatory system.

> Bethy: …The circulatory system has a heart, blood, and the vessels… Actually, the function of the circulatory system is to transport blood to the cells. By this way [transporting blood to the cells with the help of the circulatory system] the oxygen is transported to our cells, and our cells are fed. Besides, [it is the function of the circulatory system] to collect the wastes and transmit them to the lungs to be cleaned again, that is, to make them rich in oxygen... There are many occurrences taking place in the organs. For example, the formation and expelling of the wastes from our body is carried out thanks to the circulation process.

Then, Bethy was requested to list 12 words that she thinks of whenever she is confronted with the circulatory system. Her wordlist was divided into four categories, which are *cell* (i.e., white blood cells, red blood cells), *tissue* (vessels, blood, artery), *organ* (i.e., heart), and *other terms* (i.e., blood types). She also added the following utterance: "*We do not use the term thrombocyte in middle school. We use terms such as white blood cells, red blood cells, and platelets.* The list of the words she included in shown in the Table 4.46.

After she listed these words, she was also asked to explain the relationship between them. She indicated that relationship as follows:

> There is blood and the blood is composed of blood cells… There is water in the blood and this water includes blood cells and there is blood group factor which is different for each individual. The heart is responsible for pumping blood. Then, the heart consists of chambers which are ventricles and atria. And of course, there should be vessels to transport blood. These vessels are arteries and veins. And the biggest vena cava is the aorta.

Then, Bethy was asked to construct a concept map which would reveal her understanding of the circulatory system (see Figure 4.20). Bethy's circulatory system concept map shows that she included only blood, heart, and vessels. She indicated only a few linking words to represent the relationship between the organs and their functions. Moreover, her linking words represented only one-way relationship. She said that constructing concept map was difficult for her and she needed more time to draw the concept map.

Table 4.46 Bethy's WAT about Circulatory System

Groups of concepts	**Corresponding Concepts**
Organ	Heart
Tissue	Vessels Blood Artery Chambers Atria Ventricles Aorta
Cell	Blood cells White blood cell Red blood cells Platelets
Other	Blood types

It can be seen that Bethy mentioned the structures and the organs that make up the circulatory system such as blood, vessels, and a heart with the help of her wordlist and concept map. After she mentioned these organs, she was requested to draw the human circulatory system.

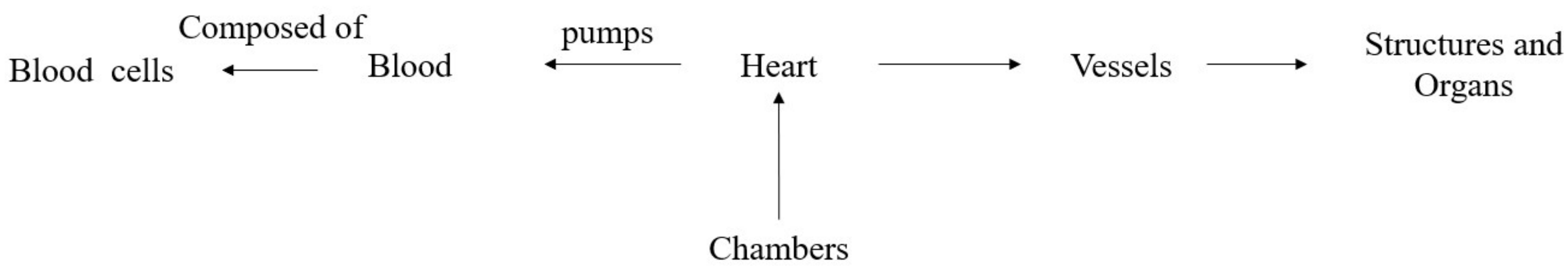

Figure 4.20 Bethy’s Concept Map of Circulatory System

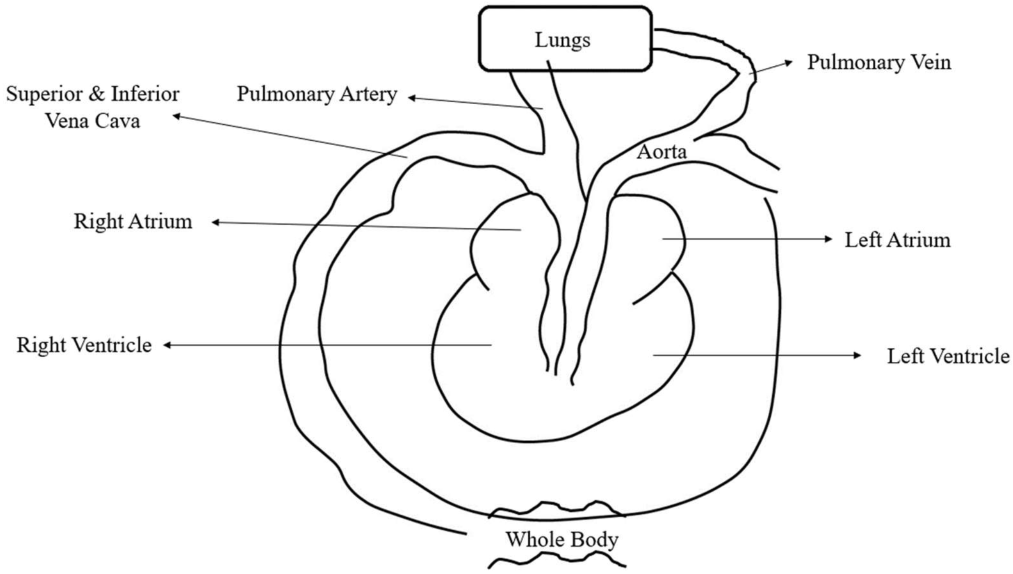

Figure 4.21 Bethy's Drawing of Circulatory System

As seen in Figure 4.21, in her drawing, she represented *vessels* such as inferior vena cava, superior vena cava, aorta, pulmonary artery, pulmonary vein; chambers of *heart* which are atria and ventricles; *lungs.* Since she mentioned the structures and the organs that make up the circulatory system both in her wordlist and drawing, she was also requested to explain the functions of them. Her explanation is given as follows:

> The blood is responsible for feeding cells and producing oxygen. The blood consists of blood cells. Each of blood cells has different functions. The white blood cells are responsible for body defense. The platelets are responsible for blood clotting. The heart is responsible for pumping blood. The vessels are responsible for both transmitting blood to the structures and the organs as well as returning the blood to the heart again. The vessels carry the blood that the heart pumps. The vessels are grouped as arteries, veins, and capillaries. Moreover, these are divided into capillary artery, and capillary vein. The arteries, except for the pulmonary artery, carry the blood which is oxygen-

> rich throughout out body. The veins, except for pulmonary vein, return deoxygenated blood to the heart. The capillaries are very thin vessels that provide transportation among veins and arteries.

As a follow up question, she was asked if there was a relationship between the structures and the organs. She said, "*The heart pumps the blood. I repeated the same explanations however the heart needs vessels to pump the blood to each organ.*"

Although Bethy stated that blood produces the oxygen, in fact, blood transports the oxygen. As she indicated, there are three types of blood cells which will be given in more detail in the following sections.

The definition of blood pressure and pulse were also asked to Bethy since these are related with vessels and heart. She provided the following definitions: "*The number of times that the heart beats in a minute is called pulse… I think blood pressure is… I am not sure whether it is related with artery or vein…Mmm… Blood pressure is called the pressure that the blood creates on the vessel walls*".

Afterwards, since she has already mentioned blood in her responses, she was asked to explain blood in more detail. Bethy's responses to the questions show that she is aware of the functions of blood, blood cells, blood groups, Rh factor, and Rh incompatibility. Moreover, when she was asked about the terms "dirty and clean blood", she correctly explained that these are inappropriate terms to use. Unfortunately, although she knew that blood consist of blood plasma and serum, she could not remember the difference between them. Her responses also show that she was aware of the necessity of blood donation.

> Researcher: Can you explain the blood in more details?
>
> Bethy: Well… There are hormones, enzymes, water, blood cells in blood. There is a proportion among these [hormones, enzymes, water, blood cells], but I do not remember that in detail. There is serum in blood. When blood is centrifuged, the blood cells get together at the bottom while the yellow part which includes hormones, enzymes, waste materials, rises to the top. The

functions of the blood...Mmm…as I said before the white blood cells are responsible for body defense by strengthening the immune system. The red blood cells are responsible for delivering oxygen to other cells. I know that the platelets are responsible for coagulation.

Researcher: What do you understand when we say, “dirty blood and clean blood”? Do you mention “dirty blood and clean blood” during your teaching?

Bethy: Well… The term “clean blood” is what our teachers used to teach us back in the time. “The clean blood” represents the oxygen-rich blood while “dirty blood” represents the blood that includes more carbon dioxide and rich in terms of waste material. Yes, we mention “dirty blood” and “clean blood”. For example, I ask questions like “*What does clean and dirty blood mean*?”, “*In what way is the blood clean or dirty?”*. After all, if blood is rich in oxygen, it is important for it to be carried to other cells. Instead of these terms, we try to use terms like oxygen-rich, oxygen-poor, or waste-rich, waste-poor blood.

Researcher: What about blood groups and the Rh factor?

Bethy: Blood groups are determined through special proteins that blood has such as A, B, or both. The blood groups are A, AB, B, and 0…Rh is a protein called Rhesus found in blood. There were Rhesus monkeys and because the protein in their blood was also present in human blood, it was called Rh factor. If we have this type of protein in our blood, it is said that we have Rh-positive (Rh+) blood, and if this protein is absent in our blood, we call it Rh-negative (Rh-) blood.

As follow up question Bethy was requested to explain how blood transfusion occurs. She stated, “*Each blood group can only donate to or receive blood from the same blood group. The misconceptions such as the universal donor, and the universal recipient are no longer available.”*

Furthermore, when erythroblastosis fetalis (Rh incompatibility) was asked to Bethy, she correctly stated that Rh incompatibility is a condition when Rh-negative mother's blood is mixed with her baby's blood, which should be Rh-positive.

> Bethy: Rh incompatibility is a condition that happens when the mother has a negative blood group, and the father has a positive blood group. If the baby is positive and if the baby's blood is mixed with the mother's blood during the birth, a Rh incompatibility situation occurs. And I think doctors try to prevent these negative consequences by giving the mother an injection for the first baby. As far as I remember, the absence of this protein is not a problem, but now I think there is an antigen-antibody relationship. I know that there is such a danger because antigens and antibodies recognize this protein as foreign matter and attack that protein and precipitate it when they are mixed with each other. Because of the precipitation in the blood, the situation may even cause deaths.

Another important finding from the analysis is that Bethy explained the importance of blood donation for society by saying; "*It is important for solidarity and social awareness since it can save someone's life...Also, we should be careful about blood donation. For example, if we have Hepatitis, we should be aware that it is an obstacle to donate blood. We should warn doctors about our illness.* In addition, Bethy was asked about the institutions and the organizations dealing with blood donation, she mentioned that Red Crescent and hospitals provide blood donation to the people in need.

Apart from these, when her ideas about the adaptations that occur in the circulatory system was questioned, she stated that she does not know much about any evolutionary process of the circulatory system. She put forward only an idea about the blood groups.

So far, since she did not mention the types of circulation in her answers, she was also requested to explain these. She stated that *there were systemic and pulmonary* *circulation.* As a follow up question, the difference between systemic and pulmonary circulation was asked to Bethy.

> Bethy: First of all, the purpose of these circulations are different. The purpose of the systemic circulation is to transport oxygen and nutrients while the purpose of the pulmonary circulation is to enrich blood with oxygen coming from the lungs.

After she explained the difference between systemic and pulmonary circulation, she was requested to draw these circulation models (see Figure 4.22). She argued that she could only show these circulation type on a drawing of a heart (Figure 4.21). Bethy's explanation given below shows that she is aware of the types of circulations and their functions.

> Bethy: I want to explain them by using a heart. I can say that the blood is pumped by left ventricle. The blood is transmitted to the body by aorta. The blood reaches to right atrium by inferior and superior vena cava; and this indicates systemic circulation. I may have missed something, but I teach circulations through drawings in the classroom. During pulmonary circulation when the right atrium contracts, the blood is transported to the right ventricle. Then, the blood reaches to the lungs from the right ventricle by pulmonary artery and the blood becomes enriched with oxygen. Then, the blood reaches to the left atrium with the help of the pulmonary vein.

As it can be clearly seen, she represented the systemic and pulmonary circulation pathways (see Figure 4.22). Moreover, when she was asked about the relationship between systemic and pulmonary circulation, she stated that *the oxygen-poor blood, which is a result of systemic circulation becomes oxygen-rich as a result of the pulmonary circulation.*

In the next section, Bethy's responses about the health of the circulatory system is presented.

Pulmonary Circulation

Right Ventricle → Pulmonary Artery → Lung → Pulmonary Vein → Left Atrium

Systemic Circulation

Left Ventricle → Aorta → Whole Body → Superior & Inferior Vena Cava → Right Atrium

Figure 4.22 Pulmonary and Systemic Circulation Drawing

4.2.3.1.2.2 The Health of the Circulatory System

In this sub-title, Bethy's knowledge about the health of the circulatory system is given. Bethy was asked about the circulatory system diseases, the relationship among the diseases, and our responsibilities to keep the circulatory system healthy. Bethy mentioned hypertension, atherosclerosis, heart attack as examples of the circulatory system diseases. Furthermore, she pointed out that there was a relationship between heart attack and atherosclerosis.

> Bethy: I know that nutrition is related in order not to deteriorate the structure of the veins. Exercises, walking are important for the health of the circulatory system. What else… In short, nutrition and sports are important to protect heart health… There may be atherosclerosis, heart attack, high blood pressure, problems with heart valves. There may be problems with contraction and relaxation of the heart, cardiac dysrhythmia. There are some diseases in which the heart cannot do its function, but I do not know their specific names. Is there a relationship between diseases? … That is, one illness can trigger another one. The deterioration and failure of one of the organs may cause a new problem in our body. But there is a relationship especially between atherosclerosis and heart attack, of course, when the vein is occluded, the rhythm of the heart changes, the blood pumped by the heart changes.

In brief, according to Bethy's interview responses, she seemed aware of the organs that constitute the circulatory system, the general functions of the circulatory system, types of circulation, and circulatory system diseases.

Next, the classroom observation data in comparison with Bethy's interview analysis were presented.

Classroom Observations Findings

Similarly, the data obtained during the classroom observations show that Bethy addressed the function of the circulatory system, the types of circulation; namely systemic and pulmonary circulation, the importance of using terms such as oxygenated and deoxygenated blood during her lectures. She also mentioned the relationship between the circulatory system and other human body systems such as digestive system, respiratory system, urinary system, and endocrine system. Similarly, she included the health of the circulatory system (i.e., angiography, atherosclerosis, heart attack) during her classes.

At the beginning of the circulatory system topic, Bethy initiated question-answer session and asked students what the purpose of circulatory system was. Then, she started relating the circulatory system to other human body systems.

> Bethy: What happens to the building blocks of the nutrients in digestive system?
>
> Student: They [the building blocks of the nutrients] enter into the bloodstream.
>
> Bethy: Nice. What will happen to this blood?
>
> Student: It [blood] will circulate in our body.
>
> Bethy: Yes. Blood will circulate in our body and reach to cells. What provides this circulation?
>
> Student: Blood.
>
> Bethy: Can blood be pumped without a heart? Thus, the answer should be the circulatory system. The circulatory system makes sure that blood can be distributed to the relevant parts in our body… We take oxygen, and that oxygen needs to reach to our cells with the help of the circulatory system. You will also learn the respiratory system after this subject finishes. How does oxygen reach to the cells in the respiratory system? How is the carbon

dioxide in the cells expelled?... You will understand these much better when you consider circulation and respiration together.

Bethy explained the purposes of the circulatory system through additional slides in her classes.

Then, she addressed to the chambers of heart before showing heart dissection. She taught students to draw a heart by stating; "*You cannot learn the working principles of the heart without using a heart figure"* (Figure 4.23). While Bethy was presenting the heart dissection, she showed the coronary vessels, the connection between atrium and ventricle in addition to the main parts of the heart given in the science curriculum. She asked various questions gradually such as the following: "*What happens when the left atrium contracts?", "What happens when the right ventricle relaxes?".* Bethy drew a heart in the classroom in a similar way to her interview.

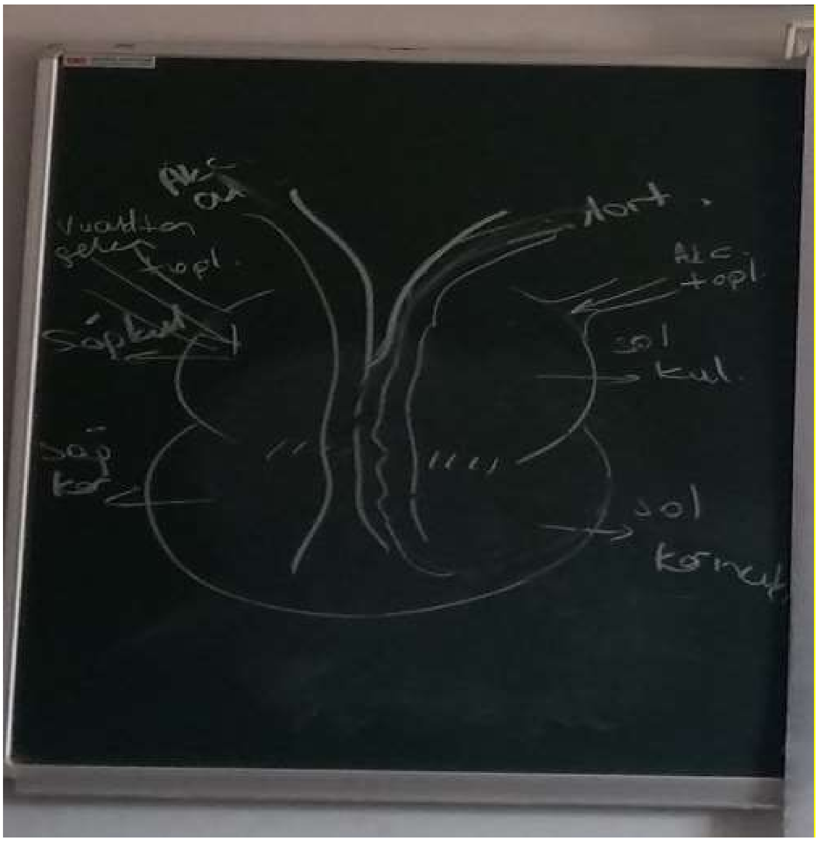

Figure 4.23 Bethy's Drawing of a Heart

She also addressed the pulse and blood pressure while explaining relaxation and contraction of the heart similar to her interview. In addition, Bethy also explained angiography and atherosclerosis during the classes.

In addition, Bethy used a metaphor to indicate the specialization of the vessels.

> Bethy: You should not imagine vessels as a radiator pipe. Radiator pipe have beginning and ending points unlike vessels. Vessels do not have beginning and ending points. Vessels are specialized according to their structure and functions.

Also, she explained that clean and dirty blood are inappropriate terms to use just like she stated them in her interview process.

> Student: Why do books present vessels in blue or red colors?
>
> Bethy: It is a nice question. Coloring vessels as blue and red is a symbolic representation. Please pay attention. Clean blood and dirty blood are incorrect terms. What does it mean if something in our body is clean or dirty? We will use the words oxygenated and deoxygenated blood. All the arteries except for the pulmonary artery carry oxygen-rich blood, and all the veins except for the pulmonary vein carry oxygen-poor blood. For this reason, oxygenated blood is shown in red, while deoxygenated blood is shown in blue colors.

Summary of Bethy's Finding about The Circulatory System

Considering Bethy's statements in her teaching and during the interview, she appears to be knowledgeable enough about the circulatory system based on the objectives given in science curriculum. Although name of chambers of heart are given as limitation in middle science curriculum, she taught name of chambers (i.e., left atrium, right ventricle) in classroom. She addressed the types of circulation, the purposes of the circulatory system, the circulatory system organs, the relationship between these organs, the health of the circulatory system, and again the relationship between the circulatory system and other human body systems. She does not seem aware of the adaptation process of the circulatory system in a detailed way. Therefore, in general, it can be said that Bethy is knowledgeable about the circulatory system.

Bethy highlighted the importance of the circulatory system for all human body systems to work in the best way possible. She addressed relationship between the circulatory system and other human body systems such as digestive system, respiratory system, urinary system, and endocrine system. Therefore, following section present her knowledge on that respiratory system.

4.2.3.1.3 Bethy's Knowledge of the Respiratory System

Bethy's knowledge of the respiratory system is presented below with interview questions including concept maps, drawings, word association tests, and classroom observations. Interview data and the classroom observation findings are presented in a respective manner in the following sections and summarized Table 4.47.

Bethy's knowledge regarding the respiratory system during interview is examined into two titles which are Understanding of the Respiratory System, and Its Components, The Health of The Respiratory System.

4.2.3.1.3.1 Understanding of the Respiratory System and Its Components

This part includes the related data findings about Bethy's understanding of the function of the respiratory system, organs and structures that constitute the respiratory system. She explained that the respiratory system was necessary to produce energy by combusting and expelling carbon dioxide from our body with the help of the gas exchange. Furthermore, Bethy's answers showed that she was aware of the fact that the respiratory system consists of nose, larynx, pharynx, trachea, lungs, bronchus, bronchioles, alveoli. In addition to this she addressed diaphragm has a role through breathing. She was also able to identify the difference between breathing and respiration. To identify Bethy's understanding of the respiratory system, Bethy was requested to explain the terms respiration, gas exchange, and the respiratory system.

At first, Bethy was asked about the term *respiration*. She began by explaining the difference between the *cellular respiration and breathing*.

Table 4.47 Bethy's Knowledge of the Respiratory System

Respiration	− A process by which nutrients are combusted to produce oxygen in our cells
Breathing	− A process which includes inhaling oxygen and exhaling carbon dioxide
The Role of the Respiratory System	− expel carbon dioxide from the body − ensure that blood was enriched with oxygen and to provide energy production in our cells
The Respiratory System Components	− Nose − Trachea − Larynx − Pharynx − Lungs
The Health of The Respiratory System	*Disorders* − COPD − Bronchitis − Lung cancer − Bronchiolitis − Allergic ailments *Conditions for healthy respiratory system* − avoid very dusty and dirty environments − support our immune system − avoid smoking

Researcher: You have already mentioned the respiratory system when you talked about the digestive and the circulatory system. Therefore, now we will talk about the respiratory system. So, what does respiration mean to you?

> Bethy: Okay, first of all there is a term that is called cellular respiration. Cellular respiration is a process by which nutrients are combusted to produce oxygen in our cells. Cellular respiration is different from breathing. Breathing is a process which includes inhaling oxygen and exhaling carbon dioxide.

Then, as a follow up question, the changes that happen in our body while breathing was asked to Bethy.

> Bethy: Okay, I will try to explain breathing mechanism. When we inhale and exhale, there is gas exchange in the alveoli. However, I do not know whether blood flow becomes faster or not.
>
> Researcher: You can mention something like expanding if you like.
>
> Bethy: Well, the reason why we breathe is the expansion in the volume of lungs. The flattening of the diaphragm causes decrease in the pressure inside (our lungs expand). As the volume increases in our lungs, we take oxygen from the outside. There is such a relationship. On the contrary, when the diaphragm relaxes, the pressure inside the lungs increases because the volume in the lungs decreases, and this time we give out carbon dioxide gas.

After she mentioned the difference between breathing and cellular respiration, she was requested to explain her understanding of the respiratory system. Her response is given below:

> The respiratory system consists of organs that is responsible for producing the oxygen in our cells. For example, these organs are nose, trachea, larynx, and pharynx. Well, we can also add lungs that include bronchus and bronchioles. What else... There are alveoli at the branch of the lungs. Alveoli can be thought as air sacs. I did this (Figure 4.24) drawing in the classroom.

When she was asked the question of what the function of the respiratory system was, Bethy stated that *the function of the respiratory system was to expel carbon dioxide from the body, to ensure that blood was enriched with oxygen and to provide energy production in our cells.*

After Bethy explained the respiratory system and listed the organs that make up the respiratory system, she was requested to write 12 words about the respiratory system. These words, which are similar to her previous response, are presented below in the Table 4.48.

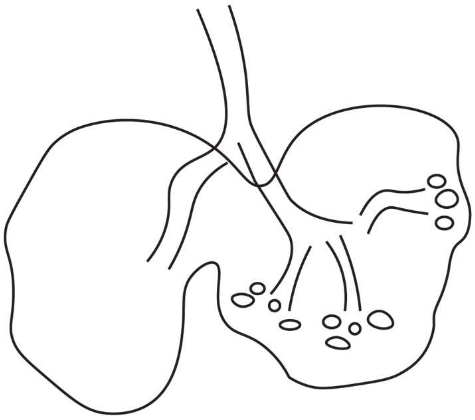

Figure 4.24 Bethy's Drawing of Lung

As presented in the Table 4.48, the words that Bethy provided were grouped in four categories. These categories included *organ* (i.e., diaphragm, nose), *structure* (i.e., bronchioles, bronchus), *molecule* (i.e., oxygen, carbon dioxide), and *process* (i.e., energy production, gas exchange).

She explained the relationship between the words she came up with as follows:

> Bethy: First of all, the air enters into the body, and it is healthier to breathe through a nose instead of a mouth since the nose has the functions of warming, moistening, and filtering the air taken. Then, there are also passages that air passes through. Air reach lungs after reaching trachea. When air reaches lungs there is a pathway that is followed from bronchi and bronchiole, and later to alveoli. There is oxygen and carbon dioxide exchange in alveoli. The purpose of this system [the respiratory system] is to produce energy by combusting oxygen and expelling carbon dioxide from our body with the help of the gas exchange. Of course, there are some events in diaphragm that also supports breathing.

Table 4.48 Bethy's WAT about Respiratory System

Groups of concepts	Corresponding Concepts
Organ	Lungs Trachea Diaphragm Nose Pharynx Larynx
Structure	Alveolus Bronchus Bronchioles
Molecule	Oxygen Carbon dioxide
Process	Energy production Gas exchange

As it can be seen above, Bethy correctly mentioned the role of nose and trachea during breathing and explained the gas exchange process in alveoli by mentioning the organs that constitute the respiratory system.

To better grasp Bethy's understanding of the respiratory system, she was requested to draw the respiratory system in humans. She presented organs like a flow chart by showing flow of air. Her drawing was shown in Figure 4.25.

When it comes to her explanations through drawing, she mentioned the role of pharynx and larynx by saying;

> Pharynx is a passageway, and it has no function. Only valves are closed… It should be closed when we inhale so that air moves to larynx. There are vocal cords in larynx. The air movement in larynx supports us to create voice. Vocal cords vibrates when we exhaled because we cannot talk while inhaling. Trachea divided into bronchi and each bronchi branches into bronchioles. And there are alveoli at the end of bronchioles. All of them (bronchi, bronchioles, and alveoli) are located into lungs.

Up to now, Bethy mentioned the function of nose, larynx, and pharynx. Thus, Bethy was requested to draw a concept map to reveal her understanding among organs (Figure 4.25).

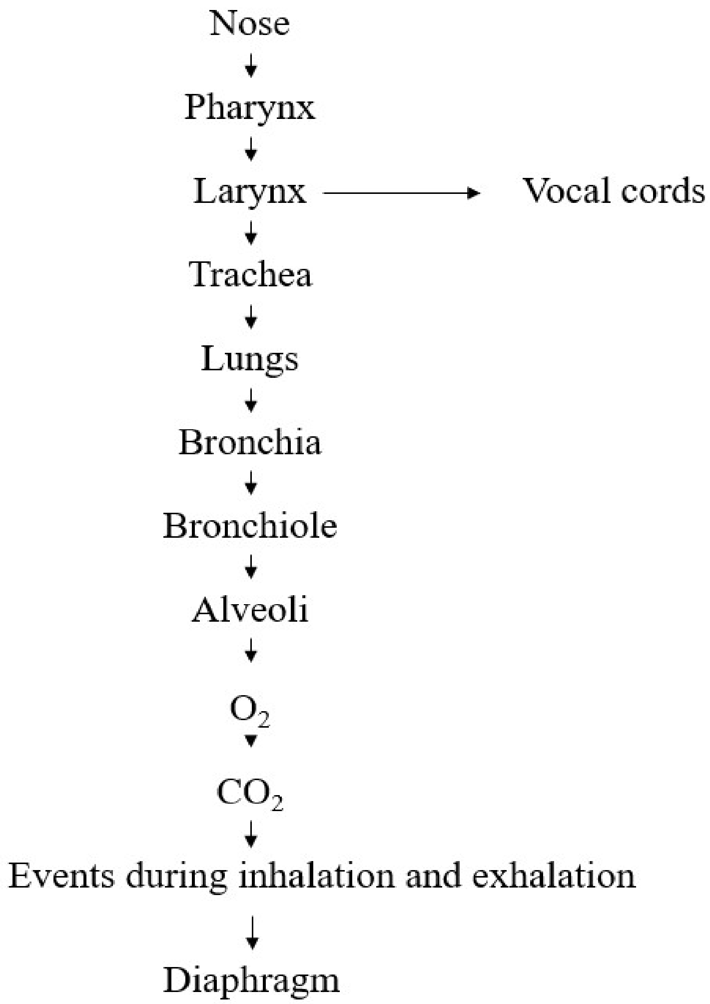

Figure 4.25 Bethy’s Drawing of Respiratory System

Furthermore, Bethy was expected to refer back to the role of trachea and diaphragm. For this reason, she was requested explain the functions of organs and structures that constitute the respiratory system. In addition to the responses [the role of nose, larynx, and pharynx] given above, she stated, “*There is a secretion called mucus on the inner surface of the trachea, and this secretion holds the dust there…I do not* *know any special function of the bronchiole. Alveoli increases the surface area and increases the capacity of gas exchange.*"

When the relationship among these organs [nose, larynx, pharynx, trachea, lungs…] were asked to Bethy, she implicitly referred organization in human body.

> Bethy: As I said before, the nose has to do its function so that the air passing through the trachea is cleaner and moist. In other words, organs need each other to perform their functions in a healthier way.
>
> Researcher: What about diaphragm? You mentioned it while you were creating your wordlist?
>
> Bethy: Diaphragm is a strong muscle. I mean, the movement of the diaphragm such as expanding or contracting, changes the volume of the lungs and it helps breathing.

In addition to these, her ideas about the adaptations that occur in the respiratory system was asked and she stated that she does not know much about any evolutionary process of the respiratory system.

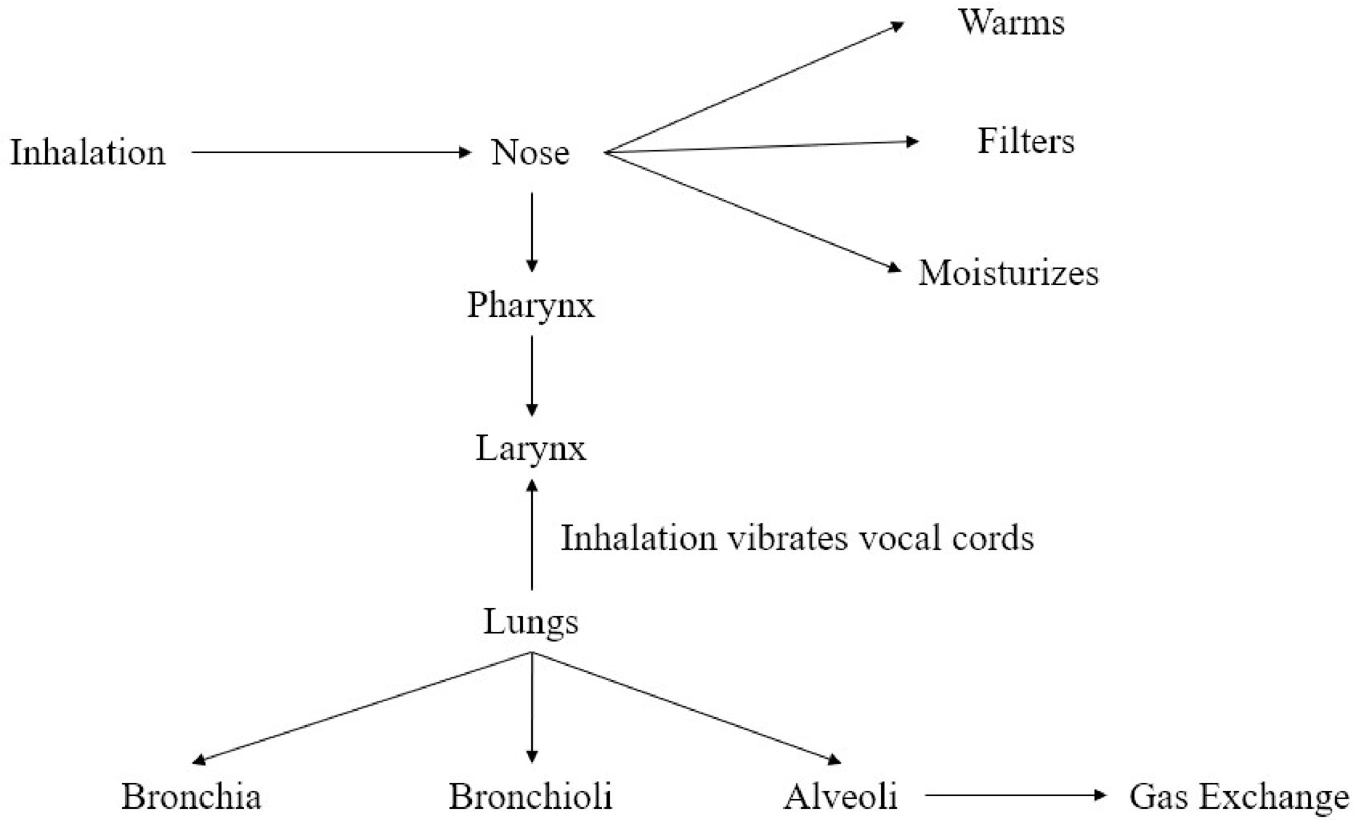

Figure 4.26 Bethy's Concept Map of the Respiratory System

In short, Bethy's explanations related to all the above-mentioned processes (i.e., gas exchange) and components of the respiratory system are compatible with the scientific explanations. However, she does not have any ideas about the adaptation of respiratory system.

4.2.3.1.3.2 The Health of The Respiratory System

To identify Bethy's understanding of the health of the respiratory system, she was requested to explain our responsibilities to keep the respiratory system healthy, respiratory system diseases, the institutions related with the respiratory system, and the relationship between the respiratory system diseases. She exemplified Chronic Obstructive Pulmonary Disease (COPD), bronchitis, lung cancer, bronchiolitis, and allergic ailments as respiratory system diseases. Besides, she mentioned the importance of clean air, nutrition, and avoidance of smoking.

> Bethy: It is important that the air of our environment should be clean. I think it is also important that we should avoid very dusty and dirty environments since there are many things that are transmitted by air which may affect us negatively and cause respiratory system diseases. Allergy is one of the diseases of the respiratory system and being in dirty and dusty environments causes allergic reactions. What else…Of course, people should not smoke, and we should avoid being a passive smoker. In fact, I think it is important to support our immune system. That is, our nutrition is important. When our immune system is weak, our body may still develop some diseases…I am not sure whether Green Crescent is directly related or not, but it is the first organization that comes to my mind as it is fighting with addictions such as smoking and drinking alcohol. I cannot remember if there are other institutions…COPD ... If you are caught to this disease, you have to live connected to a machine in the later stages of your life because breathing becomes very problematic for you. There is bronchitis which our kids generally experience, lung cancer, bronchiolitis, and allergic ailments related

> to the respiratory system. I am not sure about that whether tuberculosis is respiratory system disease or not because it directly affects our lungs and causes us to cough… So, for example, smoking can cause 90% chance of COPD. Apart from that, smoking can cause lung cancer. As I said before, a damage on the functions of one organ also affects other organs as well. For example, the degradation of alveoli structure affects gas exchange. I wonder if cancer damages the structure of alveoli. I do not know these in so many details. I think there is a relationship between diseases, but I cannot understand what kind of a relationship it is.

Bethy's classroom observation notes were represented in in the next section.

Classroom Observation Findings

Bethy addressed all the objectives given in curriculum in a more comprehensive manner. She taught the functions of the respiratory system, the organs and the structures that make up the respiratory system (i.e., nose, lungs, trachea) with their function, and the process of breathing in a similar way to her interview responses.

She started explaining the respiratory system by asking; "*What does respiration mean to you?*" to her students. Students remembered the respiratory system model they did in 4th grade. Bethy drew a basic respiratory system model that includes trachea, lungs, and diaphragm to help students remind this model. Then, she asked more questions such as "*What do balloons represent in this model?", and "How does air enter the body?"*. After such questions, she started explaining the organs and the structures that make up the respiratory system. Furthermore, Bethy implicitly addressed the relationship between the respiratory system and the nervous system by saying that respiration is a process which is controlled from the spinal bulb.

Bethy mentioned the importance of inhaling from nose instead of mouth because it can warm, moisten, and filter the air just like she mentioned it in the interview.

Moreover, she explained the diffusion process as a prior knowledge in order to ease the explanation of gas exchange in alveoli.

> Bethy: Gas molecules tend to move from an area of high concentration to an area of low concentration. Thus, oxygen tends to move through capillaries where oxygen concentration is low, and carbon dioxide tends to move through alveoli where carbon dioxide concentration is low.

In addition, she referred to pulmonary circulation to create a connection between the respiratory system and the circulatory system. Thus, she reminded the students of the purpose of pulmonary circulation.

> Bethy: …The enrichment of blood with oxygen during the pulmonary circulation is provided through the gas exchange in the alveoli.

Also, while she was explaining the breathing process, she mentioned the relationship of volume and pressure in addition to responses in interview.

> Bethy: … Assume that you are gas molecules in this classroom. If I increase the volume of the classroom, can I get more people in? Well, do we have to remove a few students from the classroom if the volume decreases? It is similar to lungs. When diaphragm is contracted, the volume inside increases. When the same volume increases, more oxygenated air can enter into the lungs. During that time, as the volume increases, the pressure of the air inside the lungs decreases. What do you understand from the term, pressure?
>
> Student: I think of pressure more like a compression of air when inflating a balloon.
>
> Bethy: Nice. What happens when the volume increases?
>
> Students: It [pressure inside balloon] decreases.
>
> Bethy: The compression of balloon means that the pressure inside decreases. Imagine again that you are the gas molecule in the classroom. When you move, you can hit each other, and you can also hit the wall. All of them these procedures express the concept of pressure. Assume that the classroom gets bigger. Will the number of collisions decrease? The decrease in the number

of collisions means that there is a decrease in the pressure. Just like this example, as the volume decreases, the pressure decreases as well, and more oxygen enters the body.

Summary of Bethy's Finding about The Respiratory System

In summary, the data gathered through the interviews and the classroom observations reveal that Bethy seems knowledgeable enough about the respiratory system. She knows the terms respiration and breathing, the purpose of the respiratory system, the respiratory system organs and relationship between these organs, the health of the respiratory system and the relationship between the respiratory system and other human body systems. However, it is also obvious that she lacked the necessary information about the adaptions occurring in the respiratory systems.

Bethy addressed the importance of the relationship between human body systems for all human body systems to work properly, therefore the next section provides Bethy' knowledge of the urinary system and its relationship with other human body systems.

4.2.3.1.4 Bethy's Knowledge of the Urinary System

Bethy's knowledge of the urinary system is presented with interview questions including concept maps, drawings, word association tests, and classroom observations. This section presents the interview data and the classroom observation findings in a respective manner and summarized in the Table 4.49.

To elaborate on Bethy's knowledge of the urinary system during the interview, her responses were examined in two different subtitles. These subtitles are as follows: *Understanding the Urinary System and Its Components, The Health of the Urinary System.*

Table 4.49 Summary of Bethy's Knowledge of the Urinary System

Excretion	− A disposal process of the waste materials in our body through filtering with the help of kidneys
The Role of the Urinary System	− To carry out the excretion process
The Urinary System Components	− Kidneys − Ureter − Urethra − Urinary bladder
The Health of The Urinary System	*Disorders* − Nephritis − Kidney inflammation − Kidney failure − Kidney stones − Cystitis *Conditions for healthy urinary system* − drink plenty of water − avoid alcohol and smoking − Not to keep the urine in our body for a long time − avoid spicy foods

4.2.3.1.4.1 Understanding the Urinary System and Its Components

Bethy's knowledge of definition of the excretion, urine formation and the role of the urinary system is presented under this title. She described the excretion as a disposal process of the waste materials in our body through filtering with the help of kidneys. She knew that the urinary system consists of kidney, ureter, urethra, and urinary bladder and she was able to explain the functions of these organs. Bethy appeared to be knowledgeable enough about what urine includes, and how urine is formed.

First, Bethy was requested to explain the excretion. As a follow up question, she also was asked to describe how excretion happens.

> Bethy: Excretion is a disposal process of waste materials in our body by filtering with the help of kidneys…How does excretion happen… There is a urinary system and other systems that help excretion to occur. First, the blood reaches kidneys with the help of the organs that constitute the urinary system. The blood is filtered in kidneys with the help of nephrons. Then, the filtrate is gathered, and it reaches to the urinary bladder with the help of ureter. The last stop for this process is urethra. In summary, excretion takes places through blood filtering.

After this explanation, she was asked to explain the urinary system and its functions. Bethy mentioned the organs and the structures that constitute urinary system. She also addressed the removal of the wastes from the body through excretion.

> Bethy: Urinary system is a system that does the excretion with the help of the organs and structures that constitute it. It [urinary system] consists of kidney, ureter, urethra, and urinary bladder. Also, it [urinary system] includes renal artery and renal vein since it is required to carry the blood in some ways throughout the circulation system…The function of the urinary system is to carry out the excretion process step by step. Each organ and structure have a role to play in order to complete the excretion… Waste materials have to be removed from our body somehow, and ultimately, in order for our cells to be enriched with oxygen and for our organs to be fed, we need blood which is rich in terms of nutrients and oxygen. However, here, the waste materials released during digestion or respiration processes must be removed. Therefore, excretion is quite needed for our bodily functions.

Then, Bethy was requested to list 12 words that comes to her mind. As presented in the Table 4.50 below, these words were grouped under four different categories. These categories included *organ* (i.e., kidney, urinary bladder)*, structure* (i.e., nephron, renal cortex)*, molecule* (i.e., urine)*,* and *tissue* (i.e., blood, renal artery).

As a follow up question, the relationship between the aforementioned words was asked to her. Anna explained the relationship among the words by explaining urine formation as follows:

> Bethy: First of all, blood comes to the kidney through the renal artery. The renal artery carries waste-rich blood and at the same time carries oxygenated blood because both the cells there need to be fed and these waste materials must be filtered in the nephrons through the arteries. Therefore, the blood comes to the kidney with the help of the renal artery, and then it is filtered in the nephrons. We call this filtrate urine. Of course, during this process, the necessary substances for our body can escape from their original places. That is why, these substances are reabsorbed into water, and they are back into the bloodstream with the renal vein and, they eventually return to the heart. Meanwhile, the urine formed as a result of dissolution is collected in the renal pelvis. After the urine is collected in the renal pelvis, it is thrown into the urinary bladder with the help of the ureter and out of the body from the urinary bladder with the help of the urethra. There is such a relationship between the aforementioned words.

As it can be seen, she addressed three processes which are filtration, reabsorption and excretion process occur in nephron by omitting secretion process. In fact, urine is the result of filtration, reabsorption, and secretion.

Then, it was requested for Bethy to draw a concept map (see Figure 4.27) related to the urinary system to see how much she relates concepts.

Bethy correctly addressed all the organs and the structures that constituted the urinary system while she was constructing her concept map. In addition to this, she also mentioned the heart to indicate that blood, which is filtrated by nephrons, reach back to it with the help of renal vein. She also mentioned reabsorption. She used some linking words and arrows to express the relationship among structures and organs.

Table 4.50 Bethy's WAT about Urinary System

Groups of concepts	Corresponding Concepts
Organ	Kidney Urinary Bladder
Structure	Nephron Urethra Ureter Renal cortex Renal medulla
Tissue	Blood Renal artery Renal vein
Molecule	Urine
Other	Reabsorption Filtration Infiltration

Then, Bethy was requested to explain the urinary system through drawings (Figure 4.27). In addition to her concept map, she also addressed to the Malpighi pyramids. Her explanation about the role of organs is given as follows:

> Bethy: There are nephrons in the renal cortex and nephrons are involved in filtering blood. The Malpighi pyramids in the renal medulla are actually responsible for reabsorption. In reabsorption, there are probably capillary blood vessels which are in a condition like they are spread to the tissue, and reabsorption occurs through those venous capillaries. However, I do not know any more details.

As a follow up question, the relationship among these organs was asked to her. She stated that there was a cooperation among these organs. She also added that these organs were responsible for completing the same functions.

Later, Bethy questioned about the additional organs that help the process of excretion in our body

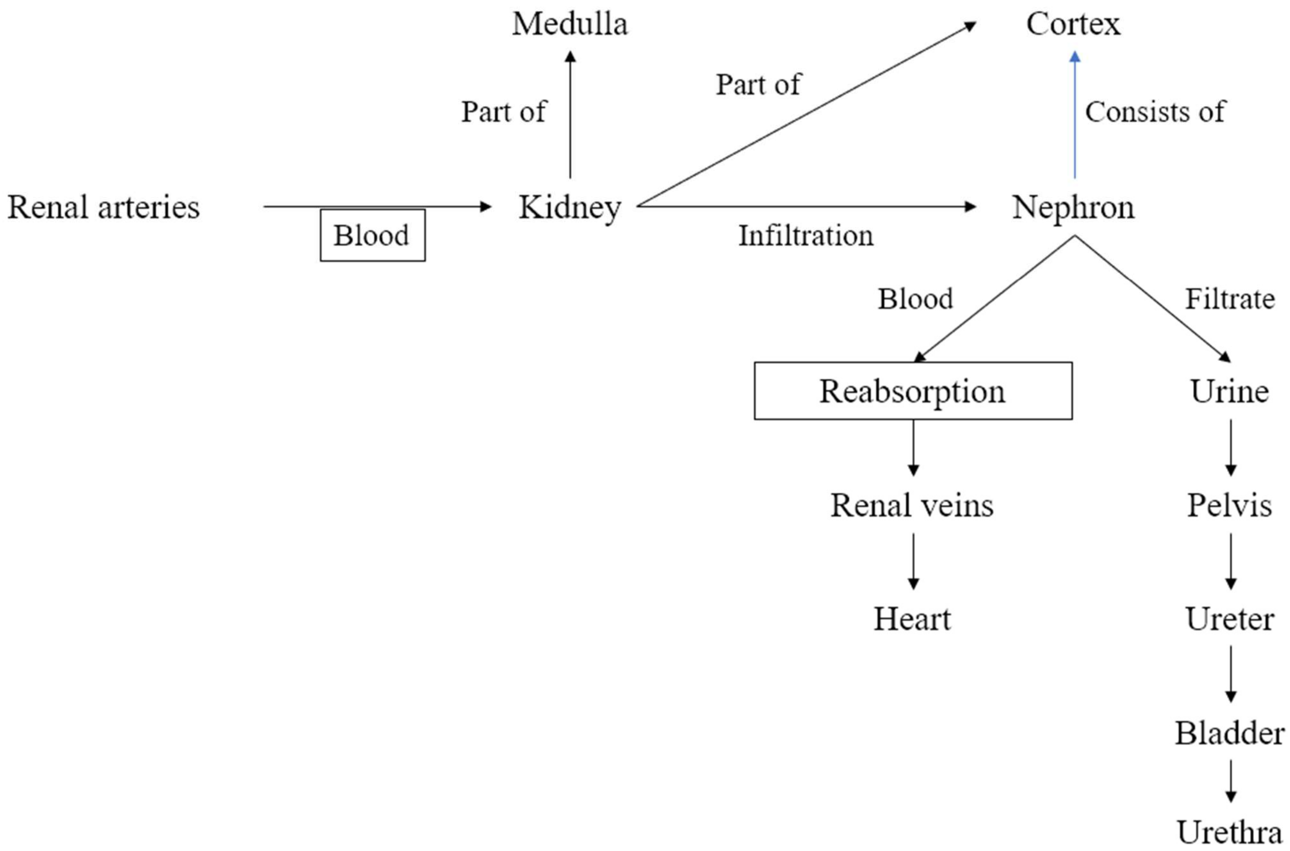

Figure 4.27 Bethy's Concept Map about Urinary System

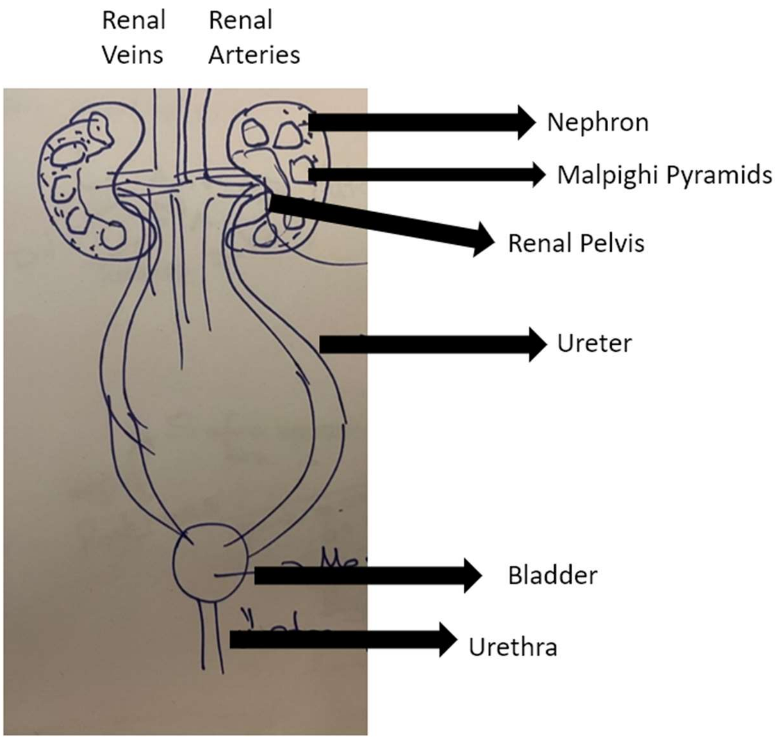

Figure 4.28 Bethy's Drawing of the Urinary System

Bethy: Let me tell you… These [lungs, liver, large intestine, skin] are the organs that remove the wastes from the body. Ultimately, the liver helps excretion, but the lungs directly remove the waste. The large intestine and skin directly remove waste, but the liver only converts ammonia, the digestive product of proteins, into less harmful substances which are urea and uric acid. There are lungs, of course. The lungs expel respiratory system wastes, namely carbon dioxide and water vapor. Also, there is the liver, hmmm… What was the liver doing? [pause]. The liver converts ammonia, which is result of the digestion of proteins, first to urea, and then into uric acid. Also, the large intestine throws away the wastes of the digestive system. There is also our skin. Our skin removes the excessive salt and water through

> sweating. These [lungs, liver, large intestine, skin] are the organs that help the excretion in our body.

Moreover, she was asked to explain the structure of the kidneys since she has already mentioned nephrons.

> Bethy: Actually, I do not know many details. I just know that there are parts of the kidney with different functions. The renal cortex is a part that has millions of nephrons. The renal medulla has Malpighi pyramids, which are responsible for reabsorption. The renal pelvis is a part where the urine is collected…I can also talk about the content of the urine. Urine consists 90% of water. Other than that, there are salt, urea, and uric acid in the formation of urine. These should be expelled from water with the help of excretion mechanism.

Then she was requested to express the term “waste”. Her explanation was as follows:

> Actually, wastes are substances that are formed as a result of bodily processes and usages. They do not have any duties in the body, and their presence may harm the body …The urine system considers the urine, carbon dioxide, urea, and uric acid as a waste.

In addition to these, the adaptations that occur in the urinary system was asked, but she stated that she is not familiar with evolutionary process of the urinary system.

4.2.3.1.4.2 The Health of the Urinary System

In this sub-title, her understanding about the health of the urinary system is analyzed. The interview questions were about our responsibilities to keep the urinary system healthy, the institutions dealing with the urinary system, the urinary system diseases, and the relationship between these urinary system diseases. She highlighted the importance of drinking water and consuming healthy nutrition.

Bethy: The first rule is drinking plenty of water. The second one is avoiding alcohol and smoking. Also, we should not keep the urine in our body for a long time and go to the toilet whenever we feel the need. I do not exactly now why, but it is also necessary to avoid spicy foods… Of course, there should be some institutions working in the field of the urinary system …Maybe, there are some institutions about nephrology or urology. However, I do not know the name of any such institutions…Some of the urinary system diseases are nephritis, kidney inflammation, kidney failure, kidney stones, and cystitis…. My son had nephritis when he was younger. There were stones in his kidneys, he was treated, so we went through such a process, we went through a very serious process… Of course, since I communicated with too many doctors, it made me know more than a normal teacher. Especially about protecting our health, what to do in such situations… Also giving an example, telling something you experience causes students to listen more and more carefully… I think that I could be more useful by attracting their attention.

Then, she was asked if there was any relationship among these [nephritis, kidney inflammation, kidney failure, kidney stones, cystitis] diseases.

Bethy: In other words, as in every system, I think that the failure of one organ to perform its function probably affects the functions of other organs and structures. For example, if the kidney stone blocks the urethra, problems may begin in the kidney because the urine is no longer produced. Naturally, all diseases actually cause the impair the functions of other organs, that is, the discomfort in one affects the other over time.

Classroom Observations Findings

Similarly, classroom observation field notes reveal that Bethy addressed all the objectives given in curriculum. Therefore, she referred to the function of the urinary system, the organs that urinary system consists of, the waste materials in our body as a result of metabolism (i.e., CO_2, feces), what urine includes, the role of liver, the parts of kidney, the nephrons, the health of the urinary system by mentioning dialysis, and the effects of kidney failure. She also taught students to demonstrate their kidneys on their body.

At beginning of the topic, Bethy stated that the students always think about the large intestine as a part of the urinary system similar to her interview.

> Bethy: We remove the digestive system waste with the help of the large intestine. The large intestine removes waste. But when I say the structure and organs of the urinary system, I do not want you to give the large intestine as an example ... While water and salt are disposed from the skin, the lungs also remove carbon dioxide ...

Moreover, she also mentioned the adrenal glands, which she did not address in her interview, with the help of kidney figure she used. She explained that adrenal glands were secrete hormones, and that she would teach them the functions of the hormones in a later stage. She also emphasized the vessels on the kidney figure.

> Bethy: Which veins do you think are the veins represented in blue and red?
>
> Student: Blue one is the deoxygenated blood… Red one is the oxygenated one.
>
> Bethy: How do urine, uric acid and salt come to the kidneys?
>
> Student: (with) Veins
>
> Bethy: They are transferred by blood. (She asks to the class that which veins carry these wastes to the kidneys) So, you mentioned deoxygenated blood... Renal vein carries blood that is rich in carbon dioxide. What substance is the renal artery rich in? Can I say that it is rich in waste and oxygen?

Furthermore, Bethy also addressed the relationship between the urinary system and the circulation in the human body by giving more information on vessels.

> Bethy: Since blood is pumped from the heart to the whole body through the aorta, it must somehow have connections with other organs in the body. The

blood enriched by carbon dioxide must return to the heart, that is, it must be connected to the superior and inferior vena cava and be returned to the circulation. Naturally, the blood rich in carbon dioxide should come to the heart with superior vena cava, but at the same time, the blood should reach the kidney with the renal artery through the aorta… All human body systems are interrelated and working in harmony…. The blood coming through the renal vein is rich in carbon dioxide, and the waste material decreases. Where will blood rich in carbon dioxide go? It will go to the heart and from there to the lungs to oxygenate... You are confused because it is called dirty blood.

Then, Bethy mentioned the health of urinary system. For example, she referred to dialysis, the effects of kidney failure, and the importance of drinking water.

> Bethy: If you do not drink enough water, your urine will be dark colored. You can understand if you are drinking enough water by the color of your urine. What should be the color of urine? It should be very light yellow. It is better if it is transparent. Drinking too much water is also harmful, of course, this time, minerals will be lost… why do we drink more water in the summer? We lose water with sweat. Or why do we feel the need to drink water after training? Because we are losing water… Headache, dark urine, weakness, dry mouth signal that your body needs water… Also, caffeinated beverages such as coffee change the filtering period of the kidneys because it increases blood pressure.

She also mentioned the urine formation and the substances that urine includes.

> Bethy: Urine includes urea, uric acid, water, CO_2, and water. However, there are substances that should not be present in the urine. Like blood test, urinalysis is used in the diagnosis of diseases. The amount of urea, uric acid in the urine is important. Sugar in the urine causes panic. It is a symptom of diabetes.

Although Bethy mentioned the role of nephrons, she did not give any details by taking the restrictions into consideration given in the curriculum (see Table 4.3). Moreover, she explained that although reabsorption is not included in the curriculum, she stated that reabsorption is important for the urinary system.

Summary of Bethy's Finding about The Urinary System

In brief, Bethy's classroom observations and interview findings are compatible with each other. She mentioned urinary system in a more detailed manner than the middle science curriculum proposed. For example, she addressed Malpighi pyramids, reabsorption process. She is aware of excretion, purpose of the urinary system, the urinary system organs and relationship between these organs, the health of the urinary system. Thus, Bethy seems knowledgeable enough about the urinary system.

Up to now, Bethy's SMK regarding each system reported separately. Since human body system as a as complex system, the extent to which Bethy understand human body system as a complex system was uncovered. The findings were reported in next title.

4.2.3.1.5 Bethy's Understanding of Human Body System as a Complex System

Bethy was asked to define the concept of system to capture her understanding. She indicated that for something to be considered as a system, there should be many parts included. She gave an example of bicycle as a system. She implicitly implied that there is interaction among the components that constitute a system.

> Bethy: So…It [system] has to be made up of parts. I think of the system as a whole and there should be many parts of it. I think I need those parts to create that system.
>
> Researcher: What is it that makes your example a system?

Bethy: Actually, it comes from my observations of the environment. Even a machine is a set of systems. When I think of the bicycle, the pedal, the chain, the place where I will hold it, the handlebar... If one of the parts is damaged, it affects the others, like a chain reaction. Naturally, the stomach, intestines, esophagus are a whole. They have a systematic work. If there is a disruption somewhere in that work, it affects all the others. Therefore, my observations in nature and in my own body are the reasons for why I came up with such a definition.

Then, the extent to which Bethy understand human body system as a complex system was revealed with additional questions. She indicated that there were organs which work cooperatively with specific functions to form the whole body.

Researcher: What do human body systems mean to you?

Bethy: I think, all the organs that come together to do a certain work can be defined as a system. But of course, when we lower the range and talk about sub-systems such as the muscular and skeletal system, the circulatory system, the respiratory system, the nervous system, the hormonal system… What else? Urinary system…As I have just said, all of these organs have various functions for a specific purpose… I think they are systems because they serve a specific purpose and form a whole.

Researcher: What is the relationship between these [the muscular and skeletal system, the circulatory system, the respiratory system, the nervous system, the hormonal system, urinary system] systems you just mentioned?

Bethy: There are many relationships…. Nothing happens without a circulatory system [for example] … The most important thing[system] is circulation… If there is not any nerve activity in the body, the orders will not be fulfilled, the hormones will not be secreted. Therefore, I consider all of them as a chain of events… Assume that I wake up in the morning, I go to the bathroom to wash my face… I first think about it with my brain, then, my muscular and skeletal system is working. I live and when I breathe, my circulatory system is working, my heart is beating, so all of them are linked together.

Bethy also addressed organization in human body by emphasizing interdependence of chain of events as she explained a system previously.

Researcher: How does human body work?

Bethy: I mean, in a certain order... Overly organized and how can I explain it? Should I say systematic or chained? That is interdependent, none [chain of events in our body] will be without the other. There is a mysterious order here.

Then, Bethy was requested to write 12 words that comes to her mind about the human body systems in order to elaborate on previous comments. These words were put in different categories. These categories included *tissue* (i.e., Blood, Arteries), *process* (i.e., Respiration, Circulation,), and *other* (i.e., Secretion). She did not mention any organs related to human body systems in her wordlist.

Table 4.51 Bethy's Concepts of Human Body System as shown in WAT

Groups of concepts	**Corresponding Concepts**
Tissue	Blood Arteries Veins
Process	Respiration Circulation Digestion Physical Digestion Chemical Digestion Absorption Removal of waste
Other	Secretion

As a follow up question, Bethy was asked to relate these words to each other in order to find out if she was able to create any kind of associations. She touched briefly on the function of circulatory, digestive, urinary, and respiratory systems in human body and the relationship between them. Bethy also mentioned importance of components that constitute a system to complete its function. For example, she addressed that blood and vessels are specialized for a different role, but both of them are crucial for circulatory system to fulfill its function. She implicitly addressed hierarchy in human body.

> Bethy: First of all, I cannot think of these systems independently. These are all structures that actually have a role in the functioning of the organism, and they all have a relationship with each other. The circulatory system does not function without blood. I mean, the circulation takes place with the help of the blood. There are arteries and veins in our body that allow blood to circulate. Each of them [arteries and veins] has a different role. One takes the blood and takes it from the heart to the body, while the other does the collection and takes it to the heart and lungs. Apart from that, what happens as a result of circulation? For example, the blood collected in the body needs to be enriched with oxygen somehow. There is a respiratory system that completes this [enriching blood with oxygen] task. Then, that blood circulates throughout our body, but at the same time, it feeds our cells, tissues, and organs. When it comes to the food and nutrition, these foods must somehow enter the bloodstream. It [food] requires physical and chemical digestion. It has to be absorbed in order to enter the bloodstream ... Then, during these [circulation, digestion] events in our body, many waste materials are created such as the digestive system wastes, or the urinary system wastes. They need to be removed from our body somehow. There are wastes that are also removed from our skin, removed through sweat. Urine is removed from our kidneys and carbon dioxide is removed from our lungs, there is such a relationship between all the systems.

During her instruction, she addressed hierarchical organization in human body. Her sample excerpts are given as follows:

> Cells work together to form us. But of course, cells come together to form the tissues, the tissues work together to form organs, and the organs do the same to form up the systems in our body such as the respiratory system, the nervous system, and the circulatory system. These systems, in the end, make up the organism. (*Classroom observation*)

In her interview, Bethy was also requested to draw a concept map of human body systems (see Figure 4.29). In addition to her wordlist, she mentioned nervous system, endocrine system, and muscular and skeletal system to represent the interaction among systems.

Her explanations that she made while she was creating her map is given as follows:

> Bethy: I think the circulatory system is something that covers all systems, I do not know how to show it ... Let me relate the circulatory system to the urinary system and the respiratory system. For example, if I put an arrow and think that nutrients enter the blood stream as a result of digestion. The respiratory system actually works together with the circulatory system. No system makes sense without a circulatory system. Likewise, the urinary system is important for the disposal of wastes of the circulatory system and urine. The respiratory system is important for removing carbon dioxide. Now, at the same time, I wonder if an arrow comes out of this digestive system to all systems. Because they are related to circulation, to all cells… The circulatory system has a relationship with the muscular and skeletal system. In addition, I want to add the nervous and hormonal system…Because there are cells that need to be fed, there are two-way arrows here.

It can be clearly seen that Bethy mostly expressed the relationship between the circulatory systems and the other systems. For this reason, she was asked about the relationship between the human body systems once more. She indicated that the circulatory system is crucial for all other human body systems to work properly. Bethy seemed aware that there was a relationship between the digestive system and the circulatory system as she indicated that the digested foods should be transported with circulation. Also, Bethy established a relationship between the digestive system and the muscular and skeletal system by mentioning the improvement of bones.

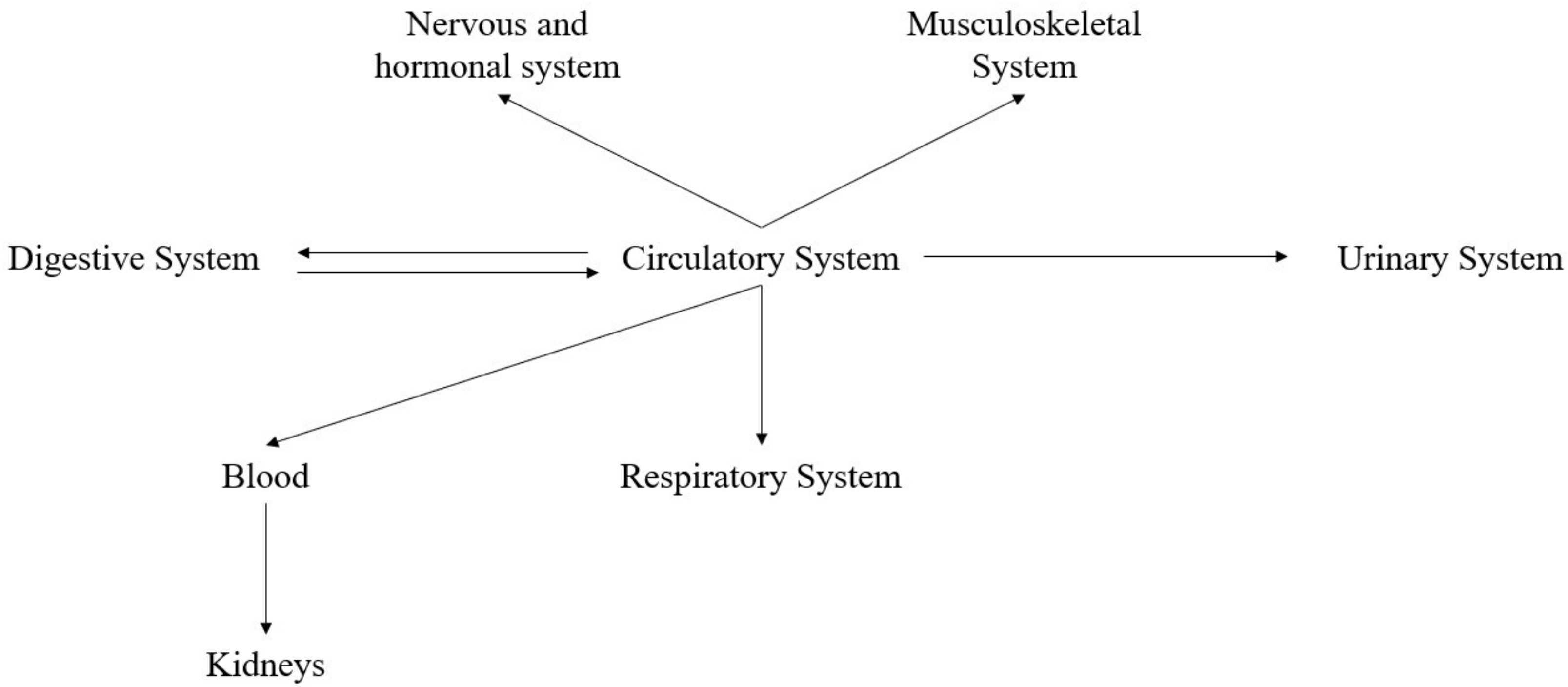

Figure 4.29 Bethy’s Concept Map Drawing of Human Body System

through a healthy diet. Moreover, she implicitly mentioned gas exchange and kidney. Her responses were provided as follows:

> Of course, there is a relationship between the digestive system and other human body systems. All cells need energy and nutrients. The transportation of the energy to the cells occurs when the digested food enters the bloodstream as a result of absorption. In other words, to feed the cells, the digested food must enter the bloodstream...However, to feed the bones…They [the digested foods] should be transported with circulation... The circulatory system is needed for the nourishment of the organs in all body systems and for the transportation of oxygen to the organs…The blood is more oxygenated at the end of the circulation…At that moment, there is gas exchange in the alveoli…Of course, our lungs take part in the process of enriching blood with oxygen. Our lungs have a role in the pulmonary circulation…For the nutrition of the kidney, and for the energy to be produced in the kidney, the blood must reach there with the help of digestion. I mean there is a relationship among all the human body systems…. For example, when we do sports, our breathing rate increases, or when we run, our need for oxygen increases. Maybe gas change becomes faster at this time… In my opinion, other human body systems (i.e., digestive system, urinary system) do not make sense without a circulatory system because all other body systems need the circulatory system to work properly. If circulation ends, the life ends.
>
> Researcher: What about skeletal and the movement system?
>
> Bethy: Yes, the skeletal and the movement system… We also have ribs and rib cage that protect our lungs. In the cavity of our chest, it acts like a protector of our lungs.

During the interview, Bethy was asked to explain dynamism, and homeostasis. She explicitly indicated the “chain reaction” among human body systems. However, she was not familiar with the term homeostasis.

Researcher: Are systems in our body dynamic?

Bethy: Of course, they are dynamic. I always think of them like a chain reaction and yes, they are dynamic because they affect each other. If there is a disruption somewhere in that process, it affects all of them as I said before…If a cancer that starts in the liver or pancreas affects the whole-body step by step, this is an indicator of this dynamism.

Researcher: What is homeostasis?

Bethy: Yes, there is such a thing… Let me think what it is… I think it was the loss of the function of the organ or the loss of the organ. As far as I heard from the news or the environment, but I did not really search it. I do not really know its meaning.

Although Betty was not familiar with the term "homeostasis", she was able to mention many terms related to homeostatic mechanisms in the human body. During the interview, she mentioned that one of the functions of the circulatory system was to regulate the human body temperature, which can be considered as an example of thermoregulation process, as far as urinary system is considered, she failed to realize system's function in the osmoregulation process, even though she was knowledgeable enough about the urinary system.

In short, she seems aware that human body system is a complex system by mentioning integrity and relationships among organ systems. She aware of the hierarchical organization in human body.

4.2.3.2 Bethy's Syntactic Knowledge

In this section Bethy's syntactic knowledge is presented. VNOS-C questionnaire was used to elucidate her knowledge of the nature of science in the context of human body systems.

First of all, Bethy was asked the following questions to reveal her understanding of the concept of science.

> Researcher: What, in your view, is science and what makes science (or a scientific discipline such as physics, biology, etc.) different from other disciplines of inquiry (e.g., religion, philosophy?
>
> Bethy: Hmm …. It [what science mean] is a tough question…How can I tell you? [At the moment] I cannot really put my thoughts into my words … In my opinion, science requires investigation, data collection … Should I say a 'method'? No, I do not say 'method'. I mean, science is a process ...actually science is the steps of a learning process with evidence… it [science] seems more like a process that involve experimental proofs for me…I mean, actually…while biology, physics, chemistry are based more on proof, evidence and experiment…religion and philosophy are based mostly on philosophical opinion [than science] … but I am hesitant on whether it means that they [religious and philosophy] are not science? I think that our field [science] is more experimental and requires proof [compared to religious and philosophy].

Then, the questions; "*What is an experiment?", and "Does the development of scientific knowledge require experiments?*' were asked to Bethy to in order to get a deeper understanding of her stance.

> Bethy: Experiment is a study to prove a hypothesis. I mean, it [experiment] is a study to test a hypothesis…Thus, it [experiment] is necessary to test whether a scientific knowledge is correct or not… to convince the audience, it is important for you to have proved and test knowledge. It [scientific knowledge which is tested by experiment] is more persuasive, more convincing, and more realistic…

These responses clearly reflect Bethy's understanding of empirical NOS. In particular, she thought that science is a process that includes investigation, data collection, experiment, and experimental proof. She asserted that experiment is important to persuade the target audience. However, it is important to say that experiment not only proves a hypothesis, but it may also disprove it. Bethy indicated that science differs from philosophy and religion since it involves experimental proofs and evidence.

The following questions were asked to Bethy in order to figure out her understanding of tentative NOS.

> Researcher: After scientists have developed a scientific theory (e.g., atomic theory, evolution theory), does the theory ever change?
>
> Bethy: Of course, yes…scientific theory can change… For example, decades ago it was said that it was not possible to land on the Moon, but we have learned that it was possible… It clearly shows that scientific knowledge may change with the development of the technology and new research studies.
>
> Researcher: Well, can you give any example in the context of human body systems?
>
> Bethy: For example, the loss in the function of appendicitis… During the evolutionary process, appendicitis has lost its function, so it [appendicitis] is currently dysfunctional in our body…For example, appendicitis had a lot more functions back in the time where we relied more on plants as a food. So, I think it [the loss of function of appendicitis in the evolutionary process] might be an example [for changeability of scientific knowledge] ... What else? I am thinking about human body systems. …. The process of blood transfusion can also be an example. I mean the concepts of the universal recipient and the universal donor in blood groups are outdated. Scientists identified subgroups of the blood groups because there were health problems such as thrombosis and deaths due to these previous mistakes during the blood transfusion process, which were initially carried out according to the concepts of universal recipient (AB) and universal donor (0). Our blood

groups are categorized with the AB0 system. New antigens that are bound to erythrocytes have been detected and scientists have found sub-blood groups such as A1 and A2 in this system [AB0]. In short, conducting blood transfusions incorrectly used to cause many health problems. So, scientific knowledge can surely change…The phenomena which does not support the theory may cause these changes. After the telescope was developed, scientists reached plenty of data... For me, technology, equipment, accumulated knowledge, research and development [R&D], scientists' progress in their [scientists'] horizons and curiosities and asking more questions might cause a theory to change. There were not any research and development departments in the past, but now every institution etc. has such departments where studies are conducted constantly… For example, many theories have been put forward about the formation of the Earth or as one atomic theory was inadequate. Then, the next atomic theory was proposed. But over time, these [theories] were outdated, and the new ones [theories] were proposed... Their [theories] deficiencies were eliminated, the missing points were corrected, and eventually the theories were falsified. For example, there are theories that claimed the Earth was not round, …Theories about the formation of the Earth, …theories about the formation of the universe. Theories... As an experienced science teacher, I should be more knowledgeable, yet, I have just realized a deficiency of mine right now…

Researcher: If these theories are changing, why are we trying to teach them?

Bethy: [we trying to teach theories] because scientific studies have processes, and they [scientific studies] develop step by step. These [scientific studies] did not appear suddenly. In fact, scientific studies came out from scientists. For instance, the idea of an atom belongs to Democritus… If he [Democritus] had never used such a philosophical approach, there would be no more research conducted on atom models. Knowing this [developmental] process guides the students and teaches them to be patient and selfless…. It also helps them realize the importance of keep the records of what you are doing……when you teach a student the process of development of scientific knowledge, you actually teach them [students] the characteristics that scientists should have. In order to convince a student that development of the theories is all about these processes, they are required to think critically. Students need to compare old and new models in terms of their deficiencies, limitations…and let them think about what leads to the development of a new hypothesis…. I think that learning in a comparative manner is actually more effective...

Researcher: You mentioned the skills or the characteristics that scientists should have. What do you think these characteristics are?

Bethy: [Scientists should] Being patient most importantly, having a curiosity to record, being competent in scientific research methods and being a good observer. Determination is also important.

When asked if there was a difference between a scientific theory and a scientific law, she indicated her responses as follows:

Bethy: Well...that’s a good point... I know that the theory and the law are different... The theories are more changeable…. Laws have been proven and do not change. Laws are certain... Studies on theory can be continued and they [theories] may change… There is the multiple proportion law, law of constant proportions etc. Today, in many things [scientific knowledge] the application of these laws can be observed [multiple proportion law, the law of constant proportions]. For example, the formation of a compound, or chemical recombination rates are still proven by [application of] those laws [multiple proportions of law, and the law of constant proportion]. In addition, Newton’s laws of motion... I mean, many things can still be explained by using these laws.

These questions given above give clues about Bethy’s understanding of tentative NOS and empirical NOS. She stated that scientific knowledge develops over time with technology and research. Bethy emphasized the characteristics that scientists should have. These characteristics included patience, curiosity, competence, determination, and effective observational skills. In this way, she showed that she was aware of the important role of observation. She thought that it was important to explain the tentative nature of theories, developmental process of theories to the students in order to imitate how scientists works. She gives the loss of function of appendicitis in the evolutionary process and the discovery of sub-blood groups (A1, A2) as the examples of changes in the scientific knowledge. Her responses to the question of whether or not there was a difference between a scientific theory and a scientific law showed that Bethy was aware of the difference between scientific theory and scientific law. However, her explanation for this difference was insufficient. She emphasized that laws such as multiple proportion law, or the law of constant proportions were proven true while theories such as the formation of Earth may change. However, the assumptions which claim that the laws are always proven is inappropriate (Abd-El-Khalick & Lederman,2002). Bethy did not give any examples about the theories, or the laws regarding the human body systems. Although she did not directly say that there was a hierarchical relationship between theories and laws, she was not sure whether theories would turn to laws when they were proven. However, theories and laws are different, and one does not superior the other (Abd-El-Khalick, Lederman, Bell & Schwartz, 2000).

The following question was asked to Bethy to capture her understanding of inferential NOS and creative and imaginative NOS in developing scientific explanations.

> Researcher: Science textbooks often represent the atom as a central nucleus composed of protons (positively charged particles) and neutrons (neutral particles) with electrons (negatively charged particles) orbiting that nucleus. How certain are scientists about the structure of the atom?
>
> Bethy: So, let me say... For example, there are experimental studies on the existence of protons. I mean that there are experiments with cathode tubes

etc. In experimental studies, Dalton, for example, was the first scientist to prove the existence of atom & atomic particles in an experiment. In history [of science] there have been studies before Dalton's study, but they lacked the experimental proof. It is very important to have an experimental proof as Dalton did in the history of science. For example, there had been some experiments about the presence of the protons, neutrons and electrons. Millikan's oil drop experiment... They [Millikan and his colleagues] send hydrogen-alpha beam to the cathodes, … and they observe that the beam was scattering. For example, they [Millikan and his colleagues] saw that beams deviate to (+) [charged plate] and deviate to (-) [charged plate]. I think with these things [experiments], they [scientists] proved the existence of them [the atom and the particles such as proton, neutron, electron] in experimental studies. To summarize, the idea that the atom is spherical was put forward after all these scientific processes.

Bethy's responses and examples about the certainty of the scientists about the structure of the atoms represent her inferential and empirical NOS. She only mentioned the experiments that scientists conducted about the atoms. Moreover, she thought that experiments were used to proof scientific knowledge. She did not mention the role of human inference and creativity while developing scientific knowledge. Moreover, although she gives Millikan's Oil drop experiment as an example, she confused it with Rutherford Gold Foil experiment as she provided the details of it.

The following questions were also asked to Bethy in order to reveal her understanding of subjective NOS, inferential NOS, and socio-cultural NOS.

Researcher: It is believed that about 65 million years ago the dinosaurs became extinct. Of the hypotheses formulated by scientists to explain the extinction, two enjoy the widest support. The first, formulated by one group of scientists, suggest that a huge meteorite hit the earth 65 million years ago and led to a series of events that caused the extinction. The second hypothesis, formulated by another group of scientists, suggest that massive and violent volcanic eruptions were responsible for the extinction. How are these different conclusions possible if scientists in both groups have access to and use the same set of data to derive their conclusions?

Bethy: I mean, of course, [scientists'] individual differences, their point of views, experiences, what they [scientists] bring [from their life], and their background are very important [to derive different conclusions**]**. I think it is like looking at the same picture and seeing different things. I think that some of the characteristics of scientists, the way they [scientists] interpret the data may affect the results of different experiments or how the results are evaluated. For example, some of them [scientists'] may look at the event in through a more critical and different stance.

The question and her response above demonstrate Bethy's understanding of subjective NOS. She correctly argued that scientists' experiences, their background, and the individual differences between them may affect their inferences.

The following question was also asked to Bethy to determine her understanding of the subjective NOS, inferential NOS and socio-cultural NOS.

Researcher: Some claim that science is infused with social and cultural values. That is, science reflects the social and political values, philosophical assumptions, and intellectual norms of the culture in which it is practiced. Others claim that science is universal. That is, science transcends national and cultural boundaries and is not affected by social, political, and philosophical values and intellectual norms of the culture in which it is practiced. Do you think science is universal, or do you think that it is affected by social and cultural values? Why?

Bethy: I want to think that science is not affected by social and cultural values because all of those scientific studies are conducted for the sake of humanity…Although we may all have different religions, languages, and races, the studies conducted are for our own benefits... [studies for all humanity] …it [science] should not be affected. I mean, it [science] is universal…

Researcher: Why do you think that science is universal? Can you give an example?

Bethy: So actually, all those inventions were made by foreign scientists. They have made a ton of inventions and [today] we are continuing our studies by using these inventions. For example, there are Newton's laws, Kepler, Galileo's investigations, Ali Kuşçu's studies [*He was an important astronomer and mathematician. He proposed the alternative planetary model for Mercury and drew the map of the moon for the first time*]. Maybe all of these studies have been conducted in different cultures. However, their results affect all of us ... Scientists share their work continuously with the whole world … For example, the treatment for the cancer can be found and it may be shared with all the countries of the world.

Researcher: So, do you believe that science is universal?

Bethy: ... There is a correlation between the value given to the scientists and the development of that country. For example, as an expert in the field of genetics in Turkey, you cannot earn any money. However, you can earn a ton of money abroad because you have many opportunities to conduct various research studies. This affects the number of scientists and the researchers positively ...Most of the discoveries were made by the foreign scientists. This is quite related to our cultural norms, or our limited horizon. All these factors also affect our education negatively…Therefore, I should say that science should be universal. However, I cannot find anything to support my idea right now.

These questions given above clearly show Bethy's understanding of socio-cultural NOS. Her statement where she claimed that science should be universal is inappropriate. However, she was confused about the question because she thought that science was universal because the inventions of the scientists or the results of the experiments are shared with the whole world. However, her idea in which she claimed that science should always be objective because it is for everyone's sake reflects a misconception that she has. She did not consider science as a human endeavor.

The following question was asked to Bethy to reveal her understanding of the creative and imaginative NOS.

> Researcher: Scientists perform experiments/investigations when trying to find answers to the questions they put forth. Do scientists use their creativity and imagination during their investigations?
>
> Bethy: Absolutely... For example, one of the most criticized points in the education system at the moment is that although children are creative staring from a very young age, we are continuously blunting their creativity. These practices cause reductions in the number of discoveries that they can make. I think it is important to be creative, and to be imaginative. I think that all the inventions begin with creativity. Thus, imagination, creativity and curiosity are very important.
>
> Researcher: At what stage do you think scientists use their creativity and imagination?
>
> Bethy: They [scientists] may use their imagination both during their design process, and perhaps during the development of the questions. Then, they [scientists] may have use their imagination in the designs of their inventions.

Bethy's responses give clues about her understanding of the Imaginative and Creative NOS aspects. Although she was aware of the role of human imagination and creativity while developing scientific knowledge, she only stated that scientists start their studies with creativity, and their designs with imagination.

> Researcher: Finally, we talked about systems such as circulation, digestion, respiration, and urinary. Do you have any information about the scientists who have contributed physiologically to the development of these systems in the past?
>
> Bethy: Pasteur, discovery of the vaccine, discovery of antibiotics, ...those are related to field of medicine and health but related to human body anyway…what else...the invention of microscope… but ultimately, they may have been found by examining the human body and its systems. I do not know if I understand the question correctly…. I do not know the scientists contributing to the development of human body systems.

One of the expected answers was the mention of scientists such as Gallen, and Harvey who contributed to the development of the circulatory system. However, Bethy mentioned Pasteur, the discovery of the vaccine, the discovery of an antibiotics to create a relationship between the human body systems.

Summary of Syntactic Knowledge Findings

To conclude, Bethy seems confused about the tentative nature of science. First of all, Bethy thought that scientific theory can change with the help of technology and scientific research. She mentioned the theories about the formation of the Earth as an example. When she was requested to give an example from the human body systems, she indicated that the assumptions about the blood transfusion have changed. She also supported her arguments by referring to the outdated theories to highlight the development of scientific knowledge and reflect characteristic of scientists to students. However, when she was asked to explain the different between laws and theories, she stated that the laws were proven, and they would not change.

Bethy's responses related to the tentative NOS was summarized in Table 4.52.

Table 4.52 Bethy's Sample Statement in Tentative NOS

NOS Aspect	Sample Statement
Tentative NOS	➢ scientific theory can change ➢ scientific knowledge may change with the development of technology and new research ➢ [the loss of function of appendicitis in the evolutionary process] might be an example [for changeability of scientific knowledge] ➢ the concepts of the universal recipient and universal donor in blood groups are outdated ➢ one atomic theory was inadequate, then the next atomic theory was proposed ➢ Laws have been proven and do not change. Laws are certain ➢ technology, equipment, accumulated knowledge, research and development [R&D], development the competence of scientists' development in their [scientists'] horizons and curiosities, asking more questions cause theory change

Then, she was asked to explain the experimentation. She believed that experiment is crucial to convince people about the scientific knowledge. She believed that science is different from other disciplines in terms of experimental proofs. Bethy also implied that scientists do observations and conduct experiments. Bethy's responses related to the empirical NOS were shown in Table 4.53.

Table 4.53 Bethy's Sample Statement in Empirical NOS

NOS Aspect	Sample Statement
Empirical NOS	➢ science requires investigation, data collection ➢ … it [science] seems more like a process that involve experimental proofs ➢ Experiment is a study to prove a hypothesis ➢ it [experiment] is necessary to test whether a scientific knowledge is correct or not ➢ [Scientists should] be patient most importantly, curious to record, be competent about scientific research methods be a good observer and determined, …conduct experiment, explore ➢ there are experimental studies on the existence of protons.

Moreover, Bethy was questioned about the theory and law. She was not very well-informed enough about the explanations of laws and theories. She argued that the laws are certain while theories may change. She gave the multiple proportion law, the law of constant proportions as examples.

Bethy's responses related to Theory and Laws aspect NOS was shown in Table 4.54.

Table 4.54 Bethy's Sample Statement in Theory and Laws Aspect NOS

NOS Aspect	Sample Statement
Theory and Law	➢ the theory and the law are different... ➢ The theories are more changeable……. Studies on theory can be continued and they [theories] may change… ➢ Laws have been proven and do not change. Laws are certain … ➢ There is the multiple proportion law, law of constant proportions etc. ➢ … the theories were falsified…

Furthermore, when she was asked about how scientists were certain about the structure of the atom, Bethy argued that there were experimental studies that scientists conducted (i.e., Millikan' oil drop experiment). Bethy's responses related to the Inferential NOS were shown in Table 4.55.

Table 4.55 Bethy's Sample Statement in Inferential NOS

NOS Aspect	Sample Statement
Inferential NOS	➢ I think they [scientists] proved the existence of them [the atom and the particles such as proton, neutron, electron] in experimental studies.

When she was asked how scientists reached to different conclusions even though they had the same set of data, Bethy mentioned their experiences, backgrounds, and individual differences as effective factors in their evaluations. Bethy's responses related to the subjective NOS were shown in Table 4.56.

Table 4.56 Bethy's Sample Statement in Subjectivity NOS

NOS Aspect	Sample Statement
Subjectivity NOS	➢ [scientists'] individual differences, their point of view, experiences, what they [scientists] bring [from their life], and background are very important [to derive different conclusions]

Bethy implied that science should not be affected from culture. She also stated that science is universal since the results of scientific studies affect all humanity. Bethy's responses related to the Socio-Cultural NOS were shown in Table 4.57.

Table 4.57 Bethy's Sample Statement in Socio-Cultural NOS

NOS Aspect	Sample Statement
Socio-Cultural NOS	➢ I want to think that science is not affected by social and cultural values because all of those scientific studies conducted for the humanity… ➢ …it [science] is universal…

In addition to the given data above, Bethy also asserted that creativity is an important step to start inventions and design. She argued that scientists should also use their creativity and imagination in every phase of the scientific studies. Although she did not give a specific example, she supported her idea by mentioning the invention of the telephone. Bethy's responses related to the Creative and Imaginative NOS were shown in Table 4.58.

Table 4.58 Bethy's Sample Statement in Creative and Imaginative NOS

NOS Aspect	Sample Statement
Creative and Imaginative NOS	➢ they [scientists] may have used their imagination both in their designs and perhaps while development of question at first…

Briefly, Bethy has inconsistent ideas about the tentative NOS. She correctly mentioned scientific theory can change while she also indicated that laws are certain. Regarding empirical NOS, she addressed experimentation and observation. Moreover, she had limited understanding about the definitions of laws and theories and believed that laws are certain. She mentioned experimentation while omitting human inference. In terms of subjectivity NOS, she was aware of the role of scientists' individual differences, their point of view, experiences, and background. She had inconsistent views about socio-cultural NOS and indicate that science is universal. Furthermore, she was able to explain that creativity and imagination are important for every stage of scientists' studies.

Overall data show that, regarding PCK, their central goal shows some similarities. They mostly addressed schooling goals and subject matter goals. Both teachers were knowledgeable about the place of human body systems in the science curriculum. In their instruction, they cover all related objectives prescribed by curriculum and created horizontal and vertical relationships related to human body systems. However, since they were knowledgeable about human body systems, they went beyond the restrictions posed by curriculum. Moreover, they also were knowledgeable about the difficulties and misconceptions. However, they did not used conceptual change strategies to eliminate students' difficulties because of limited time and overloaded curriculum. Concerning instructional strategies, they took advantage of multiple strategies such as questioning, demonstrations and representations including daily life examples, visuals, and comparisons. In the context of human body systems, they did not implement NOS and they did not addressed history of human body systems. They mostly focused on conceptual understanding by addressing curriculum objectives both in instruction and assessment. Participants seems knowledgeable about assessment method since they used both formative and summative assessment. In terms of substantive knowledge, participants have robust understanding of human body systems (i.e., digestive, circulatory, respiratory and urinary system). In addition, participants were aware of that human body system is a complex system. They explained an integrity and cooperation among system that constitute a human body and organized systems' components and process within a framework of relationship.

CHAPTER 5

DISCUSSIONS AND IMPLICATIONS

In this study, two experienced science teachers' pedagogical content knowledge in terms of the human body systems were examined. The participants' knowledge of human body systems and their understanding of human body systems as complex systems were studied as substantive knowledge. For the same purpose, the digestive system, circulatory system, respiratory system, and urinary system were examined as sub-systems. The following sections will present the discussion of the participating science teachers' pedagogical content knowledge in the context of human body systems.

Overall data show that, participants were aware of the place of human body systems in the science curriculum. Moreover, they addressed objectives and while omitting limitations related to the human body systems in the curriculum. They were knowledgeable enough about horizontal and vertical relationships related to human body systems. They also were aware of the difficulties and misconceptions. However, the limited time did not allow teachers to apply conceptual change strategies to promote the students' learning. They seem knowledgeable enough about the instructional and assessment strategies. In terms of instructional strategies, they used several methods such as questioning, demonstrations and representations including daily life examples, visuals, and comparisons They mostly focused on the objectives given in the curriculum [MoNE, 2018] when she assessed her students by using both traditional, and alternative assessment methods. Participants have well enough understanding of human body systems (i.e., digestive, circulatory, respiratory and urinary system). They seem knowledgeable beyond the curriculum regarding the organs that constitute digestive, circulatory, respiratory and urinary systems; knows the general function of them; disorders and conditions for healthy digestive, circulatory, respiratory and urinary system. Moreover, the extent to which participants understand human body system as a complex system were revealed. They were able to imply that human body system is complex system by indicating an integrity and cooperation among system that constitute a human body. Furthermore, they were able to organize systems' components and process within a framework of relationship.

5.1 Discussions about Science Teachers' Pedagogical Content Knowledge

In this study, participant *teachers' orientation toward science teaching* were summarized as central and peripheral goals. Then, their central and peripheral goals were categorized as subject matter goals, schooling goals and affective goals based on the substantive-level theory of science teaching orientations proposed by Friedrichsen and Dana (2005). First of all, participants' (i.e., Bethy and Anna) central goal data from the interviews, shows some similarities. Participants believed that their role was similar to the role of a guide. In their interview, they, for example, mostly addressed schooling goals. However, they emphasized the schooling goals by mentioning their different aspects. While Bethy mentioned the importance of being a scientific literate person and teaching science process skills, Anna mentioned the necessity of gaining analytical thinking skills in social life and preparing students to life with the help of the scientific methods. Participants also mentioned that science is a part of our lives. In observation data, participant teachers' subject matter goals and schooling goals become more eminent. During their teaching, these teachers aimed at transmitting curriculum objectives by also providing daily life connections, which are categorized as central goals. Therefore, there was an overlap between the participating teachers' orientations as reflected in the interviews and the classroom observations. For instance, in the interview, they asserted that science was a part of daily life. Then, in the classroom, they gave daily life examples. For example, Anna described the diffusion [the respiratory system], chemical digestion [the digestive system], blood transfusion [the circulatory system], the role of skin in excretion [the urinary system] with an example from the daily life. Bethy used daily life examples to explain the functions of the proteins [the digestive system]. Moreover, Bethy aimed to equip their students with science process skills (i.e., observation, interpretation, experimentation). The classroom observations show that, at the end of the human body systems (i.e., the digestive, respiratory, circulatory and urinary system), she distributed thought-provoking questions including figures and graphs. These questions oriented students towards interpreting graphics, reading comprehension, and making inferences. Under the light of this information, it can be said that the schooling goals step forward for both of the teachers. In fact, one of the crucial roles of a science teacher is to raise scientific literate people (Dogan, Cakiroglu, Cavus, Bilican, & Arslan, 2011). Therefore, it can be said that the participating teachers had multiple orientations. In other words, although schooling goals and subject matter goals were dominant, they also held affective domain goals.

The possible reasons that underline the teachers' orientations can be their professional experiences (Friedrichsen & Dana, 2005), overloaded curriculum (Aydın, 2012) and selection of topics (Friedrichsen & Dana, 2005). One of the possible reasons that underlie the teachers' orientations toward science could be their professional experiences. Participants in the current study had more than ten years of experience. They claimed that they had attended several seminars and workshops throughout their teaching experiences. These extracurricular activities may shape their beliefs about teaching, the role of students and teachers. For instance, in her interview, Anna stated that she constantly renewed and was aware of the innovation in education due to teacher training programs she attended. Similarly, Friedrichsen and Dana (2005) addressed the effect of professional development. They found that there was a solid connection between professional development and science teaching orientations. Results of their study show that this connection is bivious. It means that teachers' orientations towards science teaching are affected by the professional development programs, and these orientations also affect their decisions about the choice of professional development activities. Moreover, another reason that underlie the teachers' orientations toward science could be overloaded curriculums.

Similar to Aydın (2012), participant teachers in this study complained about overloaded curriculum. Teachers need time to plan and make activities (Friedrichsen & Dana, 2005). Therefore, they firstly aim at fulfilling the objectives of the curriculum in the given time. For example, participating teachers planned a learning station activity about all human body systems (i.e., digestive, circulatory and respiratory system), in which students would be actively exploring the concepts they had learned at the end of the human body system subject as a group work, but they stated that they were not able to carry out this activity due to such curricular constraints. Moreover, in the interviews, the teachers stated that they would have the students make a model representing the filtration process in the kidneys in the classroom, but it was reported that this activity was not included in the lesson observations. Therefore, as also stated in the literature, overloaded curriculum is one of the barriers affecting teachers' teaching decisions (i.e., Soysal & Radmard, 2017; Şen, 2019). Another factor that shapes the teachers' orientation could be the selection of the topics due to students' grade level (Friedrichsen & Dana,2005). For instance, Friedrichsen and Dana (2005) studied with four experienced teachers to examine the influence of contextual factors on teachers' orientations. The researchers revealed that teachers' orientations were influenced by topic and grade level that they teach at. Similarly, Anna indicated that doing experiments about human body systems was difficult at 6th grade since students did not have the required prerequisite knowledge. For example, she asserted that the experiment related to liver enzymes could be done if the students were more knowledgeable about the enzymes. Even if teachers stated such concerns of theirs, they preferred to demonstrate dissections of heart and kidney.

The teachers' general goals of teaching science show similarity with the science literature (Friedrichsen & Dana, 2005; Lee & Luft, 2008; Aydin et al., 2014; Şen, 2019) especially in terms of scientific literacy, and daily-life representation of science. First, participant results are parallel to Friedrichsen and Dana (2005)'s study data. Authors examined four experienced secondary biology teachers' science teaching orientations. Similarly, they found that all participating teachers held multiple orientations. For instance, teachers' orientations were based on affective domain goals including positive attitude toward science, curiosity as well as subject matter goals and schooling goals. Furthermore, Lee and Luft (2008) aimed to reveal four experienced secondary science teachers' PCK. All participating teachers implied that the purpose of teaching science was to facilitate students' understanding of natural phenomena in their daily life and scientific literacy. They also associated their instruction with their goals. Moreover, Aydin et al. (2014) examined two experienced chemistry teachers' PCK in terms of two different topics: electrochemical cells and nuclear reactions. They found that both participating teachers associated chemistry with daily life while they were explaining their purpose of teaching chemistry.

Participating teachers' orientation toward science may influence their knowledge of curriculum. They were not well informed about limitations offered by the curriculum and violated the science curriculum. Their violation of curriculum could be attributed to the teachers' schooling goals and subject matter goals. Participating teachers aim to teach students that science is related to their daily life and give many examples. Teachers were aware of them, and they followed the objectives provided in the national curriculum and the place of the human body systems in the science curriculum. Therefore, they were knowledgeable enough about materials and used several modelling techniques, representations, and demonstrations to teach human body systems.

It is important to mention here that the participant teachers were knowledgeable beyond the expected level in the curriculum. For example, they used the name of the enzymes (i.e., ptyalin (or amylase), lipase) when they explained the digestive process, the working mechanism of heart, pulmonary and systemic circulation by mentioning the name of the chambers, role of hemoglobin when they explained the red blood cells, coronary veins & coronary arteries while teaching blood vessels at heart dissection, lymph nodes to explain the role of white blood cells in body defense in the context of circulatory system as well as Rh incompatibility during the circulatory system Moreover, they addressed gas exchange process which occur between alveoli and capillaries in the context of the respiratory system in attempt to link circulatory with respiratory systems and mentioned the parts of kidney (i.e., renal cortex, renal medulla).

At first glance, it seems they were more knowledgeable about circulatory system and digestive system rather than others. Circulatory system and digestive system topics include more objectives and included more sub-titles compared to other systems. Moreover, it is necessary to mention that time allocated for circulatory system and digestive system is longer than the others (i.e., respiratory system and urinary system). Therefore, teachers seem to be more knowledgeable about circulatory system and digestive system. However, there was no clear difference between teachers' subject matter knowledge in terms of all systems respectively.

The possible reasons that underline the teachers' knowledge of curriculum can be their field experiences (Chapoo et al., 2014; Lankford, 2010; Şen, 2014; Yılmaz-Yendi, 2019), rich content knowledge (Şen et al., 2018), being unaware of frequent changes in the curriculum (Tekkaya & Kılıç, 2012; Coll & Taylor, 2012), and their knowledge of students. First, the knowledge they have about the objectives, goals, vertical and horizontal relationships may stem from their field experience, which includes a period of more than ten years. To illustrate, in the context of diffusion and osmosis, Lankford (2010) and in the context of biochemical cycles Yılmaz-Yendi (2019) show that experienced teachers created horizontal and vertical relationships related to the curriculum seem knowledgeable of the curricular objectives due their experience level. Another reason is that rich content knowledge may bring about curriculum violation (Şen et al., 2018). Şen et al. (2018) studied with 3 in-service science teachers to reveal their PCK in terms of cell division. Participants were categorized as content-experts, curriculum-led and content-novice according to their content knowledge. For example, content-expert teacher was quite knowledgeable about horizontal relationship and the importance of cell division in the curriculum. Yet, she violated the curriculum by mentioning extra-curricular knowledge about cell division. The reason behind their violation of curriculum limitations could be their lack of knowledge about the revised curriculum very well. Moreover, Tekkaya and Kılıç (2012)'s study, participant pre-service teachers explained that their lack of knowledge about curriculum resulted from the frequent changes in the curriculum. Moreover, it can also be said that the curriculum changes can cause teachers to ignore new reforms and continue teaching as they got used to (Coll & Taylor, 2012). However, participants did not include the enzymes as being responsible for digestion in their classes as they were aware of this limitation in the curriculum. The reason for the teachers' awareness of this limitation could be that it was involved also in the previous curriculum (MoNE, 2013). In fact, this finding was not surprising as far as their teaching experience in the field was considered (ranged from 16-20 years). During this time period, the science curriculum underwent many revisions, and they were familiar with the content of the previous science curricula. For example, 2013 Science Curricula, followed for five years, included the chambers of the heart, and the concept of Rh incompatibility (MoNE, 2013). At this point it is necessary to mention that those limitations in 2018 were not present in the previous science curriculum [MoNE, 2013], to which the teachers got accustomed previously. It is also important to indicate that at the time when the current data of the study were being collected, the science curriculum [MoNE, 2018] was being implemented for the first time in its revised form. For this reason, participating teachers may not have detailed knowledge of the limitations of the new curriculum [MoNE, 2018]. Another reason why the participant teachers violated the curriculum by giving extra-curricular information could be their knowledge of students. For instance, Anna was concerned about teaching human body system without giving cell-tissue-organ-system-organism relationship, which is given in the 7th grade, while Bethy did not address any concern as such during the interview. However, both teachers explained this relationship, and their eagerness to reply to their students' needs. To make it clearer, when Bethy's students could not understand blood cells, she initially explained the relationship among cell-tissue-organ to make blood cells more understandable. Moreover, they aimed to prevent misconceptions by talking about cellular respiration since students confuse cellular respiration and breathing. Furthermore, during classroom observation, it could be seen that many students needed to learn more about the health of human body systems, and they asked several questions related to various illnesses. Therefore, Anna had to talk about varicose, hypothermia (the circulatory system), chrono disease and urinary tract infection (UTI) (the urinary system). However, digestive, respiratory, circulatory, and urinary systems are taught during the first semester while health of these systems are taught during the second semester according to MoNE (2018). Teachers also stated that they could explain the health of each system immediately after the relevant topic next year. Thus, teachers' intention to modification of sub-topics attributed to their knowledge of target students' needs and interests as stated previously.

The current results which indicate the fact that the experienced teachers were more knowledgeable on the curriculum objectives are also consistent with studies in the literature (Lankford, 2010; Şen, 2014; Yılmaz- Yendi, 2019). Lankford (2010) revealed six experienced secondary level biology teachers' PCK on diffusion and osmosis. It was found that the participant teachers were aware of the horizontal and vertical relationships about the curriculum. Also, Şen (2014) revealed three experienced science teachers' PCK in the context of cell division. He found that all participating teachers were aware of curriculum objectives and made horizontal and vertical relationships. Moreover, Yılmaz- Yendi (2019) explained in her doctoral study that experienced teachers were knowledgeable about curriculum thanks to their 10 years of experience. On the other hand, the fact that the pre-service teachers have limited understanding of the curriculum in use is also supported by the literature (Mıhladız & Timur, 2011; Tekkaya & Kılıç, 2012; Özcan & Tekkaya, 2011). For instance, Mıhladız and Timur (2011) revealed that pre-service teachers did not have enough knowledge about curriculum and the development of knowledge of curriculum required more field experience. Tekkaya and Kılıç (2012) also studied with 7 pre-service biology teachers to reveal their PCK in terms of evolution. They found that pre-service teachers were not knowledgeable about curriculum objectives.

Participant teachers paid attention to their students' needs and interests as stated previously. They were knowledgeable enough about students' learning needs regarding the human body systems. For instance, they mentioned the classification of nutrients (4th grade) before teaching digestive system to provide more meaningful learning. Moreover, both of them were aware of the fact that students had to know the cell-tissue-organ-system-organism relationship (7th grade) to understand the human body systems in a better way. Thus, they briefly talked about this relationship in the classroom. However, Anna talked about this relationship while describing the alveoli, Bethy mentioned it when she was lecturing about the blood cells. The difference here may have arisen from the differing needs of the students in different classes. Apart from that, the students did not know the important prerequisite knowledge such as diffusion, air pressure, and surface tension. This prevented them from understanding the gas movement through body and its cells better (Mann & Treagust, 1998). Thus, participant teachers were aware of the students' lack of knowledge about diffusion, so they explained it briefly before explaining gas exchange in the alveoli. However, the teachers did not address that the students need to know osmosis and diffusion to understand the urinary system better (Tekkaya et al., 2001). Even so, the teachers briefly mentioned diffusion to explain gas exchange change in the alveoli as a part of respiratory system, which is the subject taught before the urinary system. Understanding the role of diffusion is important to understand the material exchange on capillaries (Tekkaya et al., 2001). Therefore, it can be said that the teachers were familiar with the requirements of the enhancement of their students' learning.

Participant teachers' knowledge of students may be attributed to strong SMK (Aydin et al., 2014). While many PCK studies show that robust SMK is essential to develop PCK (Shulman, 1986; Magnusson et al., 1999; Kaya, 2009; Kind, 2009; Aydın & Boz, 2012; Aydın et al., 2014), many of them indicate effective SMK is not the direct indicator of good PCK (Davis, 2004; Newton & Newton, 2010). Participant teachers had enough SMK to be knowledgeable enough about the students' misconceptions. For example, the teachers' SMK were over the requirements of the curriculum as discussed above. In that point, participating teachers' experience level could be an indicator for their strong SMK. For instance, participant teachers were knowledgeable enough about the common misconceptions among students (i.e., using clean-dirty blood, misunderstanding of breathing and respiration). Aydin et al. (2014) explored two experienced science teachers' PCK in terms of electrochemical cells and nuclear reactions. They found that participant teachers' knowledge of student is different for two topics. So, they explained that robust SMK for a topic could be the reason for better understanding of students' misconceptions, difficulties, and pre-requisite knowledge. On the other hand, teachers' limited subject matter knowledge brings about lack of awareness of students' misconceptions (Halim & Meerah, 2012). For instance, Käpylä et al. (2009) found that the biology student-teachers were more knowledgeable than primary student-teachers in terms of the knowledge of learners, so it may be explained that content knowledge is partially impactful on PCK. Pre-service teachers have many misconceptions about human body systems (i.e., digestive system, urinary system) (Andariana et al., 2020). For example, Cardak (2015) found the student teachers' misunderstanding about the lack of relationship among the digestive system organs. Moreover, the pre-service teachers held misconceptions about blood circulation, gas exchange, blood vessels (Peleaz et al., 2005), and heart (Prokop & Fančovičova, 2006; Bahar et al., 2008). Student teachers had alternative conceptions and difficulties related to respiratory physiology (Tapia et al., 2019). Furthermore, in the context of the urinary system, prospective teachers also had several misconceptions (Genc,2013).

Yet, the teachers did not implement NOS in the context of human body systems, and they did not give any examples from history of human body systems. It is important to mention syntactic aspects (NOS understanding) of SMK. Participant teachers' NOS understanding show some inconsistencies. The participant teachers had inconsistent explanations about tentative NOS and socio-cultural NOS. The reason why the teachers did not possess NOS in their instruction could be related to the science curriculum and teachers' lack of knowledge (Hanuscin et al., 2010). The lack of curriculum objectives and activities may lead teachers to neglect NOS teaching in their lessons. When MoNE (2018) is examined, it can be seen that there is no curricular objectives or suggested activities related to human body systems to teach NOS. Also, due to fact that teachers may have limited knowledge, they may have not implemented NOS (Hanuscin et al., 2010). Similar to a study conducted by Yendi (2019), although participant teachers were aware of the idea that scientific theories could be falsified and changed over time, they mentioned that laws are unchangeable. For instance, they gave gravity, law of constant proportions, multiple proportion law as examples. Therefore, the teachers have misconception that scientific laws are absolute (McComas,1998). Cansız (2019) indicated that teaching the circulatory system by mentioning its historical development was effective to implement NOS understanding and eliminate students' misconceptions related to NOS.

The participant teachers' knowledge about students' difficulties are consistent with the literature. Similar to Özsevgeç (2007), the teachers believed that the students confused the concepts of excretion and elimination. That is, students used excretion for both the disposal of digestive waste and metabolic waste. Özsevgeç (2007) stated that the reason behind this confusion was using the term of excretory system instead of the urinary system. In a similar vein, Anna believed that the reason behind students' misunderstanding of breathing and respiration was their usage of the term 'respiratory system' instead of the 'breathing system'. Moreover, participants were aware of that students have learning difficulties about gas exchange (Pelaez et al., 2005), the process of digestion (Ramadas and Nair, 2007), breathing and respiration (Mann & Treagust, 1998). Also, participants know that some sources of students' difficulties are terminology, textbooks abstract nature of topics and overloaded curriculum (Tekkaya et al., 2001).

It is important to mention that although participant teachers were aware of students' misconceptions and their learning difficulties as well as topic-specific strategies they could not effort to use any conceptual change strategies such as constructing concept maps or mind maps neither to reveal students' misconceptions nor remediate misconceptions. For example, as subject-specific strategies, both teachers utilized 5E learning models by using questioning. However, phases of 5E learning models could not be followed appropriately and teacher-directed teaching was observed. Although students were highly participative and took responsibility for their learning, questioning was dominant. The explore phase of the 5E learning cycle model could not be followed properly. For example, learning model included teacher-centered demonstrations. Specifically, both teachers bring a heart and kidney to dissect and show students in attempt to make the abstract concepts concrete. Moreover, they used analogies, drawing (i.e., the respiratory system and heart), daily life examples, and modelling (i.e., respiratory system model, kidney model and digestive system model) to attract their students' attention to the subject.

Participant teachers' great deal of subject-specific knowledge may be attributed to several results such as year of experience (Chapoo et al., 2014; Lankford, 2010; Sagbilge and Oztekin, 2021), their orientation toward science teaching (Magnusson et al.,1999; Friedrichsen et al., 2011; Aydın, 2012; Brown et al., 2013; Boesdorfer, 2015), contextual factors (Şen, 2019), and their knowledge of learners (Aydın, 2012; Park & Chen, 2012; Boesdorfer, 2015). First, one of the sources of teachers' instructional strategies could be their duration of experience. As stated earlier, participant teachers had more than years of field experience. Thus, experienced teachers were familiar with some useful strategies (Chapoo et al., 2014; Lankford, 2010; Sagbilge and Oztekin, 2021). Specifically, Chapoo et al. (2014) conducted a study with an experienced biology teacher in the context of nature of organisms and found that participant used questioning, discussion, and pictures; Lankford (2010) explored six experienced teachers' PCK about diffusion and osmosis and the participants used demonstrations, analogies, and laboratory investigations while they followed 5E learning cycle model; Sagbilge and Oztekin (2021) studied with experienced science teachers in the context of weather and climate and participants used drawings, simulations, videos, and analogies as topic-specific representations.

Orientation toward science teaching is also one of the factors that shapes the teachers' instructional strategies (Magnusson et al., 1999; Friedrichsen et al., 2011; Aydın, 2012; Brown et al., 2013; Boesdorfer, 2015). Teachers who adapted central goals as schooling goals and subject matter goals tented to use modelling (i.e., respiratory system model, kidney model) during their instruction. Anna mentioned that she still remembered what her own science teacher said about experimentation: she believed that touching organs (i.e., heart, kidney) would led students to become doctors. Therefore, it can be said that Anna's beliefs about learning science could shape her knowledge of the representations in the context of the circulatory system. In addition, participants used demonstration to make topics more concrete on students' mind. Boesdorfer (2015) revealed that teachers' orientation toward science was an indicator of their representations (i.e., models, analogies, simulations) in the classroom. In Boesdorfer (2015)'s study, participant who believe that the purpose of teaching science is to help students to apply their knowledge into new situation used analogies, models, role-playing. Also, Brown et al. (2013) studied with four prospective biology teachers and found that teachers' instructional strategies and their orientation were in similar horizons.

Furthermore, one of the reasons shaping the teachers' instructional strategies may be contextual factors (Şen, 2019). The teachers were working at a private school which had sufficient laboratory facilities. Thus, it can be said that schools may provide opportunities for teachers to enhance their instruction by supplying the materials they need (heart, kidney, etc.). Şen (2019) studied with two science teachers to reveal the relationship between contextual factors and PCK. The researcher found that the school sources (i.e., laboratory materials) affect teachers' instructional strategies. For example, participants of this study stated that they could not do a density experiment because there were no equal-arm scales at school. Moreover, the lack of a projector in the school or the fact that the existing machine was broken negatively affected the teachers' instruction, as they were not able to show the visuals about the topic to their students.

Moreover, teachers' knowledge of learners may shape their knowledge of instructional strategies (Aydın, 2012; Park & Chen, 2012; Boesdorfer, 2015). For example, Anna was aware of the fact that students had difficulty in understanding the pulmonary and systemic circulation due to the fact that systemic and pulmonary circulation were abstract concepts. Therefore, they showed simulations about how heart worked, and Anna utilized card games as a role play activity to show circulation process. Besides, Bethy was aware of the fact that students did not understand the physical digestion of fats with the help of the bile. For this reason, she represented the physical digestion of fats with bile by tearing the paper and breaking it into small pieces. Similarly, Park and Chen (2012) revealed integration of the components of PCK in the context of heredity. The researchers found that the knowledge of students and knowledge of instructional strategies were highly integrated with each other. For instance, since one of the participants were aware that students have misconceptions about rate of photosynthesis and redesign instruction by increasing examples. These examples show that the teachers' knowledge of learners may affect their knowledge of representations (Park & Chen, 2012). Similarly, Boesdorfer (2015) revealed that participants in her study used several representations since the subject they taught [periodic table] was abstract in the students' minds and, therefore, was difficult for them to understand.

Similar findings were also reported in literature (Cansız, 2019; Hmelo, Holton & Kolodner, 2000; Mathai & Ramadas, 2009). Cansız (2019) suggested to perform heart dissection to teach circulatory system since it mainly has abstract conceptualization on students' mind. Moreover, Hmelo et al., (2000) show that a designing activity and creating modelling facilitated students' understanding of the respiratory system in a more systematic manner. Mathai and Ramadas (2009) recommend models, 3D visualizations, animations, schematic representations and line drawings to teach complex situations.

Knowledge of assessment strategies is another dimension of PCK. Participant teachers in this study used similar strategies throughout their lessons. The teachers primarily focused on science content by using quizzes and exams which included multiple-choice questions, short-answer questions, matching activities, and true-false questions to evaluate students' progress. Thus, it can be said that the participating teachers mostly preferred traditional assessment methods. Teachers evaluated students' prior knowledge at the beginning of each lesson and each topic through questioning, and at the end of each topic and each unit with summative quizzes. Therefore, they benefited from both formative and summative assessment while they were teaching the human body systems. Therefore, it can be said that the teachers assessed their students in a constant manner. They also assessed their students' performance throughout the semester according to criteria that they determined (i.e., problem solving skills, using scientific knowledge etc.). However, the teachers also did not possess NOS assessment in their instruction.

The reasons behind that they mostly focus on conceptual understanding while they assess students could be the curriculum knowledge (Park & Oliver, 2008), and national exam systems (Cohen & Yarden, 2008; Tıraş, 2019; Şen, 2014), teachers' orientation toward science (Aydın, 2012; Şen, 2014; Tıraş, 2019), and knowledge of students (Henze et al., 2008; Tıraş,2019). First, curriculum objectives shaped teachers' decision about assessment (Park & Oliver, 2008). When the 6th grade science curriculum (MoNE, 2018) was considered, it can be seen that science curriculum focused on conceptual understanding. Moreover, teachers' knowledge of assessment could be shaped by the contextual factors such as the national exam systems (Cohen & Yarden, 2008; Tıraş, 2019; Şen, 2014). In Turkey, students are preparing for the High School Entrance Exam at the 8th grade, which is the last year of middle school. This exam includes multiple choice questions that mainly focuses on conceptual understanding. Moreover, teachers' orientation toward science may be the reason behind teachers' knowledge of assessment (Aydın, 2012; Şen, 2014; Tıraş, 2019). Due to the fact that participating teachers' schooling goals were dominant, they frequently asked questions during the lesson related to their daily lives and assessed the students' problem-solving skills or science process skills. For example, teachers paid extra attention to evaluate students' performance in the classroom, and they gave continuous feedback to students about their progress. Another reason behind teachers' knowledge of assessment may be their knowledge of students (Henze et al., 2008; Tıraş,2019). Participant teachers were aware of students' difficulties and misconceptions as discussed above. Henze et al. (2008) implied that teachers evaluate students better if they are familiar with students' difficulties and misconceptions. Further, the teachers used traditional assessment techniques during their teaching of the human body systems. Although they were familiar with the idea of concept mapping, which is an example of authentic assessment techniques, time constraints could be the reason why these teachers did not prefer utilizing it. Therefore, it is necessary to be mentioned that the knowledge of assessment limits the development of the learners (Hanuscin et al., 2010). For example, since teachers did not prefer using concept maps as alternative assessment methods to elicit students' understanding, their knowledge of students' difficulties were limited to their own observations. The development of the assessment knowledge may enable teachers to increase their knowledge of the students (Park & Oliver, 2008).

Similar results were also observed in the PCK literature (Tekkaya & Kılıç, 2012; Tıraş, 2019; Şen, 2014). Likewise, in Aydın's (2012) study, participant teachers made a quiz at the end of each sub-parts to help students fix their deficient knowledge. In the current study, participants also did not utilize topic-specific assessment strategies and used formative assessment strategies (i.e., quizzes) to assess students' progress in fulfilling the objectives of the related topic similar to Aydin et al. (2014). Moreover, similar results that the teachers did not possess NOS assessment in their instruction were also reflected in literature (Aydin, 2012; Şen, 2014; Yendi, 2019). For instance, participant teachers in Yendi (2019)'s study also ignored NOS tenets in the context of biogeochemical cycles and mostly focused on assessment of conceptual understanding.

At first sight, the most frequent interactions were seen between teachers' knowledge of students and instructional strategies. Participants were knowledgeable of students' requirements of learning and their misconceptions and learning difficulties related to human body systems. Therefore, they enriched their instructions by using simulations (i.e., how heart works, pulmonary & systemic circulation), models (kidney, respiratory system), and daily life examples. Moreover, teachers' knowledge of curriculum and assessment strategies were interacted with each other. For instance, teachers focused on students' conceptual understanding based on curriculum objectives while they assess students. There are several studies related to reveal interaction among PCK components in the PCK literature (Şen, Demirdöğen & Öztekin, 2022; Park & Chen, 2012; Aydin & Boz, 2013). For instance, Şen et al. (2022) revealed the interactions among topic specific PCK components for three science teachers by considering teachers' content knowledge. They found that interactions among participants' components were based on content knowledge.

5.2 Implications and Recommendations

The Magnusson et al.'s (1999) PCK model offers important tips on the characteristic of effective teaching. Hence, the results of this study have crucial implications and recommendations for science teachers, researchers, curriculum developers, and textbook authors regarding PCK and content knowledge.

The results of the study show that participants have well-developed substantive knowledge especially in terms of the organs that constitute human body systems (i.e., digestive, circulatory, respiratory, and urinary systems); the general function of organs; disorders, and conditions for being healthy. Participants also were aware that the human body system is a complex system yet, they have inconsistent views about some NOS aspects and did not implement NOS in the context of human body systems and they did not give any examples from the history of human body systems.

Accordingly, first, regarding implications for science teachers, teachers' syntactic knowledge should be developed, and they should be more informed about NOS aspects. However, improvement of teachers' NOS understanding is not enough to support the implication of NOS in the classroom Therefore, teachers should be encouraged to integrate NOS into the lesson. For instance, Akyol (2015) recommended that teacher education programs for pre-service science teachers should include the development of a positive attitude toward NOS implementation into teaching and it may be requested to teachers implement NOS through their lesson plans and teaching. Therefore, teachers may experience the positive outcomes of the implementation of NOS. Besides, to implement effective NOS instruction, teachers should be informed about all aspects of PCK for NOS (Demirdöğen, 2012). To this end, a professional development program should be planned (Demirdöğen, 2012; Hanuscin et al., 2011; Akyol, 2015). In a planned professional program, a teacher training program for in-service teachers can promote not only teachers' NOS understanding but also their PCK for NOS. A long-lasting explicit-reflective NOS instruction may help improve teachers' NOS understanding and PCK for NOS by focusing on all dimensions of PCK since teaching these dimensions explicitly is effective for teachers to internalize NOS teaching (Demirdöğen, 2012). Besides, it is important that this training should be long-lasting since teachers' orientation toward science which shapes all PCK dimensions is resistant to change (Luft & Roehring, 2007).

Concerning knowledge of instructional strategies for NOS through this planned program, Cansız (2014)'s study could be an enlightening example of NOS-related activities. He recommended that scientists who conducted a study about human body systems, such as the circulatory (i.e., Galen, Harvey, Empedocles, Hippocrates) could be explained to mention their creativity, theories about how does the heart work and how does heart distribute blood, and the subjectivity of science. Moreover, William Harvey's experiments could be demonstrated to show creativity and imaginative NOS (Cansız, 2014) Furthermore, addressing the historical development of the circulatory system in the lesson can be an effective way to promote the tentative nature of the science aspect.

Second, developing teachers' NOS understanding of NOS and PCK for NOS may be not enough to enable teachers to integrate there are important implications for curriculum developers and textbook authors. Depending on the findings of the study, teachers aimed at teaching and assessing curriculum objectives. Therefore, curriculum developers should also place NOS objectives in the curriculum in addition to science content objectives (Demirdöğen, 2012). For instance, curriculum developers should integrate the history of science into the science curriculum (Cansız, 2014).

Third, this study has some implications for both teacher education programs for pre-service teachers and teacher training programs for in-service teachers, because this study highlighted science teachers' knowledge about students' learning difficulties and possible misconceptions related to digestive, circulatory, respiratory, and urinary systems. Teachers can pay attention to the misconceptions given in the lecture, prior knowledge and learning difficulties that students need to know and improve themselves on topic-specific instructional strategies. Moreover, participants use several analogies, models, examples, and topic-specific activities (i.e., a card game about circulation) in their instruction. Therefore, these activities together with reported misconceptions and learning difficulties can be a guide for in-service teachers and pre-service teachers.

This study also has some recommendations for researchers. First, PCK depends on context. Therefore, this study could be conducted with teachers who are teaching at public schools. Private schools have more opportunities than public schools in terms of materials, laboratory equipment, thus how context affects the results could be investigated.

Second, in this study, Magnusson et al.'s (1999) PCK model which is a transformative model is used to reveal teachers' PCK. Each of the five components of this model was examined and interaction among these components was revealed through discussion briefly. However, it is strongly recommended that the relationship between teachers' PCK and students' achievement could be investigated by using Gess-Newsome (2015) PCK model and interaction among PCK components by using Pentagon model (Park & Chen, 2012). This study conducted with two experienced science teachers attending to same school. For that reason, future research should focus on collective PCK using Refined Consensus Model (Carlson & Daehler, 2019).

Third, in Turkey, there is no study about teachers' PCK concerning Human Body Systems and their understanding of the Human Body System as a complex system. Therefore, it is recommended that further research should be conducted to shed light on the findings of this study.

Fourth, teachers' syntactic knowledge and substantive knowledge are not classified while analyzing teachers' subject matter knowledge. Beyond the scope of this study, further studies can analyze teachers’ syntactic knowledge as naïve, transitional, and informed. Also, teachers’ substantive knowledge can be analyzed as not adequate, adequate, and informed.

Moreover, further studies could examine topic-specific nature of each human body system separately.

Participants of this study graduated from different faculties who graduated from science education and chemistry department (outside of specialism). In this study, the purpose of comparison was not aimed when analyzing teachers' PCK. Accordingly, further studies may compare teachers’ PCK who graduated from science education and teacher from out of science teaching.

Finally, further studies could be conducted with pre-service teachers and novice teachers to show how experience affects teachers’ SMK and PCK.

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APPENDICES

A. APPENDIX A

Human Body System Questions

VÜCUDUMUZDAKİ SİSTEMLER ALAN BİLGİSİ GÖRÜŞME SORULARI

Adı Soyadı:

Sayın Öğretmenlerim;

Bu çalışma vücudumuzdaki sistemlerle ilgili siz fen bilimleri öğretmenlerinin mevcut görüş ve bilgilerini ortaya koymak ve bu kavramın eğitim sistemindeki yerini anlamak açısından çok önemlidir. Bu nedenle konu ile ilgili içten ve samimi cevaplarınız benim için oldukça değerlidir. Vereceğiniz bilgiler kesinlikle gizli tutulacak, sadece araştırma amaçlı kullanılacaktır. Yardımlarınız için sizlere teşekkür ederim.

Görüşme esnasında söyledikleriniz ve kimlik bilgileriniz kesinlikle gizli kalacaktır. Görüşme içeriği sadece araştırma amaçlı kullanılacaktır. Görüşmeyi kaydetmek için izninizi istiyorum. Bu hem görüşmenin akışı hem de cevaplarınızın analizi açısından önemlidir. İstediğiniz zaman görüşmeyi bırakabilirsiniz.

Bana sormak istediğiniz herhangi bir soru varsa yanıtlayabilirim.

Elif KINIK
ODTÜ-Eğitim Fakültesi

1. Bir sistemi nasıl tanımlarsınız?
    a. Bu tanımı oluşturmanızda size ne yardımcı oldu?
    b. Bir örnek verebilir misiniz?
    c. Örneğinizi bir sistem yapan şey nedir?
2. Fen bilimleri içerisinde sistemi nasıl tanımlarsınız?

3. Vücudumuzdaki sistemler nedir?
    a. Neden böyle düşünüyorsunuz?
    b. Bu sistemler arasında nasıl bir ilişki vardır?
    c. İnsan vücudu nasıl çalışır?
4. Vücudumuzdaki sistemler deyince aklınıza gelen 12 kelimeyi yazar mısınız?
    a. Bu kelimeleri birbiriyle nasıl ilişkilendirirsiniz?
5. Vücudumuzdaki sistemler kavram haritasını çizer misiniz?
6. Yediğimiz besinlere ne olur?
7. Sindirim nedir?
8. Sindirim deyince aklınıza gelen 12 kelimeyi yazar mısınız?
9. Sindirim sisteminin görevi nedir?
10. Neden sindirim sistemine ihtiyacımız vardır?
11. İnsanda sindirim sistemini çizerek açıklayabilir misiniz?
12. Besinler nasıl sindirilir?
        i. Aşamaları nedir?
    b. Karbonhidratların sindirimi nasıldır?
    c. Proteinlerin sindirimi nasıldır?
    d. Yağların sindirimi nasıldır?
13. Yediğimiz besinler enerjiye nasıl dönüştürülür?
14. Sindirim sürecinde vücudumuzda ne gibi değişiklikler olduğunu açıklar mısınız?
15. Sindirim sistemi deyince aklınıza gelen 12 kelimeyi yazar mısınız?
16. Sindirim sistemi kavram haritasını çizerek gösterir misiniz?
17. Sindirim sistemini oluşturan yapı ve organlar nelerdir? Çizerek açıklayabilirsiniz.
18. Sindirim sistemini oluşturan yapı ve organların görevleri nelerdir?
19. Sindirim sistemini oluşturan yapı ve organlar arasında nasıl bir ilişki vardır?
20. Sindirim çeşitleri nelerdir?
    a. Sindirim çeşitleri arasında fark var mıdır?
        i. Varsa nedir?

21. Sindirime yardımcı organlar nelerdir?
22. Sindirime yardımcı organların görevleri nelerdir?
23. Sindirim sistemini oluşturan yapı ve organlar ile sindirime yardımcı organlar arasında ilişki var mıdır?
    a. Evet derse nasıl?
    b. Hayır derse neden?
24. Aşağıda verilen terimleri tanımlayarak örnek verir misiniz?
    - Fiziksel (mekanik) sindirim
    - Kimyasal sindirim
    - Enzim
27. Sindirim sisteminin sağlığını korumak için neler yapmalıyız?
28. Sindirim sistemi hastalıkları nelerdir?
29. Sindirim sistemi hastalıkları arasında bir ilişki var mıdır?
    a. Varsa nasıl?
30. Kendinizde, ailenizde ya da çevrenizde sindirim sistemi hastalığına sahip olan var mı?
    a. Varsa nedir?
    b. Varsa bu durum sizin ders anlatımınızı etkiliyor mu?
    c. Etkiliyorsa nasıl?
31. Sindirim sisteminin diğer sistemlerle ilişkisi var mıdır?
    a. Evet derse nasıl?
32. Sindirim sistemin dolaşım sistemi ile ilişkisi var mıdır?
    a. Varsa nasıl?
33. Dolaşım sistemini nasıl tanımlarsınız?
34. Dolaşım sistemini çizerek ve açıklar mısınız?
35. Dolaşım sistemi deyince aklınıza gelen 12 kelimeyi yazar mısınız?
    a. Bu kelimeleri birbiriyle nasıl ilişkilendirirsiniz?
36. Dolaşım sistemi kavram haritasını çizerek gösterir misiniz?
37. Dolaşım sistemi görevi nedir?
38. Neden dolaşım sistemine ihtiyacımız vardır?

39. Dolaşım sistemini oluşturan yapı ve organlar nelerdir? Çizerek açıklayabilirsiniz.
40. Dolaşım sistemini oluşturan yapı ve organların görevleri nelerdir?
41. Dolaşım sistemini oluşturan yapı ve organlar arasında nasıl bir ilişki vardır?
42. Kaç tür dolaşım vardır?
    a. Dolaşım çeşitleri arasında fark var mıdır?
        i. Varsa nedir?
43. Küçük kan dolaşımını çizer misiniz?
44. Büyük kan dolaşımını çizer misiniz?
45. Kanın yapısını anlatır mısınız?
46. Kanın görevleri nelerdir?
47. Temiz kan kirli kan denildiğinde ne anlıyorsunuz?
48. Kan grupları arasındaki kan alışverişi nasıldır?
49. Rh faktörü nedir?
50. Kan uyuşmazlığını açıklar mısınız?
51. Serum ve plazma nedir?
    a. Farkı var mıdır?
    b. Varsa nedir?
52. Kan bağışının toplum açısından önemi nedir?
53. Kan bağışında bulundunuz mu?
    a. Neden?
    b. Konu ile ilgili kurum/kuruluşlar nelerdir?
54. Bu konuda kişisel sorumluluklarımız var mıdır?
    a. Varsa nasıl?
    b. Yoksa neden?
55. Kalbin yapısı nasıldır?
    a. Çizerek açıklayabilir misiniz?
56. Kalbin görevi nedir?
57. Aşağıda verilen terimleri tanımlayarak örnek verebilir misiniz?
    - Kan damarları

- Büyük kan dolaşımı
- Küçük kan dolaşımı
- Kan grupları
- Kan bağışı
- Nabız
- Tansiyon
- Atardamar
- Toplardamar
- Kılcal damar

59. Dolaşım sistemin gelişime katkı sağlayan bilim insanları kimlerdir?
    a. Neler yapmışlardır?
61. Dolaşım sisteminin diğer sistemlerle ilişkisi var mıdır?
    a. Evet derse nasıl?
    b. Hayır derse neden?
62. Örneğin, sindirim sistemi, dolaşım sistemi ve solunum sistemi ile ilişkisi var mıdır?
    a. Varsa nasıl?
63. Dolaşım sisteminin sağlığını korumak için neler yapmalıyız?
    a. Konu ile ilgili kurum/kuruluşlar nelerdir?
64. Dolaşım sistemi hastalıkları nelerdir?
65. Dolaşım sistemi hastalıkları arasında bir ilişki var mıdır?
    a. Varsa nasıl?
66. Kendinizde, ailenizde ya da çevrenizde dolaşım sistemi hastalığına sahip olan var mıdır?
    a. Varsa nedir?
    b. Varsa bu durum sizin ders anlatımınızı etkiliyor mu? Etkiliyorsa nasıl?
67. Solunumu nasıl tanımlarsınız?
68. Nefes alıp vermek deyince ne anlıyorsunuz, tanımlar mısınız?
    a. Nefes aldığımızda vücudumuzda ne tür değişiklikler olur?? Mekanizmasını açıklar mısınız?

b. Nefes verdiğimizde vücudumuzda ne tür değişiklikler olur? Mekanizmasını açıklar mısınız?

69. Solunum ile nefes alıp vermek arasında bir fark var mıdır?
70. Solunum sistemi nedir?
71. Solunum sisteminin görevi nedir?
72. Solunumun sistemine neden ihtiyaç duyarız?
73. Solunum sistemini çizerek açıklar mısınız?
74. Solunum sistemi deyince aklınıza gelen 12 kelimeyi yazar mısınız?
    a. Bu kelimeleri birbiriyle nasıl ilişkilendirirsiniz?
75. Solunum sistemi kavram haritasını çizerek gösterir misiniz?
76. Solunum sistemini oluşturan yapı ve organlar nelerdir? Çizerek açıklayabilirsiniz.
77. Solunum sistemini oluşturan yapı ve organların görevleri nelerdir?
78. Solunum sistemini oluşturan yapı ve organlar arasında nasıl bir ilişki vardır?
79. Solunum sisteminde meydana gelen adaptasyonlar nelerdir?
80. Aşağıda verilen terimleri tanımlar mısınız?
    - Burun
    - Yutak
    - Gırtlak
    - Soluk borusu
    - Diyafram
    - Akciğerler
    - Bronş
    - Bronşçuk
    - Alveol
81. Solunum sisteminin diğer sistemlerle ilişkisi var mıdır?
    a. Evet derse nasıl?
    b. Hayır derse neden?
82. Solunum sisteminin sindirim sistemi, dolaşım sistemi ve boşaltım sistemi ile ilişkisi var mıdır?

83. Solunum sisteminin sağlığını korumak için neler yapmalıyız?
    a. Konu ile ilgili kurum/kuruluşlar nelerdir?
84. Solunum sistemi hastalıkları nelerdir?
85. Solunum sistemi hastalıkları arasında bir ilişki var mıdır?
    a. Varsa nasıl?
86. Kendinizde, ailenizde ya da çevrenizde Solunum sistemi hastalığına sahip olan var mı?
    a. Varsa nedir?
    b. Varsa bu durum sizin ders anlatımınızı etkiliyor mu? Etkiliyorsa nasıl?
87. Boşaltım nedir?
88. Boşaltım nasıl olur?
89. Boşaltım sistemi nedir?
90. Boşaltım sisteminin görevi nedir?
91. Boşaltım sistemine neden ihtiyaç duyuyoruz?
92. Boşaltım sistemini çizerek açıklar mısınız?
93. Boşaltım sistemi deyince aklınıza gelen 12 kelimeyi yazar mısınız?
    a. Bu kelimeler arasında nasıl bir ilişki vardır?
94. Boşaltım sistemi kavram haritasını çizerek açıklar mısınız?
95. Boşaltım sistemini oluşturan yapı ve organlar nelerdir?
96. Boşaltım sistemini oluşturan yapı ve organların görevleri nelerdir? Çizerek açıklayabilirsiniz.
97. Boşaltım sistemini oluşturan yapı ve organlar arasında nasıl bir ilişki vardır?
    a. Farklı boşaltım şekilleri var mıdır?
        i. Varsa nedir?
98. Aşağıda verilen terimleri tanımlar mısınız?
    - Böbrek
    - İdrar borusu
    - İdrar kesesi
    - İdrar kanalı
    - İdrar

- Atık
- Kalın bağırsak
- Deri
- Akciğer

99. Boşaltım sisteminin sağlığını korumak için neler yapmalıyız?
    a. Konu ile ilgili kurum/kuruluşlar nelerdir?
100. Boşaltım sistemi hastalıkları nelerdir?
101. Boşaltım sistemi hastalıkları arasında bir ilişki var mıdır?
    a. Varsa nasıl?
102. Kendinizde, ailenizde ya da çevrenizde boşaltım sistemi hastalığına sahip olan var mı?
    a. Varsa nedir?
    b. Varsa bu durum sizin ders anlatımınızı etkiliyor mu? Etkiliyorsa nasıl?
103. Organ bağışı hakkında ne düşünüyorsunuz?
    a. Bu konuda kişisel sorumluluklarımız var mıdır?
        i. Varsa nasıl?
        ii. Yoksa neden?
104. Organ bağışlamayı düşünüyor musunuz?
    a. Neden?
    b. Organ bağışının toplumsal dayanışmaya katkısı var mıdır?
        i. Varsa nasıl?
        ii. Yoksa neden?
105. Vücudumuzdaki sistemler dinamik midir?
    a. Neden böyle düşündüğünüzü açıklar mısınız?
106. Vücudumuzdaki sistemler birbiri ile ilişkili midir?
    a. Evet derse neden öyle düşünüyorsunuz?
    b. Bu ilişkiyi çizerek açıklar mısınız?
    c. Hayır derse neden?
107. Homeostazi nedir? Açıklar mısınız?
    a. Sistemleri göz önüne alarak açıklar mısınız?

108. Vücudumuzda homeostaziyi nasıl tanımlarsınız?
109. Her bir sistemin homeostaziye katkısını anlatır mısınız?
110. Toplumdaki ilaç kullanım bilinci hakkında ne düşünüyorsunuz?
    a. Olumsuzsa, bu konuda alınabilecek önlemler nelerdir?
111. İlk yardım nedir?
112. İlk yardım nasıl yapılmalıdır?

B. APPENDIX B

PCK Questions

EK 1. İÇERİK GÖSTERİMİ GÖRÜŞME SORULARI

Merhaba, ben Elif KINIK. Orta Doğu Teknik Üniversitesi, Eğitim Fakültesi Matematik ve Fen Bilimleri Eğitimi Bölümü yüksek lisans öğrencisiyim. Ortaokul fen bilimleri öğretmenlerinin vücudumuzdaki sistemler (sindirim/dolaşım/solunum/boşaltım sistemi) konusunda konu alan bilgileri ve pedagojik alan bilgileri üzerine bir araştırma yapmaktayım. Bunun için sizden vücudumuzdaki sistemler ve bu konunun bilimin doğası ile olan ilişkisi hakkında görüşlerinizi almak istiyorum. Bu çalışma vücudumuzdaki sistemlerle ilgili siz fen bilimleri öğretmenlerinin mevcut görüş ve bilgilerini ortaya koymak ve bu kavramın eğitim sistemindeki yerini anlamak açısından çok önemlidir. Bu nedenle konu ile ilgili içten ve samimi cevaplarınız benim için oldukça değerlidir.
Görüşme esnasında söyledikleriniz ve kimlik bilgileriniz kesinlikle gizli kalacaktır. Görüşme içeriği sadece araştırma amaçlı kullanılacaktır. Görüşmeyi kaydetmek için izninizi istiyorum. Bu hem görüşmenin akışı hem de cevaplarınızın analizi açısından önemlidir. İstediğiniz zaman görüşmeyi bırakabilirsiniz.
Bana sormak istediğiniz herhangi bir soru varsa yanıtlayabilirim.

A. KİŞİSEL BİLGİLER

- Adınız, Soyadınız:
- Yaşınız: Cinsiyet:
- Mezun olduğunuz üniversite/Bölüm:
- Ne kadar süredir öğretmenlik yapıyorsunuz?
- Görev yapmakta olduğunuz okul:
- Kaç yıldır bu okulda görev yapıyorsunuz?

- Okulun demografik yapısını nasıl tanımlarsınız? (büyüklüğü, öğrencilerin sosyo-ekonomik seviyesi…vb.)
- Sınıflarınızın ortalama öğrenci sayısı:
- Daha önce sindirim/dolaşım/solunum/boşaltım sistemi ya da diğer fen konularına yönelik etkinlik/seminer/konferans vs. katıldınız mı?
- Katıldıysanız, içeriği:
- Üyesi olduğunuz, sivil toplum/dernek/kurum/kuruluşlar (Lösev, Kızılay vb)
- Sindirim/dolaşım/solunum/boşaltım sistemi konusuyla ilgili okul dışı/kişisel/özel bir deneyiminiz oldu mu? (Günlük hayatta ilginiz var mı?)
- Kendinizde, ailenizde ya da çevrenizde sindirim/dolaşım/solunum/boşaltım sistemi hastalığı olan var mı?

B.YARI YAPILANDIRILMIŞ PEDAGOJİK ALAN BİLGİSİ GÖRÜŞME FORMU

Pedagojik Alan Bilgisi Ön Görüşme Soruları

1-Fen Öğretimine karşı Yönelimler

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

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

3. Özel olarak "sindirim/dolaşım/solunum/boşaltım sistemi" konusunu ele alırsak bir fen bilimleri öğretmeni olarak bu konuyu öğretmek sizin için ne anlama geliyor? Cevabınızı açıklar mısınız?

a) Sindirim/dolaşım/solunum/boşaltım sistemi konusunu siz, neden öğretiyorsunuz?

Konu Alanı 1. Öğrencilerin Öğrenmesi Gereken Konular

Müfredat Bilgisi

Ana Soru: Vücudumuzdaki Sistemler ünitesinde öğrencilerin neleri (hangi temel noktaları) öğrenmesini istiyorsunuz?

1. Sizce **Vücudumuzdaki Sistemler** (sindirim/dolaşım/solunum/boşaltım sistemi) konularına öğretim programında neden yer verilmiştir?

(Bu konunun öğretmenlerin öğretim programına göre konunun önemine vurgu yapmaları beklenmektedir.)

2. Sindirim/dolaşım/solunum/boşaltım sistemi müfredattaki yerini biliyor musunuz?

- Sizce "sindirim/dolaşım/solunum/boşaltım sistemi" konusu kaçıncı sınıfta okutulmaktadır?
- Sindirim/dolaşım/solunum/boşaltım sistemi konusu (6.sınıf ders programında) kaçıncı ünitedir?
- Bu konulardan önceki ve sonraki üniteler nelerdir? Cevabınızı açıklar mısınız?

3. Öğretim programında sindirim/dolaşım/solunum/boşaltım sistemi konuları diğer konularla, ünitelerle veya sınıflarla ilişkilendirilmiş mi?

- Eğer ilişkilendirilmişse önceki yıllarda işlenen hangi fen konuları ile ilişkilidir?
- Eğer ilişkilendirilmişse fen bilimleri müfredatında (4.sınıftan 8.sınıfa kadar) hangi konularla ilişkilendirilmiştir?
- Eğer ilişkilendirilmemişse, sizce hangi konularla ilişkilendirilse konunun öğretimi ve öğrenilmesi daha iyi olur? Neden böyle düşündüğünüzü açıklayınız.

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

5. Bu kazanımları önem sırasına göre sıralar mısınız?

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

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

8. Bu kazanımlardan farklı olarak sizin sindirim/dolaşım/solunum/boşaltım sistemi konuları ile ilgili önemli gördüğünüz noktalar var mıdır?

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

9. Fen bilimleri öğretim programında sindirim/dolaşım/solunum/boşaltım sistemi ile ilgili kavram yanılgılarına ve konunun anlatımı sırasında uyulması gereken sınırlamalara yer verilmiş midir?

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

10. Öğrencilerinize sindirim/dolaşım/solunum/boşaltım sistemi konularını anlatırken hangi kaynakları kullanıyorsunuz?

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

Konu Alanı 2. Konuyu Bilmenin Önemi

Ana Soru: Öğrencilerin Vücudumuzdaki Sistemler (sindirim/dolaşım/solunum/boşaltım sistemi) **konusunu bilmesi neden önemlidir?**

1. Sindirim/dolaşım/solunum/boşaltım sistemini öğrenmeleri öğrencilere ne gibi avantajlar sağlar? Neden?
2. Öğrencilerin bu kavramları bilmeleri neden önemlidir? Onlara nasıl bir katkısı olabilir?
3. Öğrenciler öğrendikleri bu bilgi ve becerileri nasıl kullanacaklar? Eğer öğrenciler fen alanında bir meslek seçmezlerse, bu bilgi ve beceriler onlara nasıl faydalı olacak? Olmayacaksa nedenini açıklar mısınız?

Ana soru: Fen bilimleri öğretiminin amaçları

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

1. Bahsettiğiniz bu amaçları hedefleri nasıl belirlediniz? Amaçları belirlemenize neler yardımcı oldu?
2. Fen öğretiminde öğretmenin rolü nedir öğrencinin rolü nedir? (Söylediğiniz amaçlara paralel düşünebilirsiniz).

1.1. Fen Öğretimine yönelik Öğretmen inançları

a. Öğrencilerin sınıfta öğrenmelerini en üst seviyeye çıkarmak için ne yaparsınız?
b. Sınıftaki öğretmen rolünüzü nasıl tanımlarsınız?
c. Öğrencilerinizin anladığını nasıl bilirsiniz?
d. Okul ortamında, neyi öğretip neyi öğretmeyeceğinize nasıl karar verirsiniz?
e. Sınıfta yeni konuya ne zaman geçeceğinize nasıl karar veriyorsunuz?
f. Öğrencileriniz fen bilimlerini en iyi nasıl öğrenirler?
g. Sınıfta öğrenme ne zaman oluyor nasıl anlıyorsunuz?

Konu Alanı: 3 Konuyu öğretmek ile İlgili Zorluk ve Sınırlılıklar

Ana Soru: Vücudumuzdaki Sistemler (sindirim/dolaşım/solunum/boşaltım sistemi) **Konusunu öğretirken yaşadığınız zorluklar nelerdir?**

1. Sizce bu konuyu öğretmek neden zordur? Bu konuyu öğretmeyi zorlaştıran etkenler nelerdir? Neden?

2. Bu konuyu öğretmenin zorluklarını nasıl öğrendiniz? (Bu konuyu öğretmenin zor olduğuna nasıl kanaat getirdiniz?)

3. Sindirim/dolaşım/solunum/boşaltım sistemi konusunun öğretimine yönelik kaygıların var mı?

a. Evet derse: kaygıların nelerdir?
b. Kaygılanma nedenin nedir?
c. Hangi faktörlerin senin sindirim/dolaşım/solunum/boşaltım sistemi öğretimini etkileyeceğini düşünüyorsun?
d. Sindirim/dolaşım/solunum/boşaltım sistemi öğretimi ile ilgili zorluklar ve seni sınırlayan faktörler olabilir mi?
e. Bu konuyu öğretmenizi etkileyen diğer faktörler nelerdir?
f. Bu konuyu öğretmenin zorlukları nelerdir?
g. Bu konuyu öğretirken yaşadığınız sınırlılıklar nelerdir?

Konu Alanı: 4 Öğrencilerin Düşünceleri

Öğrenci Bilgisi

Ana Soru: Bu aşamada öğrencilerin Vücudumuzdaki Sistemler (sindirim/dolaşım/solunum/boşaltım sistemi) **konusundaki düşünceleri/kavramaları hakkında konuşmak istiyorum. Öğrenciler sindirim/dolaşım/solunum/boşaltım sistemi konusunu öğrenirken hangi noktalarda zorlanıyorlar?**

1. Sizce öğrencilerinizin sindirim/dolaşım/solunum/boşaltım sistemi konusunu öğrenebilmeleri için gerekli olan ön bilgiler neler olmalıdır? Neden böyle düşünüyorsunuz? Cevabınızı açıklar mısınız?

2. Öğrencilerinizin sindirim/dolaşım/solunum/boşaltım sistemi ile ilgili olarak, hangi konuları anlamakta zorluk çektiklerini düşünüyorsunuz?

3. Sizce öğrencilerinizin bu konuları anlamakta zorlanmalarının sebepleri nelerdir?

4. Öğrencilerinizin sindirim/dolaşım/solunum/boşaltım sistemi ile ilgili kavram yanılgıları var mıdır? Varsa bu kavram yanılgıları nelerdir? Cevabınızı açıklar mısınız?

5. Öğrencilerinizin sindirim/dolaşım/solunum/boşaltım sistemi ile ilgili sahip oldukları kavram yanılgılarının nedenleri sizce neler olabilir?

6. Öğrencilerinizin sindirim/dolaşım/solunum/boşaltım sisteminde sahip olduğu kavram yanılgılarını nasıl saptarsınız? Kavram yanılgılarını saptamak için hangi yöntemleri kullanıyorsunuz?

- Eğer öğrencilerinizin kavram yanılgılarını saptamıyorsanız nedenini belirtiniz.

7. Saptadığınız bu kavram yanılgılarını gidermeye çalışıyor musunuz?

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

Konu Alanı 5: Öğretmenin sindirim/dolaşım/solunum/boşaltım sistemini öğretmesini etkileyen faktörler

Ana Soru: Yukarıda bahsettiğiniz kavramların öğretimini etkileyen diğer etkenler nelerdir?

1. Bu faktörler yaptığınız öğretimi nasıl etkilemektedir?
2. Bu konuyu öğretirken kendinizi ne kadar özgür/bağımsız/seçme hakkına sahip hissediyorsunuz?

Konu Alanı: 6 Öğretim Prosedürleri

Ana Soru: Öğrencilerin bahsettiğiniz kavramları anlamasına yardımcı olmak için hangi öğretim stratejilerini (analoji, gösteri deneyi, benzetim/simülasyon,

grafik, günlük hayat örnekleri vs.) kullanacaksınız? (Ya da hangi aktiviteler öğrencilerin o kavramları anlamalarında yardımcı olabilir?)

Öğretim stratejileri bilgisi

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

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

3. Sindirim/dolaşım/solunum/boşaltım sistemi ile ilgili sınıfta etkinlik yapıyor musunuz?

- Eğer yapıyorsanız bu etkinlikler nelerdir?
- Eğer sindirim/dolaşım/solunum/boşaltım sistemi ile ilgili etkinlik yapmıyorsanız neden etkinlik yapmadığınızı açıklayınız.

4.Sindirim/dolaşım/solunum/boşaltım sistemi konusunu öğretirken hangi öğretim yöntemini/ yöntemlerini kullanıyorsunuz?

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

5. Öğrencilerinizin sindirim/dolaşım/solunum/boşaltım sistemi konularını öğrenmeleri ve kavramlarını anlamaları için gösterimler, figürler, simülasyonlar, çizimler ya da metaforlar kullanıyor musunuz?

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

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

6. Konuyu öğretirken öğrencilerin konu ile ilgili yanlış kavramalara sahip olduklarının farkına varsanız ne yaparsanız?
7. Öğrencilerin kafası karıştığında ne kadar alternatif açıklama ya da örnek sağlayabilirsiniz?
8. Etkili aktivite bulmada ne kadar iyisiniz? Neden iyi/kötü olduğunuzu düşünüyorsunuz? Ya da bu kanıya nasıl vardınız?
9. Yapmayı planladığınız bu aktivite/strateji vs.'nin etkili olduğunu/olacağını nasıl öğrendiniz/anladınız/nereden biliyorsunuz?
10. Amaçlarınızla seçtiğiniz metotlar arasında nasıl bir bağlantı var, seçtiğiniz metotlar amaçlarını ne ölçüde yansıtıyor?
11. Günlük hayatta sindirim/dolaşım/solunum/boşaltım sistemi konusunun uygulamasını gördüğünüz alanlar var mı? Bunu yaptığınız öğretimde kullanıyor musunuz?
12. Öğrencileri katmada ne kadar iyisiniz? Neden iyi/kötü olduğunuzu düşünüyorsunuz? Ya da bu kanıya nasıl vardınız?
13. Yaptığınız öğretimin etkili olup olmadığını nasıl anlarsınız?

Konu Alanı: 7 Öğrencilerinin Anladıklarının Ölçülmesi:

Değerlendirme Stratejileri Bilgisi

Ana Soru: Öğrencilerin konuyu anlayıp anlamadıklarını nasıl ölçersiniz?

1. Öğrencilerin sindirim/dolaşım/solunum/boşaltım sistemi konusunda ne öğrendiklerini hangi ölçme tekniklerini kullanarak ölçersiniz?
2. Niçin bu ölçme tekniklerini kullanmayı tercih ediyorsunuz?
3. Değerlendirme sonuçlarını nasıl kullanıyorsunuz? Bu sonuçlar size neler anlatıyor?

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

5. Öğrencilerinizin sindirim/dolaşım/solunum/boşaltım sistemi ile ilgili bilgilerini ölçerken tam olarak neyi ölçmeyi hedefliyorsunuz?

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

    - Neden bu zaman dilimini seçtiğinizi açıklar mısınız?

C. APPENDIX C

BİLİMİN DOĞASI HAKKINDA GÖRÜŞLER SORULARI (VNOS-C)

1. Bilim ne demektir? Bilimi (veya fizik, biyoloji gibi bir bilimsel alanı) diğer araştırma alanlarından (örneğin, din ve felsefe) farklı kılan şey nedir?
2. Deney ne demektir?
3. Bilimsel bilginin gelişmesi için deney gerekli midir?
    a. Evetse, niçin? Görüşünüzü destekleyen bir örnek veriniz.
    b. Hayırsa, niçin? Görüşünüzü desteleyen bir örnek veriniz.
    c. Vücudumuzdaki sistemler konusundan örnek verebilir misiniz?
4. Bilim insanları bilimsel bir teori geliştirdikten sonra (örneğin atom teorisi, evrim teorisi) bu teori hiç değişir mi?
    a. Eğer bilimsel teorilerin değişmeyeceğine inanıyorsanız nedenini açıklayınız? Cevabınızı örneklerle destekleyiniz.
    b. Eğer bilimsel teorilerin değişeceğine inanıyorsanız, (a) teorilerin niçin değiştiğini açıklayınız (b) o zaman niçin teorileri öğrenmek için çaba harcadığımızı açıklayınız. Cevabınızı örneklerle destekleyiniz.
    c. Vücudumuzdaki sistemler konusundan örnek verebilir misiniz?
5. Bilimsel teori ve bilimsel kanun arasında fark var mıdır? Bir örnek veriniz.
6. Fen kitapları genellikle atomun; protonlar (pozitif yüklü parçacıklar) ve nötronların (nötr parçacıklar) bulunduğu merkezdeki bir çekirdek ile çekirdek etrafında dolaşan elektronlardan (negatif yüklü parçacıklar) oluştuğunu ifade eder. Bilim insanları atomun yapısı hakkında nasıl bu kadar emin olabilmektedirler? Bilim insanlarının atomun neye benzediğine karar verirken hangi spesifik delilleri kullandıklarını düşünüyorsunuz?
7. Yaklaşık 65 milyon yıl önce dinozorların yok olduğuna inanılmaktadır. Bilim insanları tarafından bu yok oluşu açıklamak için oluşturulan hipotezlerden ikisi daha fazla kabul edilmektedir. Bir grup bilim insanı tarafından oluşturulan birinci hipotez; 65 milyon yıl önce kocaman bir meteorun dünyaya çarptığını ve yok oluşa neden olan bir dizi olaya yol açtığını öne sürer. Diğer bir grup bilim insanı tarafından oluşturulan ikinci hipotez ise;

büyük ve şiddetli bir volkanik patlamanın bu yok oluşa neden olduğunu öne sürer. Eğer her iki gruptaki bilim insanları aynı verilere ulaşıyor ve aynı verileri kullanıyorlarsa, bu farklı sonuçlar nasıl ortaya çıkmaktadır?

8. Bazı insanlar, bilimin sosyal ve kültürel değerlerden etkilendiğini iddia etmektedir. Yani, bilim sosyal ve politik değerleri, felsefi varsayımları ve üretildiği kültürün akla uygun normlarını yansıtmaktadır. Diğerleri ise, bilimin evrensel olduğunu iddia etmektedir. Yani, bilim ulusal ve kültürel sınırları aşmaktadır ve sosyal, politik ve felsefi değerlerden ve üretildiği kültürün akla uygun normlarından etkilenmemektedir.
    a. Eğer bilimin sosyal ve kültürel değerleri yansıttığına inanıyorsanız, nedenini açıklayınız. Cevabınızı örneklerle destekleyiniz.
    b. Eğer bilimin evrensel olduğuna inanıyorsanız, nedenini açıklayınız.

    Cevabınızı örneklerle destekleyiniz.

9. Bilim insanları, ileri sürdükleri sorulara cevap bulmaya çalışırken deneyler ve araştırmalar yapmaktadır. Bilim insanları bu araştırmaları boyunca yaratıcılıklarını ve hayâl güçlerini kullanmakta mıdır?
    a. Cevabınız evetse, araştırmanın hangi aşamasında- planlama ve tasarlama, veri toplama, veri topladıktan sonra - bilim insanlarının hayâl güçlerini ve yaratıcılıklarını kullandıklarını düşünüyorsunuz? Bilim insanlarının neden hayâl güçlerini ve yaratıcılıklarını kullandıklarını açıklayınız. Mümkünse örnekler veriniz.
    b. Eğer bilim insanlarının hayâl güçlerini ve yaratıcılıklarını kullanmadıklarını düşünüyorsanız, nedenini açıklayınız. Mümkünse örnekler veriniz.
10. Dolaşım, sindirim, boşaltım ve solunum sistemlerinde katkı sağlayan bilim insanları kimlerdir?

D. APPENDIX D

ANNA’S PCK POST-INTERVIEW

1. Sindirim, dolaşım, boşaltım ve solunum sistemlerini işledikten sonra dersin işleyişiyle ilgili ilgili olumlu veya olumsuz neler hissettiniz?
2. Sizce öğrencileriniz sindirim, dolaşım, boşaltım ve solunum sistemlerini iyi anladı mı? Neden?
3. Derste sindirim, dolaşım, boşaltım, solunum sistemini öğrenen öğrencilerde herhangi bir zorluk gözlemlediniz mi?
4. Derste planlanmadığınız bir durum veya öğrencilerin sorularına göre ders planınızda kasıtlı yaptığınız bir değişiklik oldu mu?
5. Vücudumuzdaki sistemler konusu bittikten sonra istasyon tekniği yapmayı planlamıştınız ancak uygulamaya koymadınız. Planınızda yaptığınız bu değişikliğin sebebi nedir?
6. Besinlerin sınıflandırılması hazırladığınız vücudumuzdaki sistemler konu anlatımı fasikülünde yoktu ancak sindirim sistemine başlamadan önce besinlerin sınıflandırılması konusuna yer verdiniz ve etkinlik yaptınız. Planınızda yaptığınız bu değişikliğin sebebi nedir? Ders anlatımınızda faydasını gördünüz mü?
7. İlk görüşmemizde müfredat değişikliği sebebiyle hissettiğiniz kaygıdan bahsetmiştiniz. Öğrencilerinizin hücre konusunu bilmiyor oluşu ders anlatımınızı nasıl etkiledi?
8. Yazılı sınavdan sonra öğrencilere sınavdaki eksik kazanımlarıyla ilgili benzer sorular içeren bir kontrol kâğıdı uygulamanız vardı. Bu uygulamanın amacı nedir?
9. Organ nakli ve sistemlerin sağlığı konusuyla ilgili bir etkinlik yaptınız mı?

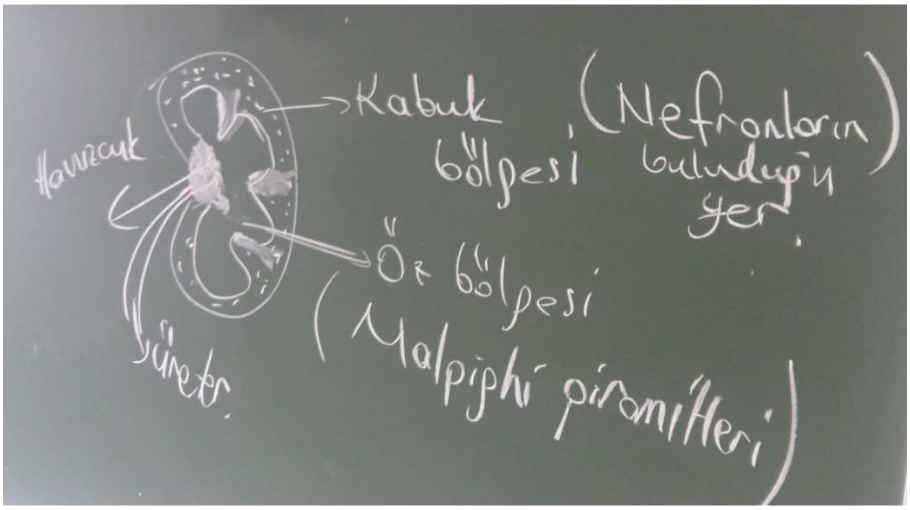
E. APPENDIX E

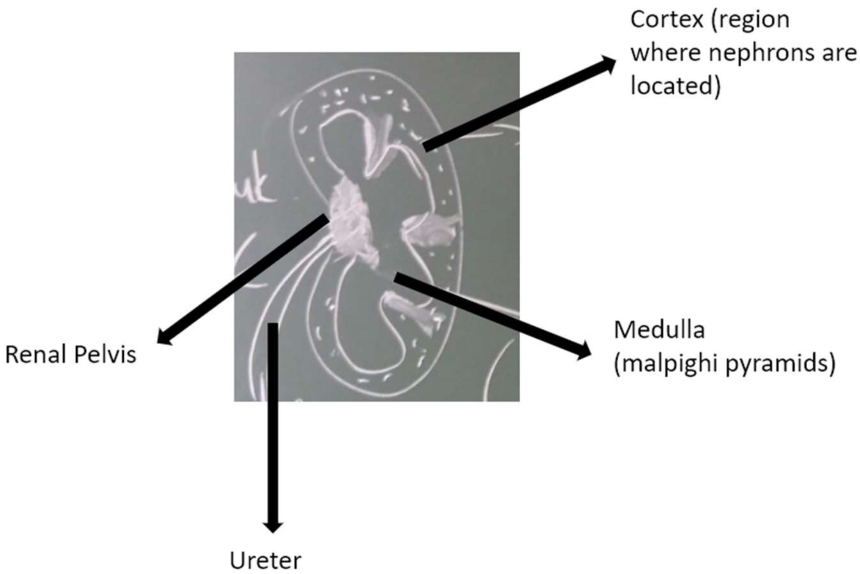
BETHY’S PCK POST-INTERVIEW

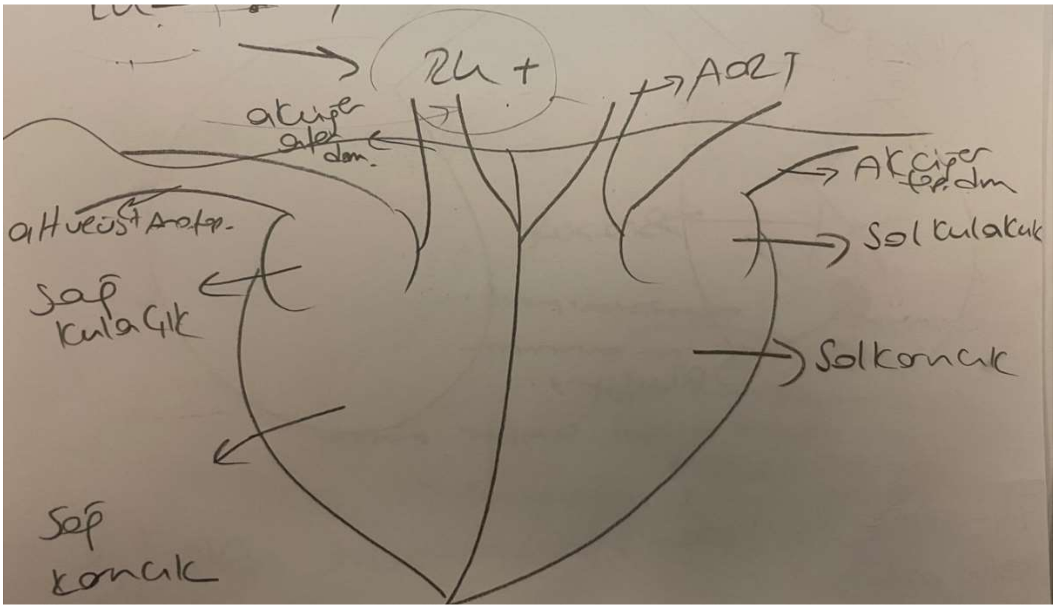
1. Sindirim, dolaşım, boşaltım ve solunum sistemlerini işledikten sonra dersin işleyişiyle ilgili ilgili olumlu veya olumsuz neler hissettiniz?
2. Sizce öğrencileriniz sindirim, dolaşım, boşaltım ve solunum sistemlerini iyi anladı mı? Neden?
3. Derste sindirim, dolaşım, boşaltım, solunum sistemini öğrenen öğrencilerde herhangi bir zorluk, kavram yanılgısı ya da hata tespit ettiniz mi?
4. Derste planlanmadığınız bir durum veya öğrencilerin sorularına göre ders planınızda kasıtlı yaptığınız bir değişiklik oldu mu?
5. Vücudumuzdaki sistemler konusu bittikten sonra istasyon tekniği yapmayı planlamıştınız ancak uygulamaya koymadınız. Planınızda yaptığınız bu değişikliğin sebebi nedir?
6. İlk görüşmemizde vücudumuzdaki sistemler konu anlatımı fasikülünden bahsetmemiştiniz. Planınızda yaptığınız bu değişikliğin sebebi nedir? Hazırladığınız ders materyalinde eksiklikler tespit ettiniz mi?
7. Öğrencilerinizin hücre bilgisine sahip olmamasına çok vurgu yaptınız. Bu sizi nasıl etkiledi?
8. Vücudumuzdaki sistemler konusu bittikten sonra istasyon tekniği yapmayı planlamıştınız ancak uygulamaya koymadınız. Planınızda yaptığınız bu değişikliğin sebebi nedir?
9. İlk görüşmemizde önceki yıllarda boşaltım sistemi modeli yaptırdığınızı söylemiştiniz ancak uygulamadınız. Planınızda yaptığınız bu değişikliğin sebebi nedir?
10. Vücudumuzdaki sistemlerin sağlığını 2. Dönemin son konuları arasında anlatmaktan kaygılı olduğunuzdan bahsetmiştiniz. Bu konudaki fikriniz değişti mi?

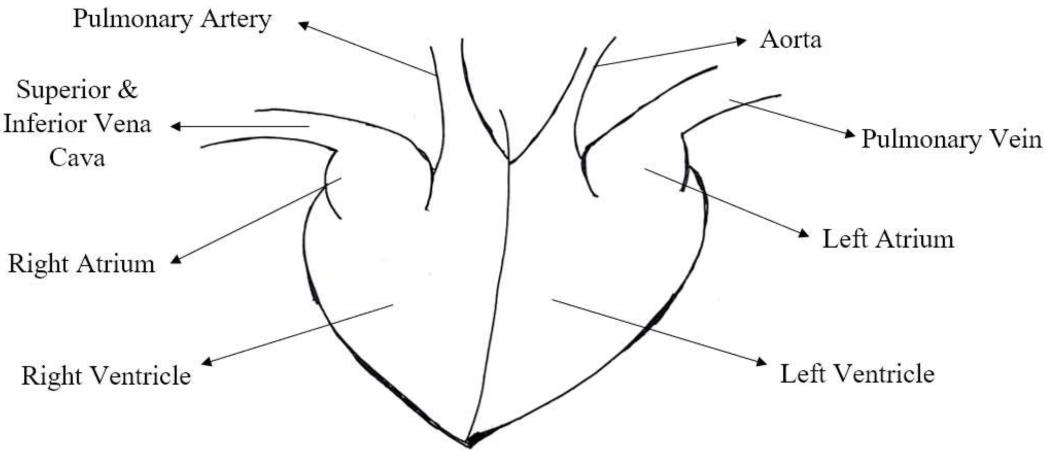
F. APPENDIX F

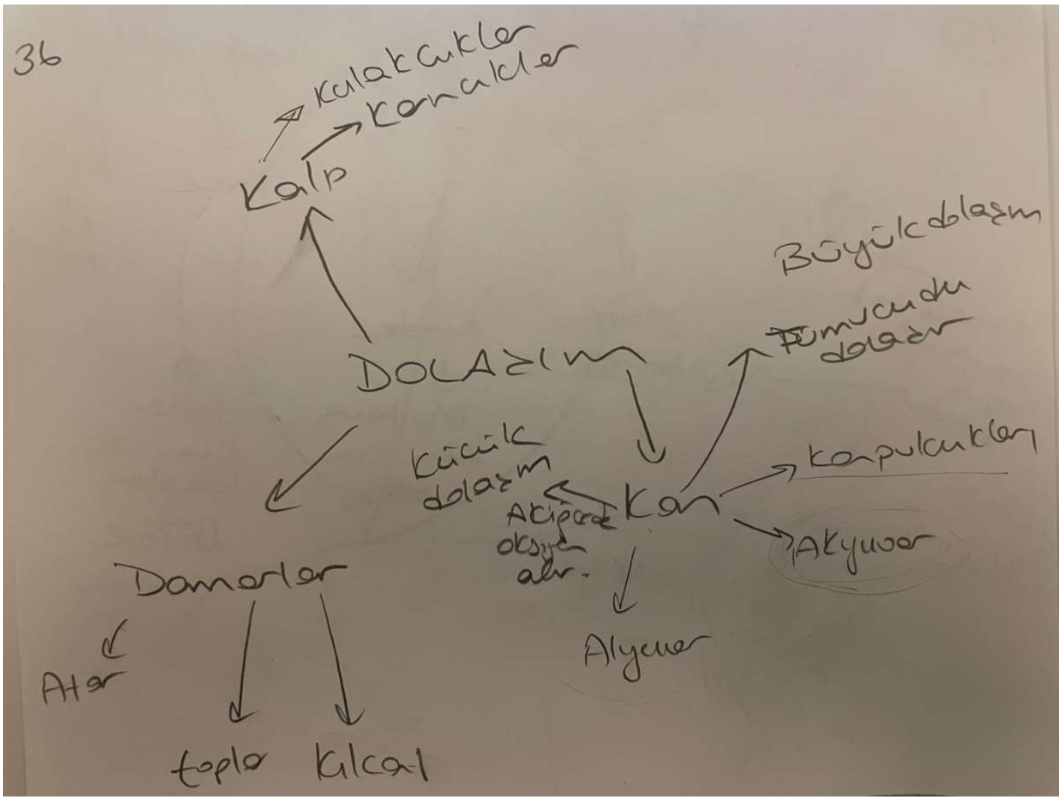
ANNA'S ORIGINAL DRAWINGS



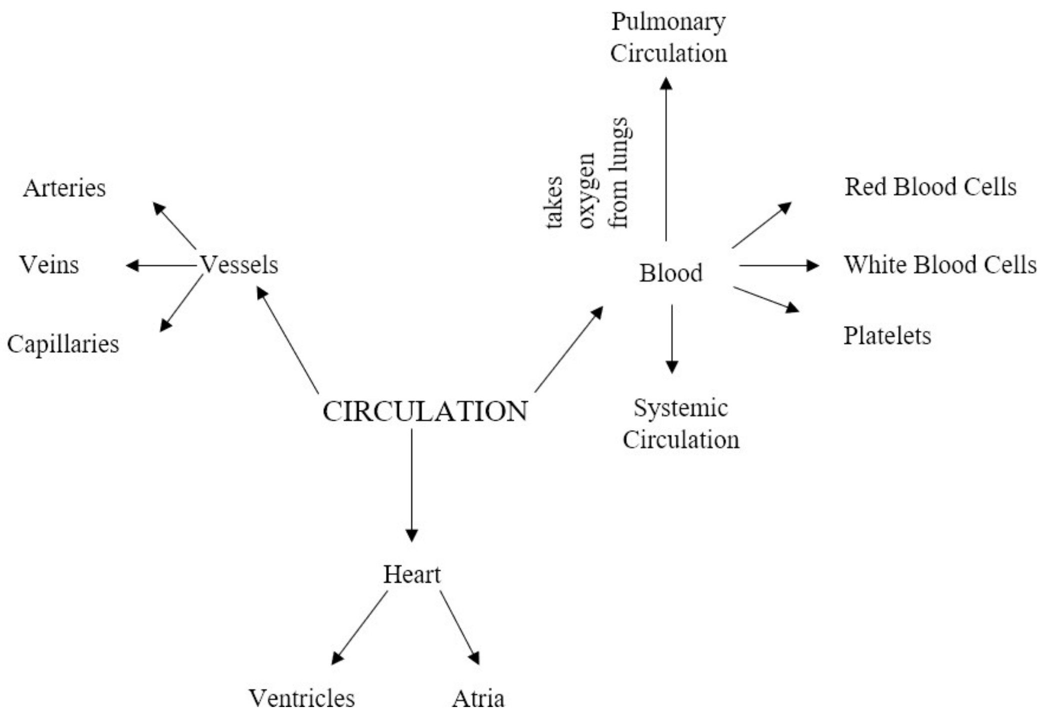



AORT

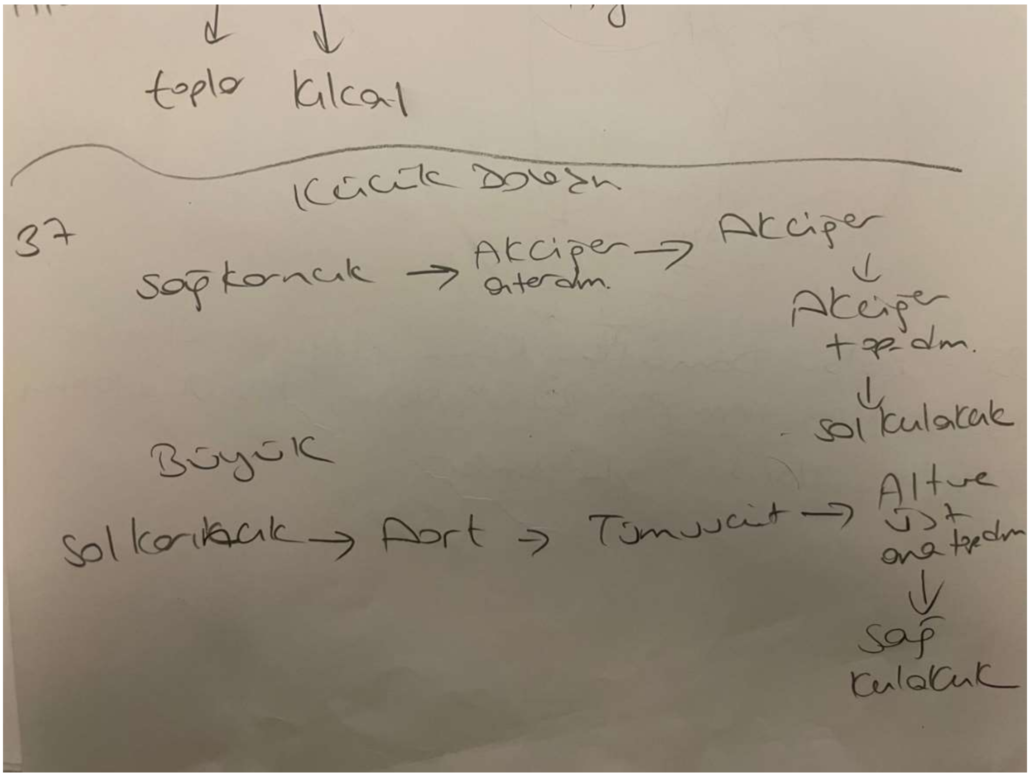

Pulmonary Artery
Aorta
Superior & Inferior Vena Cava
Pulmonary Vein
Right Atrium
Left Atrium
Right Ventricle
Left Ventricle



36
Kulakcukler
Karıncıkler
Kalp
Büyük dolaşım
DOLAŞIM
Küçük dolaşım
Kan
Kanpulcukları
Akyuvar
Akciğerde oksijen alır.
Alyuvar
Damarlar
Atar
topla
kılcal



Pulmonary Circulation
takes oxygen from lungs
Arteries
Veins
Vessels
Capillaries
Blood
Red Blood Cells
White Blood Cells
Platelets
CIRCULATION
Systemic Circulation
Heart
Ventricles
Atria

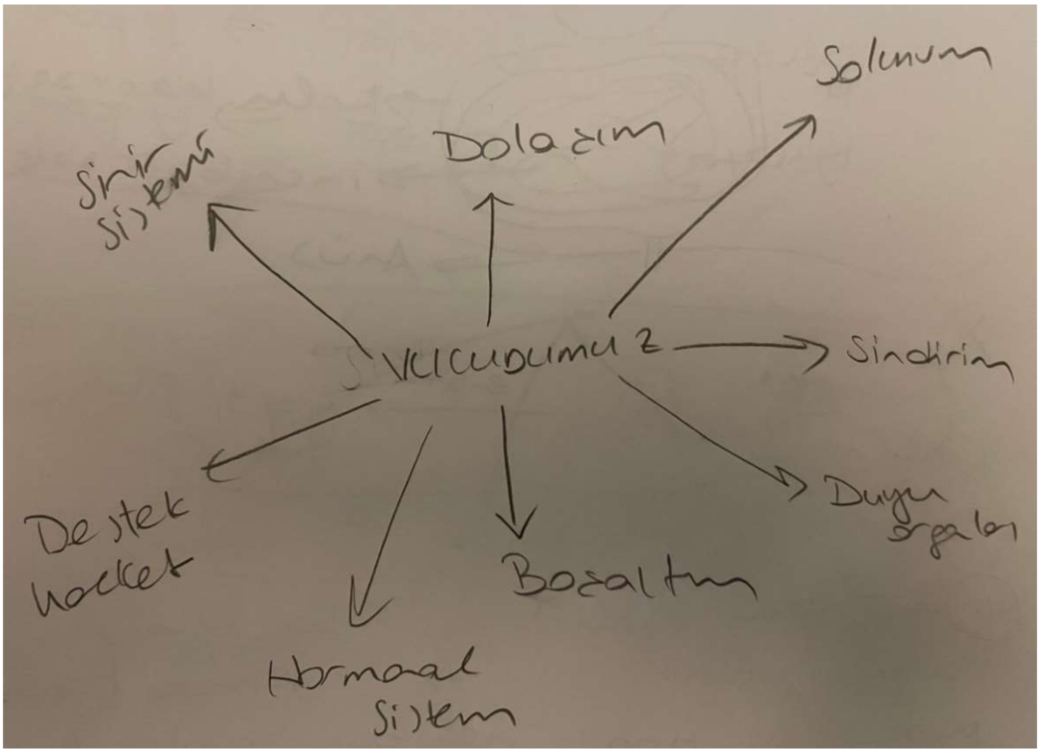


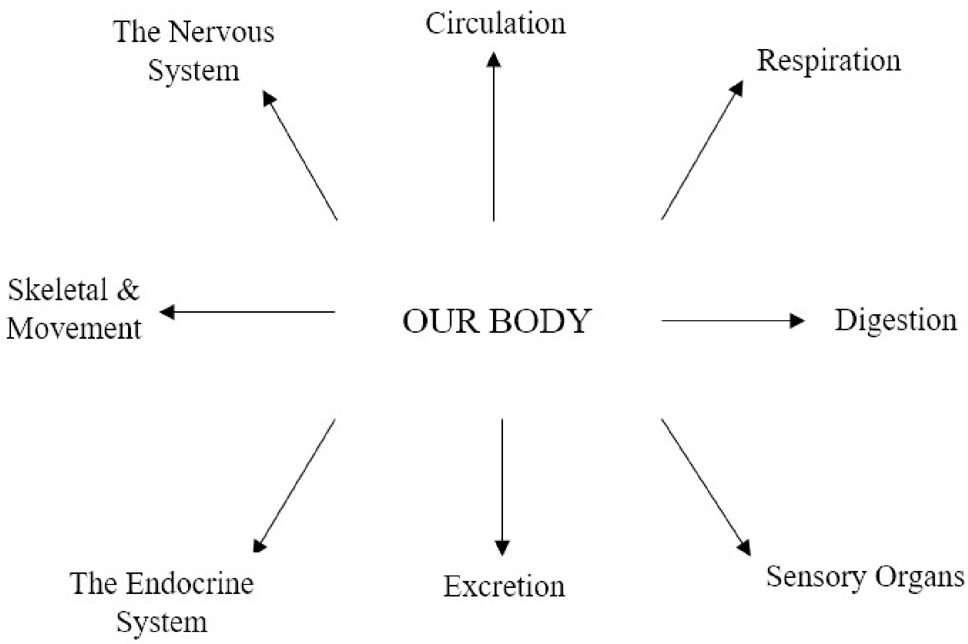
Pulmonary Circulation

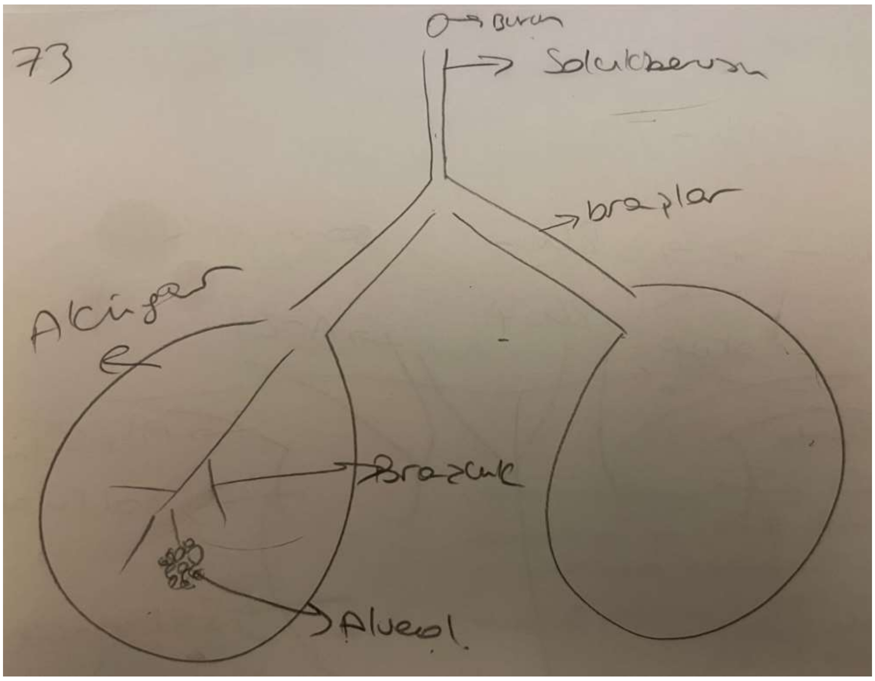
Right Ventricle → Pulmonary Artery → Lung → Pulmonary Vein → Left Atrium

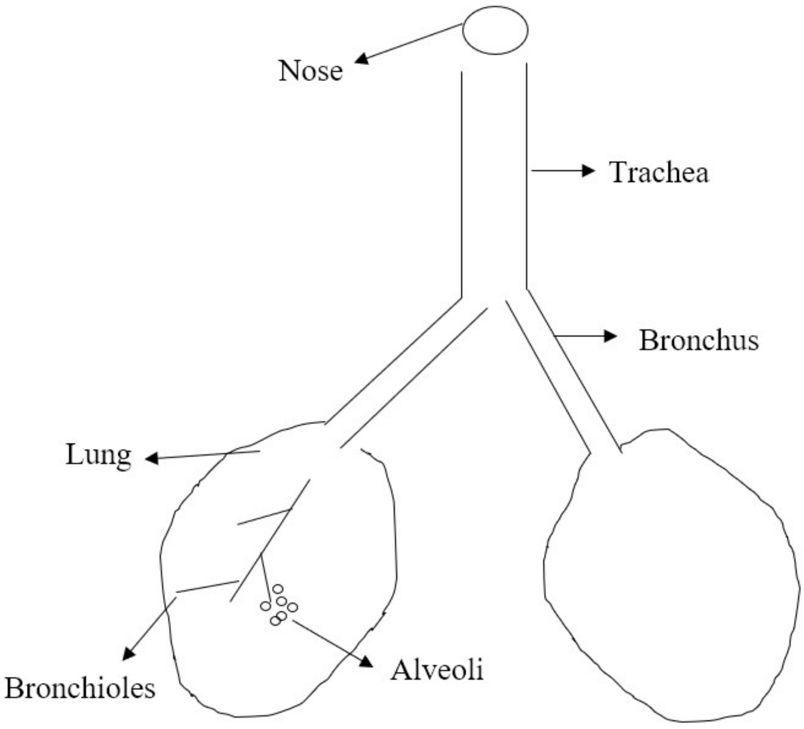
Systemic Circulation

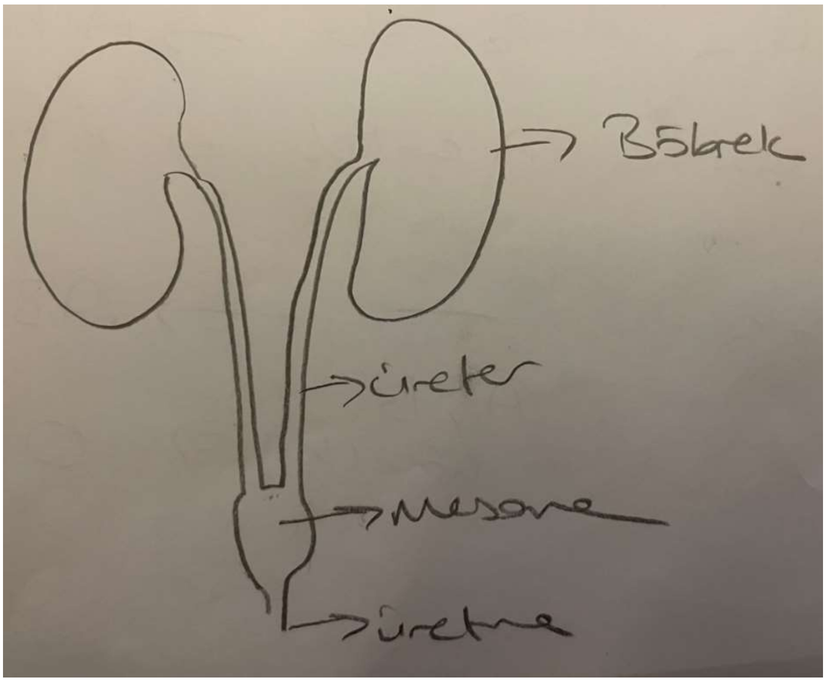
Left Ventricle → Aorta → Whole Body → Superior & Inferior Vena Cava → Right Atrium

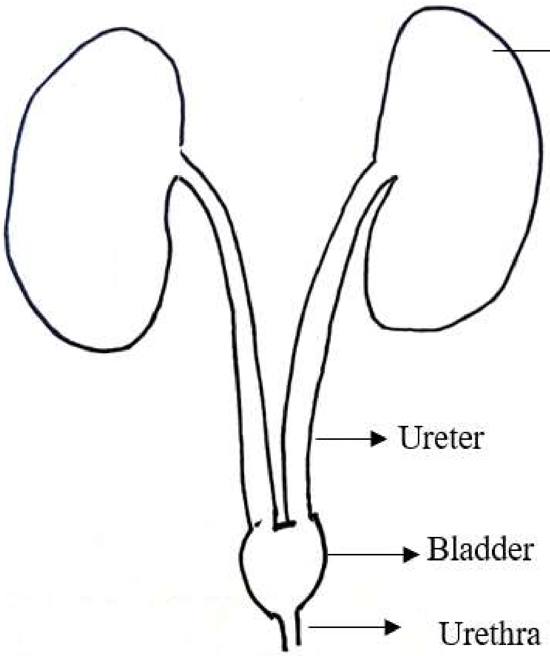

Solunum
Dolaşım
Sinir sistemi
Vücudumuz
Sindirim
Destek hareket
Duyu organları
Boşaltım
Hormonal sistem

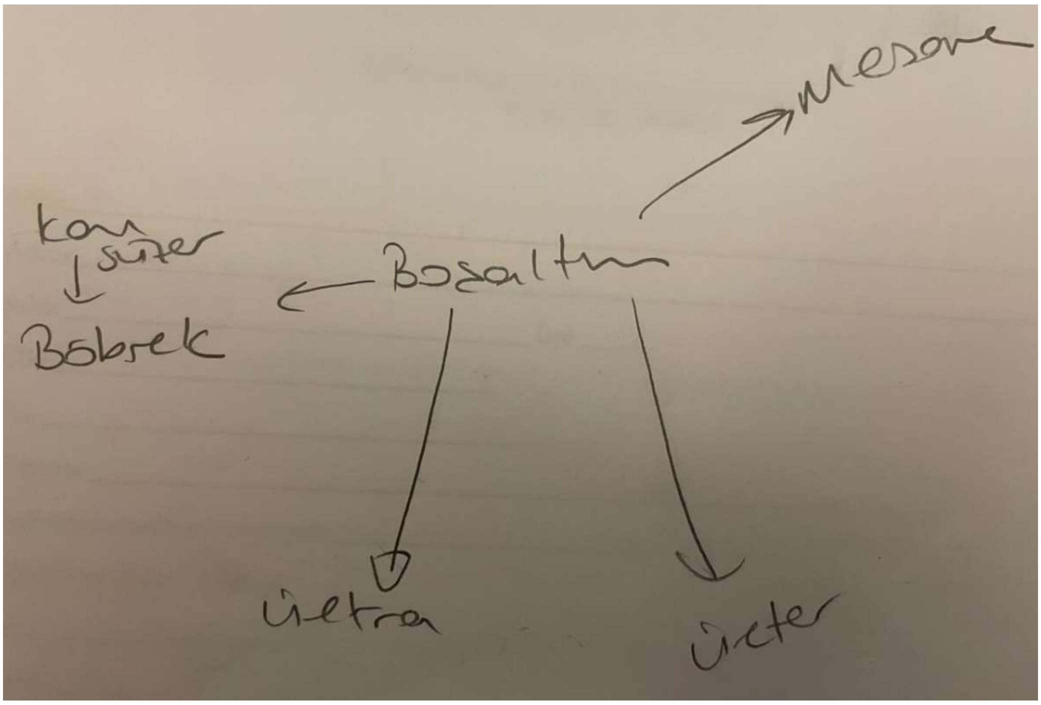

The Nervous System
Circulation
Respiration
Skeletal & Movement
OUR BODY
Digestion
The Endocrine System
Excretion
Sensory Organs

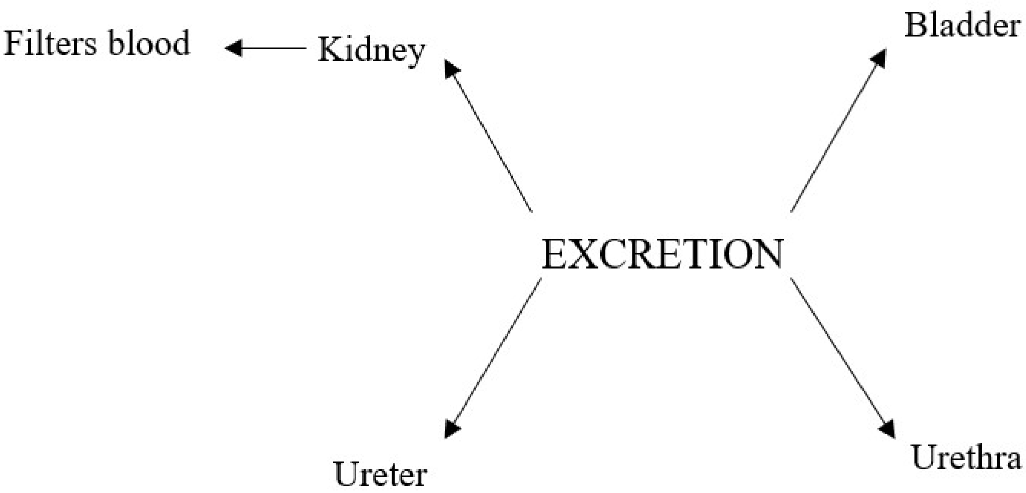

73
Burun
Akciğer
Alveol

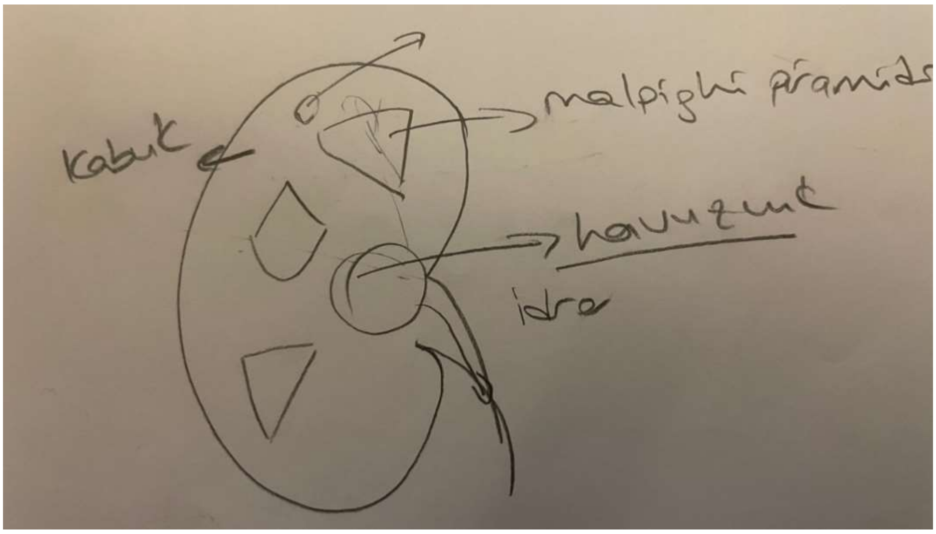

Nose
Trachea
Bronchus
Lung
Bronchioles
Alveoli

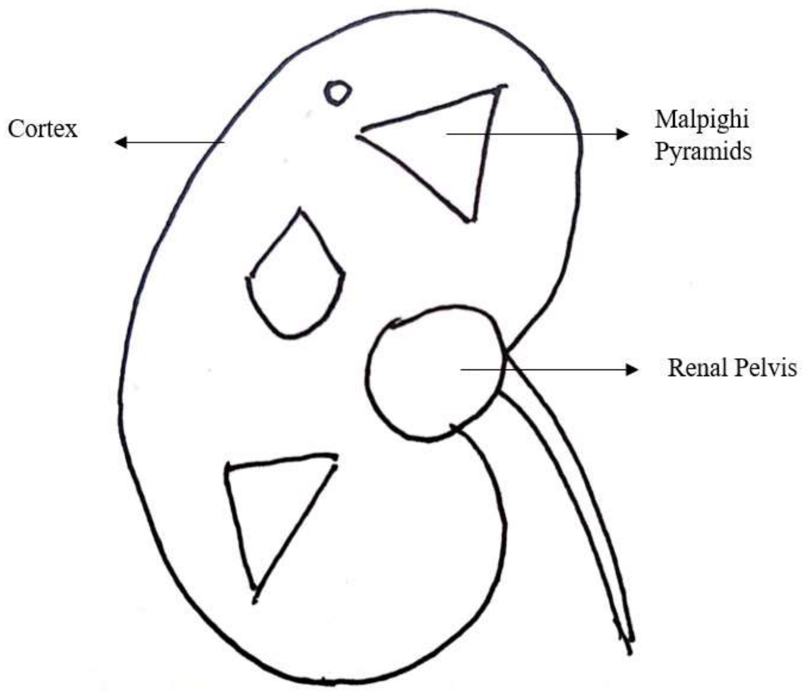

Böbrek
üreter
Mesane
üretra

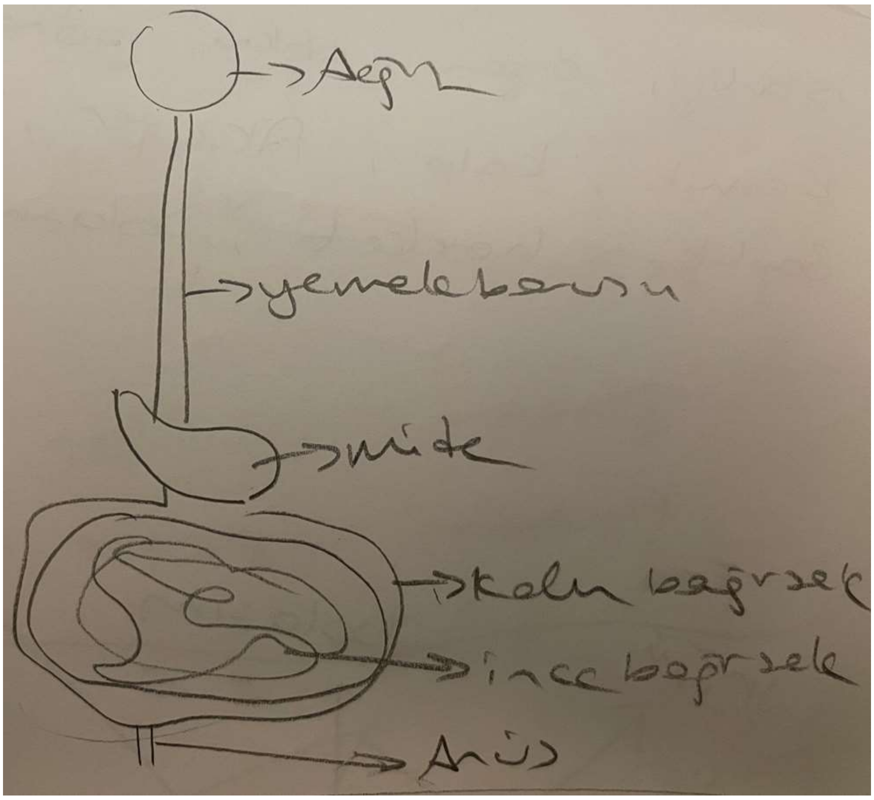

Kidney
Ureter
Bladder
Urethra

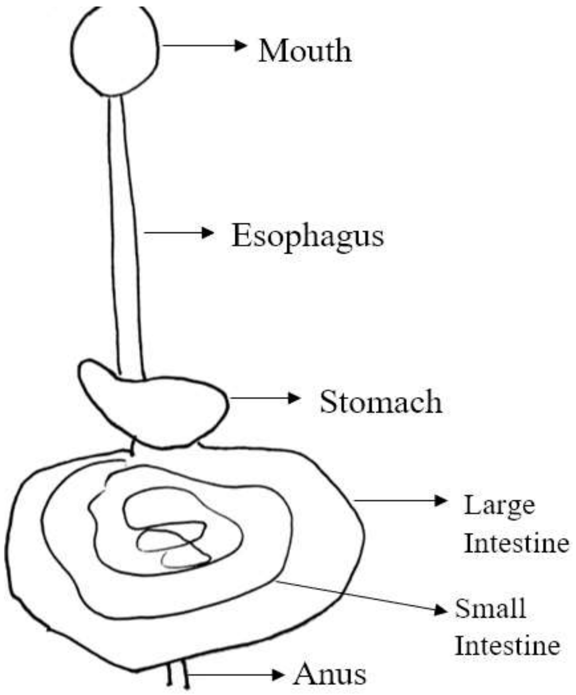

mesane
kan
süzer
Bobrek
Boşaltım
üretra
üreter

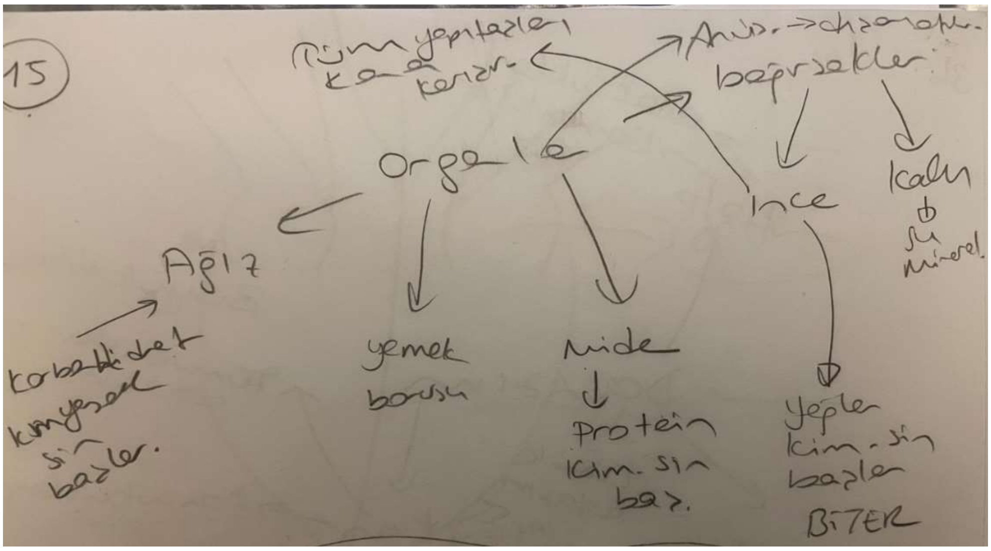

Filters blood
Kidney
Bladder
EXCRETION
Ureter
Urethra

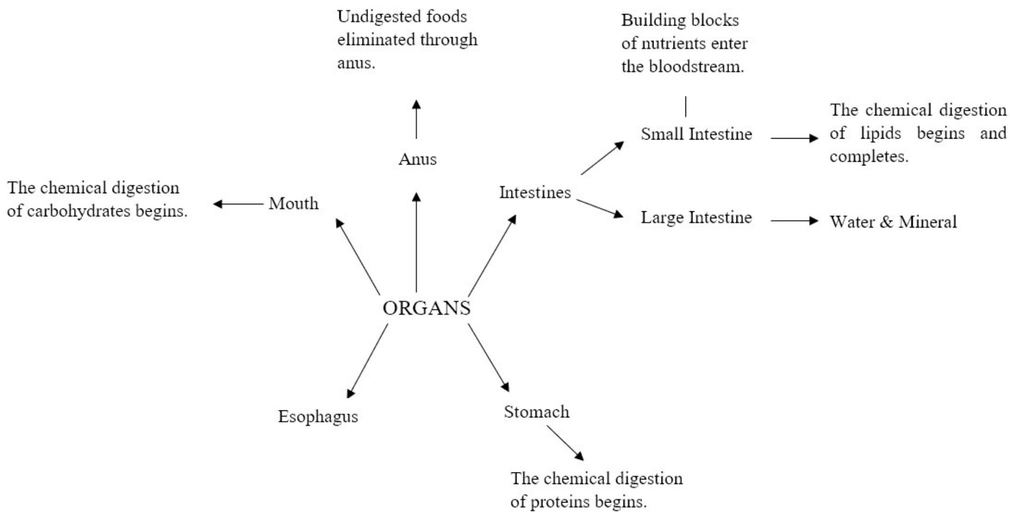

kabuk
malpighi
havuzcuk

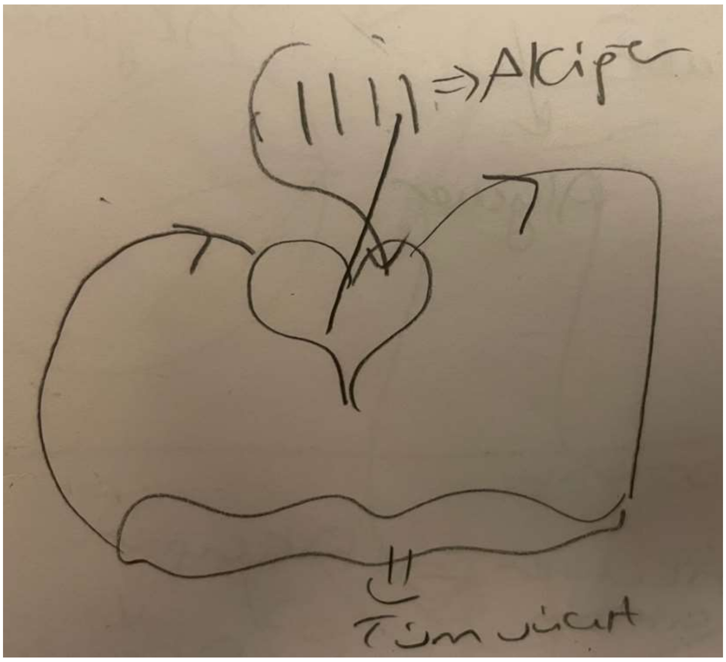

Cortex
Malpighi Pyramids
Renal Pelvis

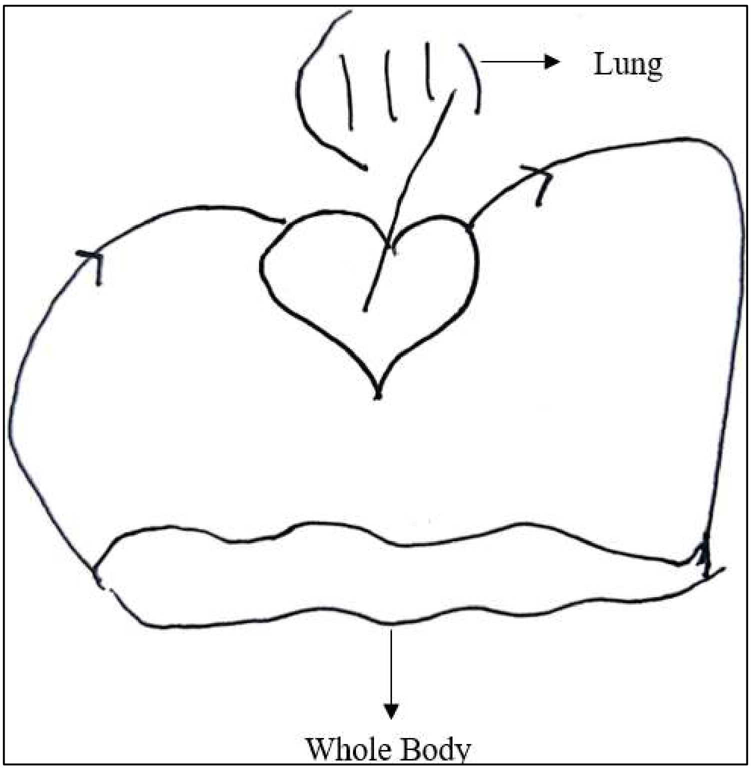



Mouth
Esophagus
Stomach
Large Intestine
Small Intestine
Anus


15
Ağız
yemek borusu
mide
protein
ince
kalın
BİTER

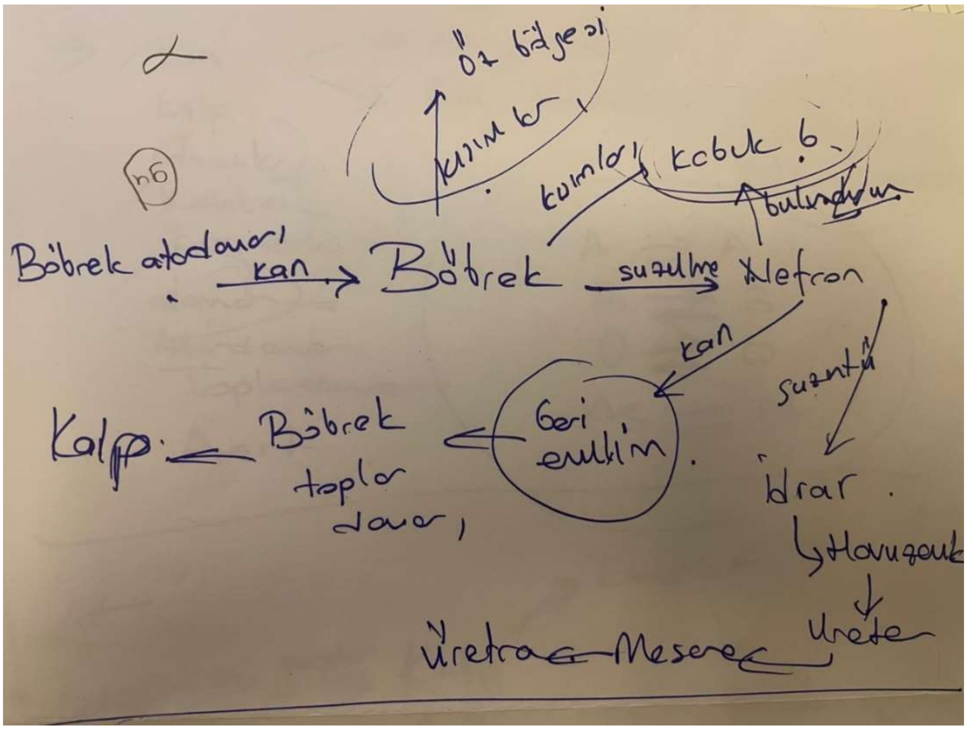

ORGANS
Mouth
The chemical digestion of carbohydrates begins.
Anus
Undigested foods eliminated through anus.
Intestines
Small Intestine
Building blocks of nutrients enter the bloodstream.
The chemical digestion of lipids begins and completes.
Large Intestine
Water & Mineral
Esophagus
Stomach
The chemical digestion of proteins begins.

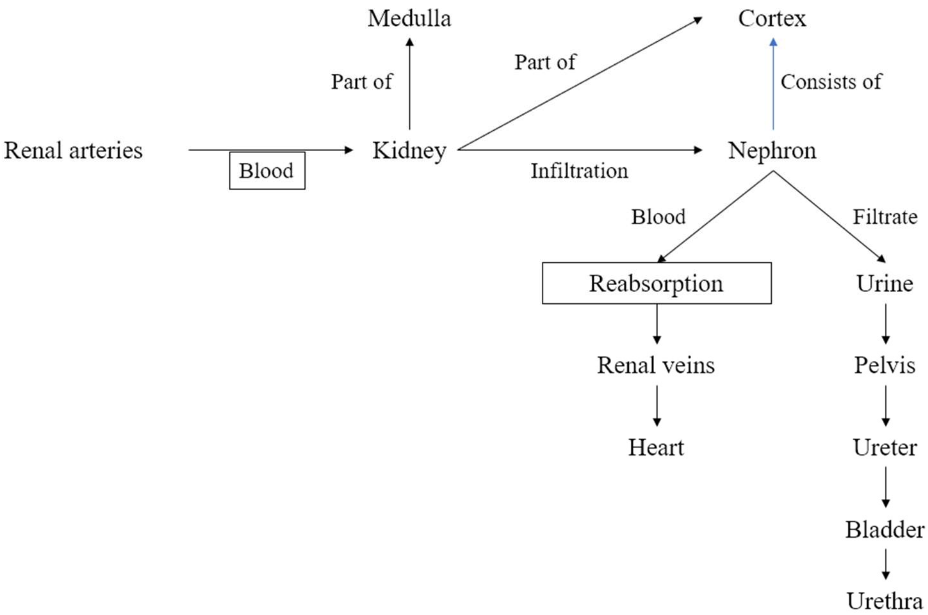

Akciğer
Tüm vücut

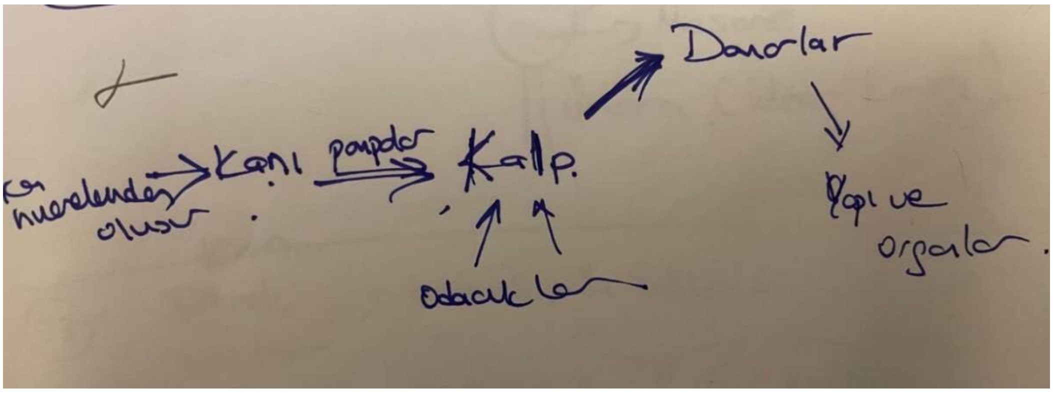

Lung
Whole Body

G. APPENDIX G

BETHY'S ORIGINAL DRAWINGS

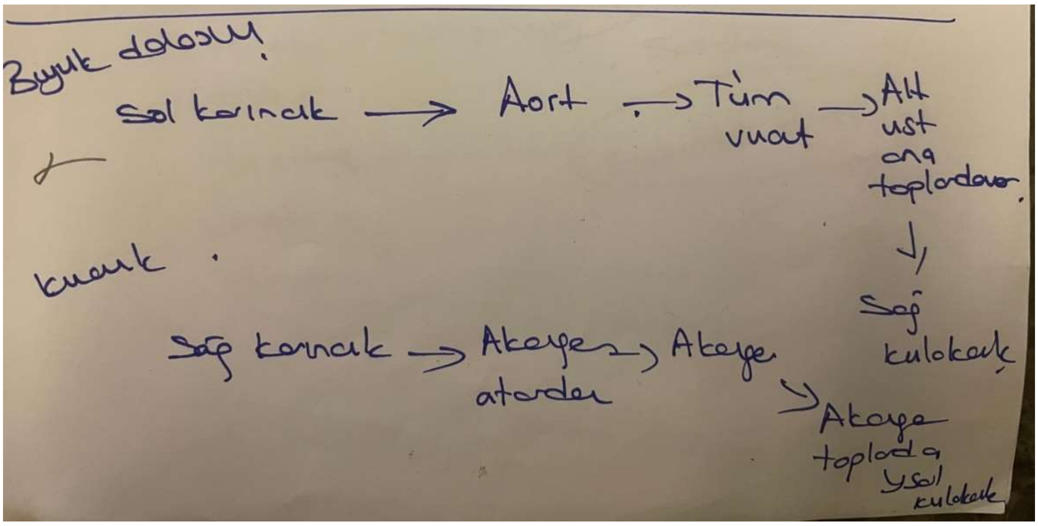






Blood cells ←(Composed of)— Blood ←(pumps)— Heart ⟶ Vessels ⟶ Structures and Organs

Chambers → Heart

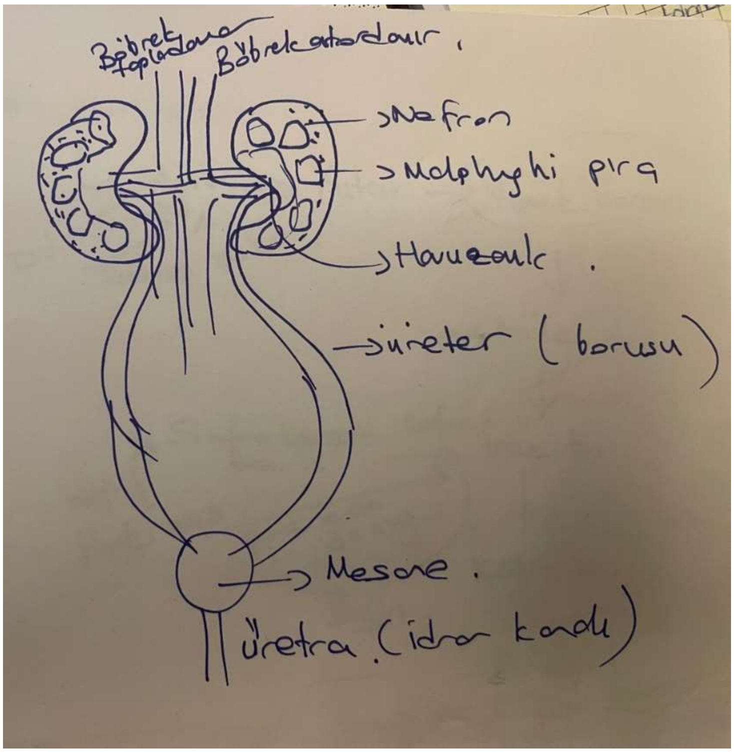


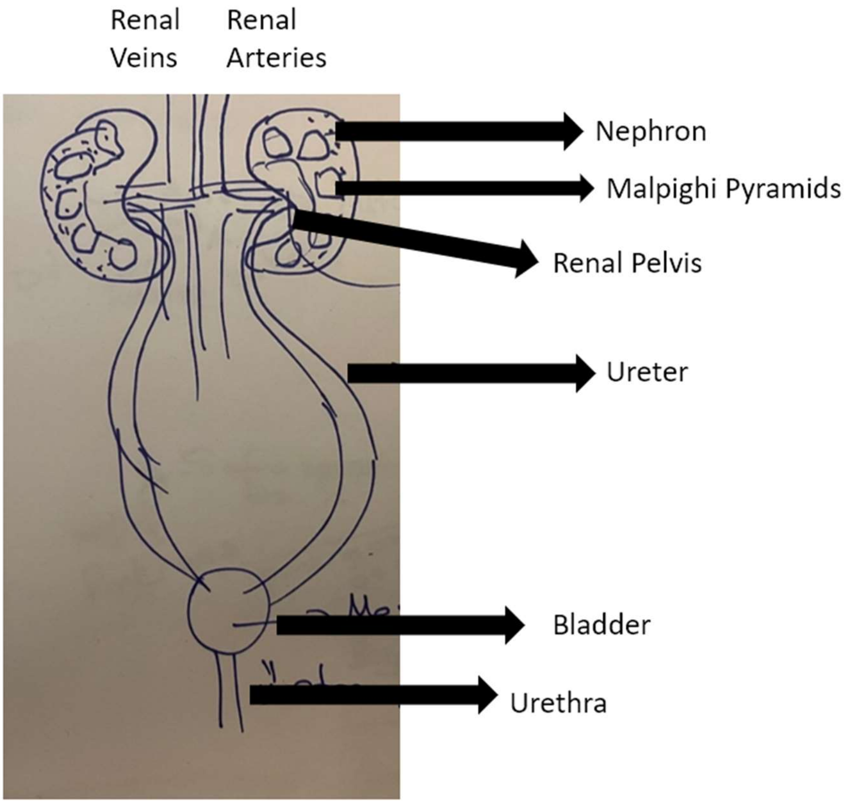
Pulmonary Circulation

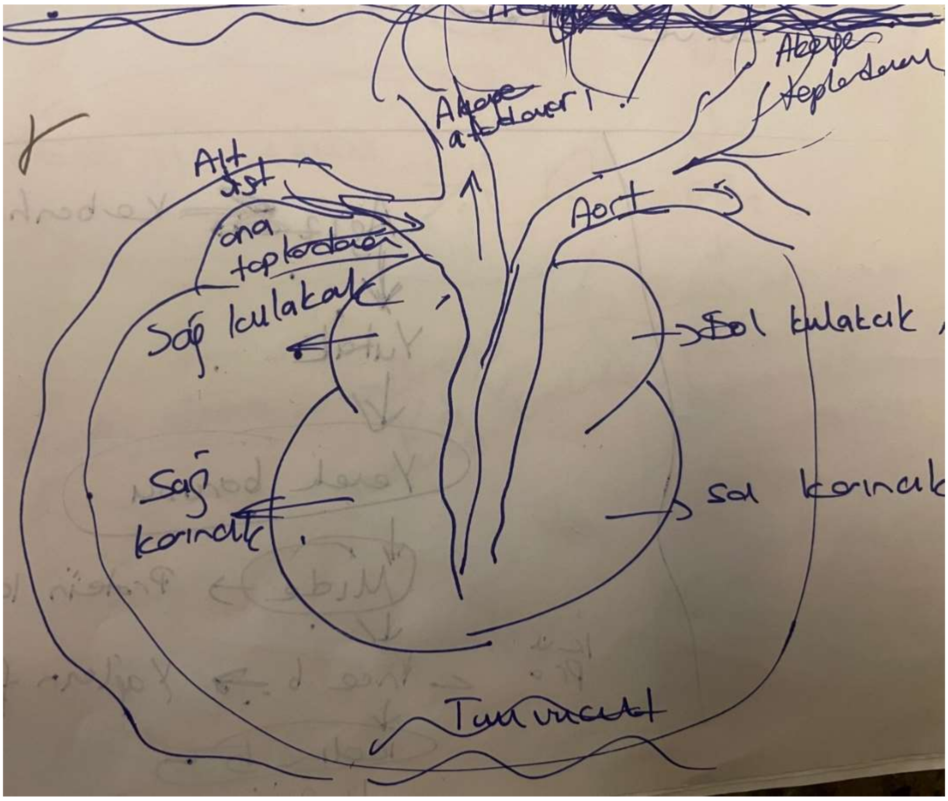
Right Ventricle ⟶ Pulmonary Artery ⟶ Lung ⟶ Pulmonary Vein ⟶ Left Atrium

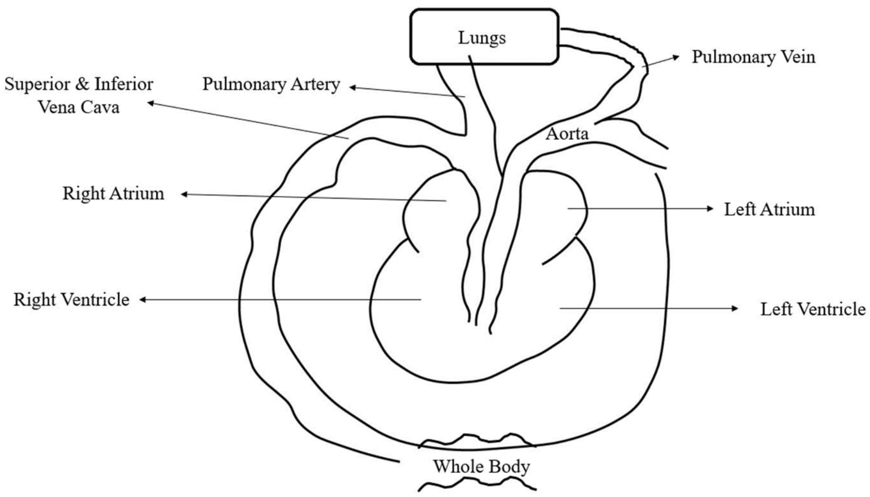
Systemic Circulation

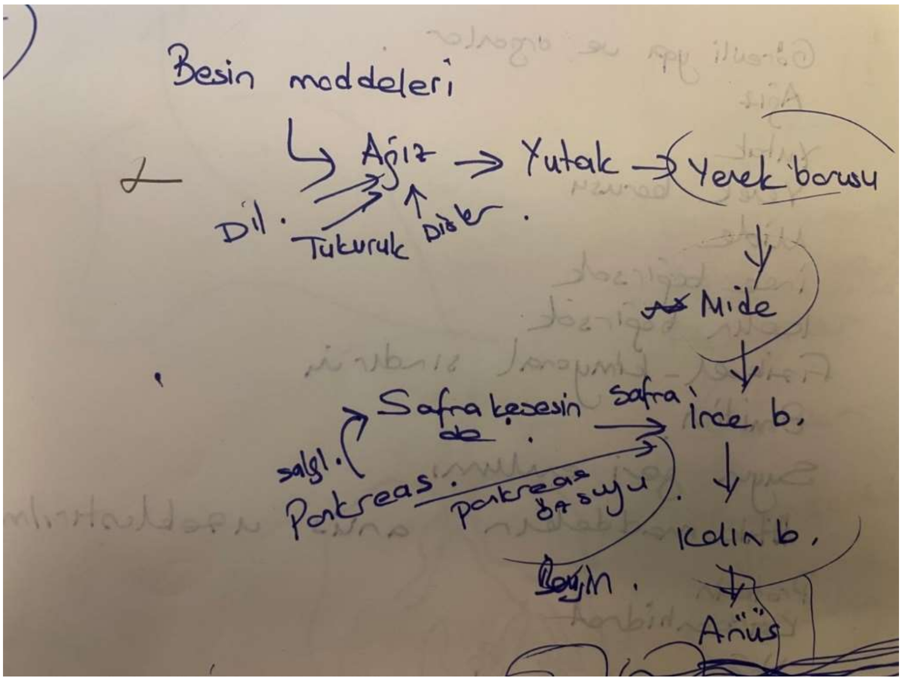
Left Ventricle ⟶ Aorta ⟶ Whole Body ⟶ Superior & Inferior Vena Cava ⟶ Right Atrium

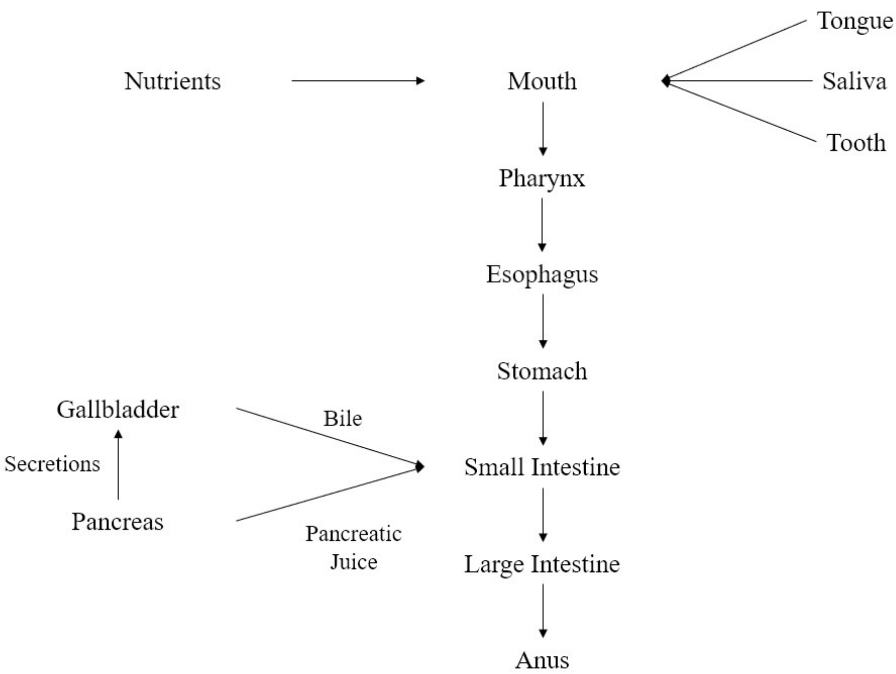

Böbrek toplardamar
Böbrek atardamar
Nefron
Malpighi pira
Havuzcuk
üreter (borusu)
Mesane
üretra (idrar kanalı)

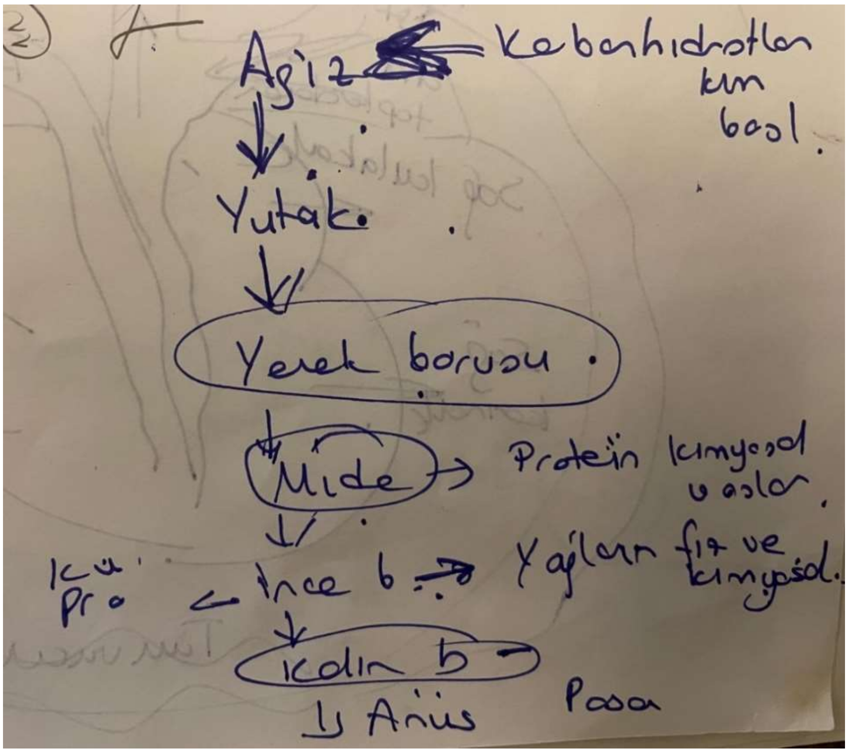

Renal Veins
Renal Arteries
Nephron
Malpighi Pyramids
Renal Pelvis
Ureter
Bladder
Urethra


Akciğer atardamarı
Akciğer toplardamarı
Alt üst ana toplardamar
Aort
Sağ kulakçık
Sol kulakçık
Sağ karıncık
Sol karıncık
Tüm vücut


Lungs
Pulmonary Vein
Superior & Inferior Vena Cava
Pulmonary Artery
Aorta
Right Atrium
Left Atrium
Right Ventricle
Left Ventricle
Whole Body


Besin maddeleri
Ağız
Yutak
Yemek borusu
Dil.
Tükürük
Dişler.
Mide
Safra kesesinde.
safra
İnce b.
salgı.
Pankreas.
pankreas özsuyu
Kalın b.
Anüs


Nutrients
Mouth
Tongue
Saliva
Tooth
Pharynx
Esophagus
Stomach
Gallbladder
Secretions
Pancreas
Bile
Pancreatic Juice
Small Intestine
Large Intestine
Anus



Mouth ← Chemical digestion of carbohydrates begins

↓

Pharynx

↓

Esophagus

↓

Stomach → Chemical digestion of protein begins

↓

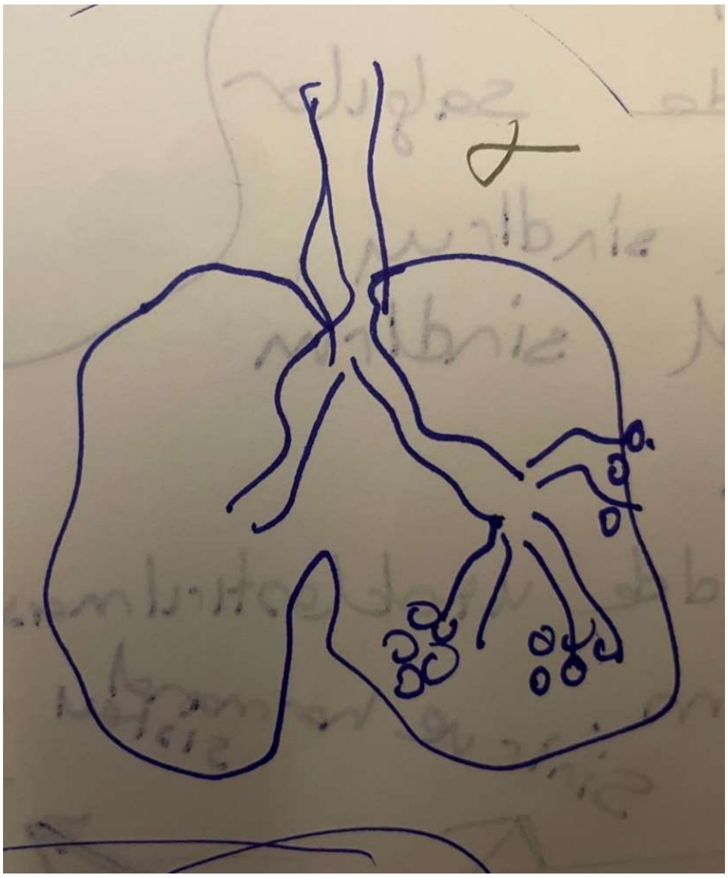
Small Intestine → Chemical and physical digestion of fats begins

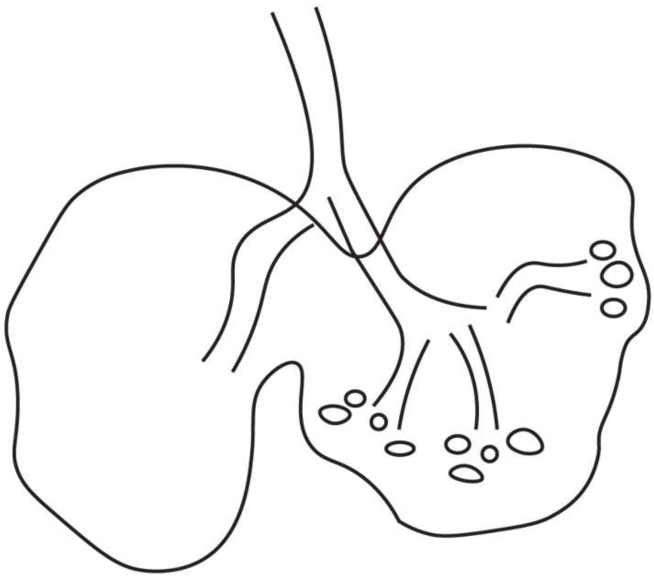
↓

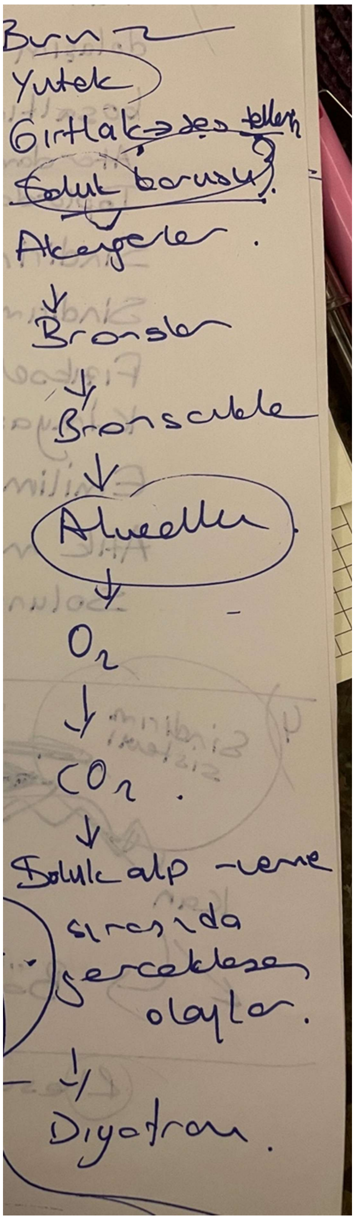
Large Intestine

↓

Anus → Feces







Nose

↓

Pharynx

↓

Larynx ⟶ Vocal cords

↓

Trachea

↓

Lungs

↓

Bronchia

↓

Bronchiole

↓

Alveoli

↓

O_2

↓

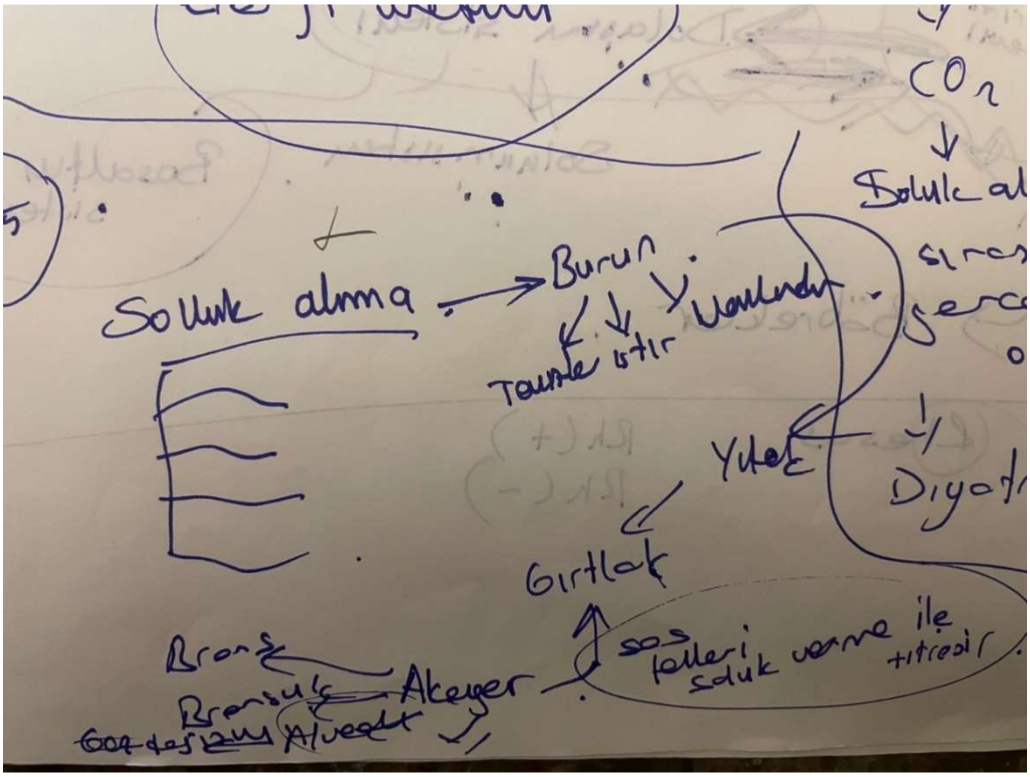
CO_2

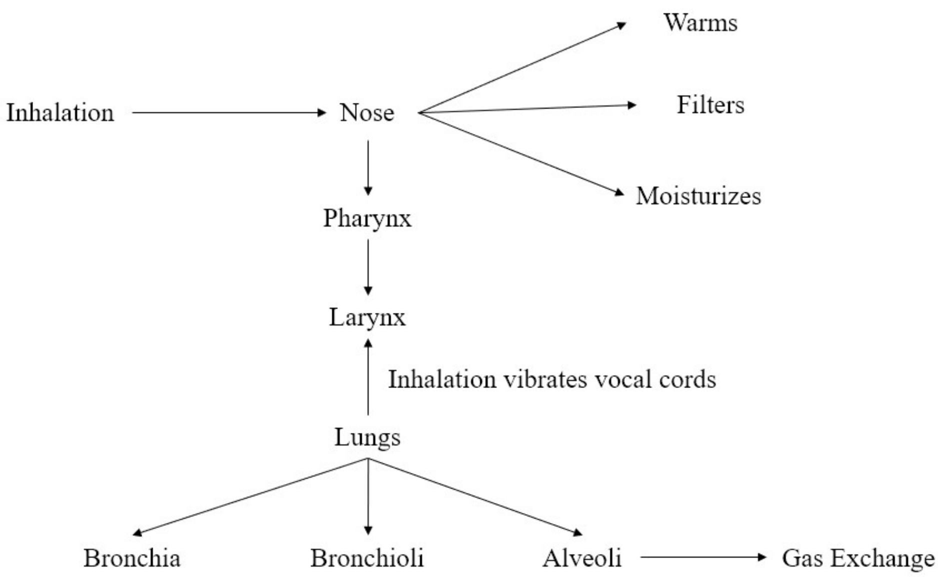
↓

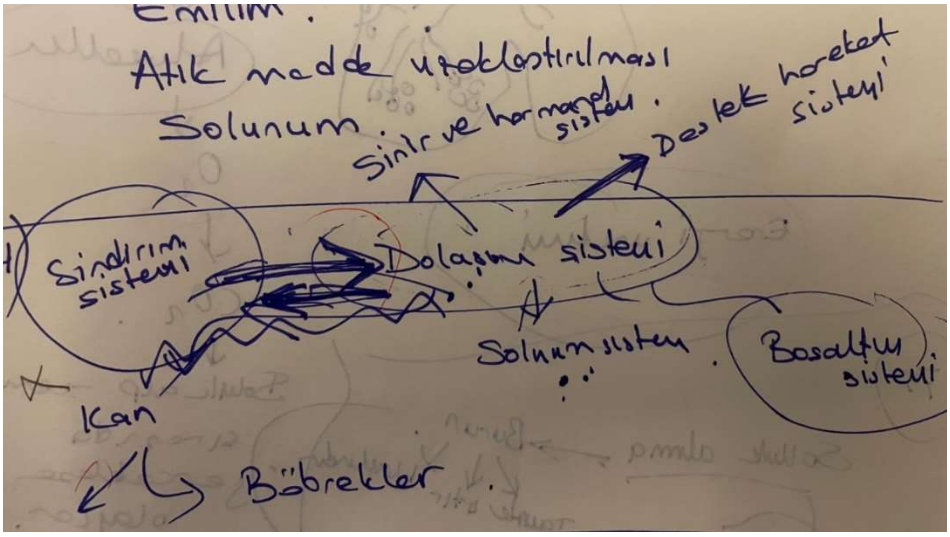
Events during inhalation and exhalation

↓

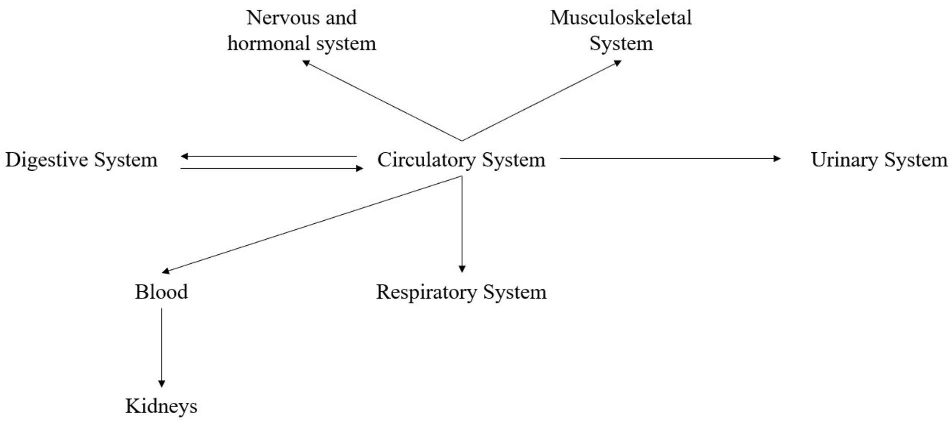
Diaphragm


CO_2
Soluk alma
Burun
Yutak
Gırtlak
ses telleri soluk verme ile titreşir
Akciğer
Bronş
Alveol


Inhalation
Nose
Warms
Filters
Moisturizes
Pharynx
Larynx
Inhalation vibrates vocal cords
Lungs
Bronchia
Bronchioli
Alveoli
Gas Exchange



Atık madde uzaklaştırılması
Solunum.
Sinir ve hormonal sistem.
Destek hareket sistemi
Sindirim sistemi
Dolaşım sistemi
Solunum sistemi
Boşaltım sistemi
Kan
Böbrekler.



Nervous and hormonal system
Musculoskeletal System
Digestive System
Circulatory System
Urinary System
Blood
Respiratory System
Kidneys

H. APPENDIX H

PCK Permission

METU Squirrelmail 3.01.2022 22:08

Görüntülenen Klasör: **Gelen Kutusu** **Oturumu Kapat**

Mesaj Yaz Adresler Klasörler Seçenekler Ara Yardım METU

Arama Sonuçları | Okunmamış | Sil İlet | Eklenti Olarak İlet | Cevap Yaz | Tümüne Cevap Yaz

Konu: Re: PCK Doküman Onay
Gönderen: Sevgi Aydın <sevgiaydin@yyu.edu.tr>
Tarih: 7 Ağustos 2018, Salı, 2:33 pm
Alıcı: elif.kinik@metu.edu.tr
Öncelik: Normal
Seçenekler: Tüm Başlıkları Göster | Yazdırılabilir Şekilde Göster | Bunu dosya olarak indir | HTML olarak göster

Merhabalar;
tabiki kullanabilirsiniz.

Başarılar dilerim.

SAG.

7 Ağustos 2018 14:03 tarihinde Elif KINIK <elif.kinik@metu.edu.tr> yazdı:

> Sayın Doç.Dr. Sevgi AYDIN,
>
> Ben Elif KINIK, ODTÜ Fen Eğitimi'inde yüksek lisans yapmaktayım. Ceren
> ÖZTEKİN hocamın danışmanlığında "Deneyimli Fen Bilgisi Öğretmenlerinin
> Vücudumuzdaki Sistemler Konusundaki Pedagojik Alan Bilgileri"ni
> çalışmaktayım. İzniniz olursa doktora tezinizde kullanmış olduğunuz
> dokümanları tezimde kullanmak istiyorum
>
> Elif KINIK
>
>
>
>
>
>

--

İ. APPENDIX I

VNOS-C Permission

METU Squirrelmail 29.12.2021 14:36

Görüntülenen Klasör: **Gelen Kutusu** **Oturumu Kapat**

Mesaj Yaz Adresler Klasörler Seçenekler Ara Yardım METU

Arama Sonuçları | Okunmamış | Sil İlet | Eklenti Olarak İlet | Cevap Yaz | Tümüne Cevap Yaz

Konu: Ynt: Doküman Kulanım Onayı (VNOS-C)
Gönderen: Kader BİLİCAN-Akademik <kaderbilican@kku.edu.tr>
Tarih: 15 Ağustos 2018, Çarşamba, 7:22 pm
Alıcı: "elif.kinik@metu.edu.tr" <elif.kinik@metu.edu.tr>
Öncelik: Normal
Seçenekler: Tüm Başlıkları Göster | Yazdırılabilir Şekilde Göster | Bunu dosya olarak indir | HTML olarak göster

Merhaba

Dokümanı kullanabilirsiniz

Kolaylıklar diliyorum

Kader Bilican

Gönderen: Elif KINIK <elif.kinik@metu.edu.tr>
Gönderildi: 15 Ağustos 2018 Çarşamba 12:16:23
Kime: Kader BİLİCAN-Akademik
Konu: Doküman Kulanım Onayı (VNOS-C)

Sayın Dr. Kader BİLİCAN,

Ben Elif KINIK, ODTÜ Fen Eğitimi'inde yüksek lisans yapmaktayım. Ceren ÖZTEKİN hocamın danışmanlığında "Deneyimli Fen Bilgisi Öğretmenlerinin Vücudumuzdaki Sistemler Konusundaki Pedagojik Alan Bilgileri"ni çalışmaktayım. İzniniz olursa tezinizde kullanmış olduğunuz "Bilimin Doğası Hakkında Görüşler (VNOS-C)" dokümanını tezimde kullanmak istiyorum.

Saygılarımla,

Elif KINIK

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J. APPENDIX J

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Konu: Değerlendirme Sonucu

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Prof.Dr. Ceren ÖZTEKİN

Danışmanlığını yaptığınız yüksek lisans öğrencisi Elif KINIK'ın **"Deneyimli Fen Bilimleri Öğretmenlerinin Vücudumuzdaki Sistemler Konusundaki Pedagojik Alan Bilgileri"** başlıklı araştırması İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek gerekli onay **2018-EGT-117** protokol numarası ile **08.08.2018 - 30.12.2019** tarihleri arasında geçerli olmak üzere verilmiştir.

Bilgilerinize saygılarımla sunarım.

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K. APPENDIX K

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EFD

T.C.
ANKARA VALİLİĞİ
Milli Eğitim Müdürlüğü

Sayı : 14588481-605.99-E.17688375 27.09.2018
Konu : Araştırma İzni

ORTA DOĞU TEKNİK ÜNİVERSİTESİ REKTÖRLÜĞÜNE
(Eğitim Fakültesi)

İlgi: a) MEB Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 2017/25 nolu Genelgesi.
b) Bila Tarihli ve E.34 sayılı yazınız.

Fakülteniz Matematik ve Fen Bilimleri Eğitimi Bölümü Yüksek Lisans öğrencisi Elif KINIK'ın **"Deneyimli Fen Bilimleri Öğretmenlerinin Vücudumuzdaki Sistemler Konusundaki Pedagojik Alan Bilgileri"** konulu tez çalışması kapsamında uygulama talebi Müdürlüğümüzce uygun görülmüş ve uygulamanın yapılacağı İlçe Milli Eğitim Müdürlüklerine bilgi verilmiştir.

Görüşme formunun (20 sayfa) araştırmacı tarafından uygulama yapılacak sayıda çoğaltılması ve çalışmanın bitiminde bir örneğinin (cd ortamında) Müdürlüğümüz Strateji Geliştirme (1) Şubesine gönderilmesini rica ederim.

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Elektronik Ağ: ankara.meb.gov.tr
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L. APPENDIX L

THE DIGESTIVE SYSTEM RUBRIC

The Digestive System

Digestive System:	
Concepts	Explanations
Digestion	"the breakdown of food into molecules small enough for the body to absorb" (Simon et al., 2018, p.476) "The four stages of food processing: ingestion, digestion, absorption, and elimination" (Simon et al., 2018, p.476)
Types of Digestion	"Mechanical digestion breaks chunks of food into small pieces, exposing them to chemical digestion the breakdown of food by digestive enzymes" (Simon et al., 2018, p.477)
The role of the digestive system	"to move nutrients, water, and electrolytes from the external environment into the body's internal environment" (Silverthorn, 2016, p.683) "To meet the continuous requirement for ATP, animals ingest and digest nutrients, including carbohydrates, proteins, and lipids, for use in cellular respiration and energy storage" (Reece et al.,2014, p.893).
Digestive System Diseases	Acid Reflux, Ulcer, Jaundice, Gallstones, Celiac disease (Simon et al., 2018)

The Digestive System Organs

Organs	Explanations
Mouth (oral cavity)	“also known as the oral cavity, is where food is ingested and where digestion starts. Mechanical digestion begins here as the teeth cut, smash, and grind the food” (Simon et al., 2018, p.479).
Pharynx	“located in your throat, is an intersection of the pathways for swallowing and breathing” (Simon et al., 2018, p.480). “connects the mouth to the esophagus (part of the digestive system). The pharynx also opens to the trachea, or windpipe, which leads to the lungs (part of the respiratory system)” (Simon et al., 2018, p.480).
Esophagus	“a muscular tube that connects the pharynx to the stomach” (Simon et al., 2018, p.480). moves food by peristalsis, alternating waves of muscular contraction and relaxation that squeeze the food ball along the esophagus (Simon et al., 2018, p.480).
Stomach	Digestion of proteins begins in the stomach (Reece et al.,2014). functions AS Storage, Digestion, Defense (Silverthorn, 2016) “The cells lining the stomach's interior secrete a digestive fluid called gastric juice, made up of a strong acid, digestive enzymes, and mucus. Gastric juice also contains pepsin, an enzyme that breaks proteins into smaller pieces” (Simon et al., 2018, p.480). Mucus protects stomach from gastric juices and from corrosive substances in food (Simon et al., 2018).

The Digestive System Organs (continued)

Small intestine	"the major organ for chemical digestion and for absorption of nutrients into the bloodstream" (Simon et al., 2018, p.482). "The first 25 cm (10 inches) or so of the small intestine forms the duodenum" (Reece et al.,2014, p.902) "The duodenum receives digestive juices from the pancreas, liver, gallbladder, and the intestinal lining" (Simon et al., 2018, p.482). Digestion of fats begins in the small intestine with the help of bile (Reece et al.,2014)
Large intestine (colon and rectum)	"The main portion of the large intestine is the colon. One major function of the colon is to complete the reabsorption of water that was begun in the small intestine" "(Simon et al., 2018, p.484). "The rectum, the last 15 cm (6 inches) of the large intestine, stores feces until they can be eliminated" (Simon et al., 2018, p.484).
Anus	"Undigested wastes are eliminated from the alimentary canal as feces through the anus" (Simon et al., 2018, p.478).
Feces	the wastes of the digestive system that consists of undigested material (Simon et al., 2018; Reece et al.,2014)

Accessory Digestive System Organs

Organs	Explanations
Pancreas	“a large gland that secretes pancreatic juice into the duodenum through a duct. Pancreatic juice neutralizes the stomach acid that enters the duodenum, and it contains enzymes that aid in digestion.” (Simon et al., 2018, p. 482)
Gallbladder	stores bile and deliver it into the small intestine when it is necessary (Simon et al., 2018).
Liver	produces bile, prepare nitrogenous wastes for disposal and detoxify the blood (Simon et al., 2018; Reece et al.,2014)
Salivary Glands	send saliva to the oral cavity through ducts (Reece et al.,2014)
Bile	“a juice produced by the liver, stored in the gallbladder, and secreted through a duct into the duodenum” (Simon et al., 2018, p.482) Bile includes salts to facilitate digestion of fats (Simon et al.,2018; Reece et al.,2014)
Functions of Saliva	Soften and moisten food, Digestion of starch, Taste, Defense (Reece et al.,2014)
Digestive Enzymes	“secreted either by exocrine glands (salivary glands and the pancreas) or by epithelial cells in the stomach and small intestine” (Silverthorn, 2016, p. 685).

M. APPENDIX M

THE CIRCULATORY SYSTEM RUBRIC

The Circulatory System

Concepts	Explanation
The Circulatory System	“carries the oxygen-rich blood to all parts of the body” (Reece et al., 2014, p.917)
Circulation	“Mammals have two circuits, an arrangement called double circulation” (Reece et al., 2014, p.918). “The pulmonary circuit between the lungs and the heart and the systemic circuit between the heart and the rest of the body” (Simon et al., 2018, p.498). “The pulmonary and systemic circuits operate simultaneously” (Simon et al., 2018, p.498). “Pulmonary circuit carries blood between the heart and lungs. In the lungs, CO_2 diffuses from the blood into the lungs, while O_2 diffuses from the lungs into the blood. The pulmonary circuit then returns this O_2-rich blood back to the heart. The systemic circuit carries blood between the heart and the rest of the body. The blood delivers O_2 to body tissues, and at the same time it picks up CO_2. The oxygen poor blood returns to the heart via the systemic circuit (Simon et al., 2018, p.497)”.
Adaptations	Four-chambered heart was an adaptation. It provides human body to efficient fuel and oxygen deliver (Simon et al.,2018).
Blood pressure	“the force that blood exerts against the walls of your arteries” (Simon et al., 2018, p.501).

Parts of the Circulatory System

Concepts	Explanation
	“Heart, blood, and blood vessels (Simon et al., 2018).
Vessels	“Blood circulates to and from the heart through three types of vessels: arteries, capillaries, and veins” (Simon et al., 2018, p.496) “Arteries carry blood away from the heart” (Simon et al., 2018, p.500). “Capillaries allow for exchange between the bloodstream and the tissue cells (via interstitial fluid)” (Simon et al., 2018, p.500). “Veins carry blood toward the heart” (Simon et al., 2018, p.500). “Veins (but not arteries) also have one-way valves that prevent backflow, ensuring that blood always moves toward the heart” (Simon et al., 2018, p.501).
Blood	A connective tissue (Reece et al., 2014) “Connective tissue, consisting of pf a sparse population of cells scattered through an extracellular matrix, hold many tissues and organs together and in place” (Reece et al., 2014, p.872). “Blood contains two classes of cells: red blood cells, which transport O_2, and white blood cells, which function in defense. Also suspended in blood plasma are platelets, cell fragments that are involved in the clotting process” (Reece et al., 2014, p.929)

Parts of the Circulatory System (continued)

Heart	“A muscular organ about the size of a fist located under the breastbone” (Simon et al., 2018, p.499). “The heart's four chambers support double circulation and prevent oxygen-rich and oxygen-poor blood of each circuit from mixing” (Simon et al., 2018, p.499). “The oxygen-poor blood from body tissues flows into the right atrium, and the right ventricle pumps it to the lungs” (Simon et al., 2018, p.499). “The oxygen-rich blood returning from the lungs does not mix with oxygen-poor blood in the heart because it enters a separate chamber, the left atrium” (Simon et al., 2018, p.499). “Valves prevent backflow and keep blood moving in the right direction” (Simon et al., 2018, p.499). “The blood is forcefully pumped out to body tissues from the left ventricle” (Simon et al., 2018, p.499).

N. APPENDIX N

THE RESPIRATORY SYSTEM RUBRIC

The Respiratory System

Concepts	Explanations
The role of the respiratory system	"Facilitate exchange of O_2 and CO_2 between the environment and cells." (Simon et al., 2018, p.507)
Breathing	"The ventilation of the lungs by alternate inhalation and exhalation" (Simon et al., 2018, p.509) "Diaphragm, a sheet of muscle, moves downward, expanding the chest cavity. All of this increases the volume of the lungs, dropping the air pressure in the lungs to below the air pressure of the atmosphere. The result is that air rushes in through the mouth and nostrils from an area of higher pressure to an area of lower pressure, filling the lungs" (Simon et al., 2018, p.511) "During exhalation, the rib and diaphragm muscles relax, decreasing the volume of the chest cavity. This decreased volume increases the air pressure inside the lungs, forcing air to rush out of the respiratory system" (Simon et al., 2018, p.511)
Path of air	Nostrils and mouth → Pharynx → Larynx → Trachea→ Bronchi → Bronchioles→ Alveoli (Simon et al., 2018)
Cellular respiration	"refers to the intracellular reaction of oxygen with organic molecules to produce carbon dioxide, water, and energy in the form of ATP" (Simon et al., 2018, p.129).
Respiratory system diseases	Bronchitis, Lung disease emphysema, Anemia, Chronic obstructive pulmonary disease (COPD), Lung cancer (Simon et al., 2018)

Parts of The Respiratory System

Parts of The Respiratory System	
Nasal cavity	"In the nasal cavity, the air is filtered by hairs and mucus, warmed, humidified, and sampled by smell receptors." (Simon et al., 2018, p.510)
Pharynx	the place that the digestive and respiratory systems meet (Simon et al., 2018). "opens to the trachea, or windpipe, which leads to the lungs (part of the respiratory system)" (Simon et al., 2018, p.480).
Larynx	"The voice box" (Simon et al., 2018, p.510). "The larynx contains the vocal cords, connective tissue bands that vibrate and tighten to create sound when air moves past them" (Silverthorn et al.,2016, p.561).
Trachea	"The trachea forks into two bronchi (singular, bronchus), one leading to each lung. Within the lungs, each bronchus branches repeatedly into finer and finer tubes called bronchioles" (Simon et al., 2018, p.509). "Air is filtered both in the trachea and in the bronchi" (Silverthorn et al.,2016, p.561).
Diaphragm	"A sheet of muscle, moves downward, expanding the chest cavity" (Simon et al., 2018, p.511).
Lungs	"The lungs consist of light, spongy tissue whose volume is occupied mostly by air-filled spaces" (Silverthorn et al.,2016, p.560).
Alveoli	"A series of interconnected sacs and their associated *pulmonary capillaries.* These structures form the exchange surface, where oxygen moves from inhaled air to the blood, and carbon dioxide moves from the blood to air that is about to be exhaled." (Silverthorn et al.,2016, p.560).

O. APPENDIX O

THE URINARY SYSTEM RUBRIC

Parts of the Urinary System

Organs	Explanations
Urinary System	“plays another important role-the excretion of wastes” (Simon et al., 2018, p.469).
Kidney	“are the site of urine formation” (Silverthorn, 2016, p.615)
Ureter	“Urine collects in the kidney and then leaves that organ via the ureter” (Simon et al., 2018, p.470).
Urinary Bladder	“Urine is stored in the urinary bladder” (Simon et al., 2018, p.470).
Urethra	“Urine is expelled from the urinary bladder via the urethra, a tube that empties near the vagina in females and through the penis in males” (Simon et al., 2018, p.470).
Urine	“the fluid waste produced by the kidneys, reflects the functioning of the body” (Silverthorn, 2016, p.614).
Urinary System Disorders	honey-urine disease, urinary tract infections (UTIs)

P. APPENDIX P

DRAWINGS OF DIGESTIVE SYSTEMS